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Burn-up Credit Criticality Benchmark

Phase IV-B: Results and Analysis of MOX Fuel Depletion Calculations

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FOREWORD

The reactivity of nuclear fuel decreases with irradiation (or burn-up) due to the transformation of heavy nuclides and the formation of fission products. Burn-up credit studies aim at accounting for fuel irradiation in criticality studies of the nuclear fuel cycle (transport, storage, etc.).

The OECD/NEA Expert Group on Burn-up Credit was established in 1991 to address scientific and technical issues connected with the use of burn-up credit in nuclear fuel cycle operations. Several benchmark exercises were conducted in order to compare computation tools used in this context. Phases I and II of these benchmarks addressed burn-up credit issues when the uranium oxide fuel involved was irradiated in pressurised water reactors. Phase III concentrated on uranium fuels irradiated in boiling water reactors. The present report is the second in the series of the Phase IV benchmarks devoted to mixed uranium and plutonium fuels irradiated in pressurised water reactors.

Electronic versions of all of the benchmark reports are available on the NEA website at www.nea.fr/html/science/wpncs/buc. Attention should be drawn to the fact that the printed version of this publication is in black and white; several of the figures were, however, originally produced in colour and can best be viewed either on CD-ROM or at the Internet address mentioned above.

Acknowledgements

The NEA Secretariat wishes to thank all those who have contributed to this study, in particular, Russ Bowden and Peter Thorne for the preparation of the benchmark specifications; the participants for their calculation of the benchmark and the submission of solutions to the exercises; Peng Hong Liem and Greg O'Connor for their analysis of the results and the preparation of the present report; and Susumu Mitake and Alain Santamarina for their peer reviews.

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1. Introduction

The investigation of burn-up credit for mixed oxide (MOX) fuels, i.e. fuel containing a mixture of uranium and plutonium oxides, is an ongoing objective of the OECD/NEA Burn-up Credit Working Group, following the study of burn-up credit methods for PWR and BWR UO_2 fuels. In the first phase of the benchmark program for MOX systems, denoted as Phase IV-A [1], the reactivity effects observed with MOX fuel were investigated. The Phase IV-A benchmark exercise concerns the calculation of infinite PWR fuel pin cell reactivity for fresh and irradiated MOX fuels. The fuel compositions have been derived by the benchmark co-ordinators. This initial exercise considered the impact of different initial plutonium isotopic compositions in the MOX fuel, associated with first generation MOX, weapons plutonium disposition and multiple MOX recycle.

Following Phase IV-A, the Phase IV-B benchmark was proposed to address the calculation of irradiated MOX fuel compositions. The Phase IV-B benchmark specification [2] is a first step in comparing methods for the calculation of isotopic inventories for the nuclides of interest to MOX fuel burn-up credit. The benchmark participants are requested to perform inventory calculations for two MOX fuel cases appropriate to weapons plutonium disposition and first recycle MOX, using three calculational modelling representations for the reactor core (a total of six cases).

The three calculational models requested for the Phase IV-B exercise cover:

1) A supercell calculation for a MOX assembly together with three UO_2 fuel assemblies, with translational boundary conditions.

2) A MOX-only core representation with reflective boundary conditions.

3) A simple MOX pin cell calculation, using the average MOX fuel composition, with pin cell geometry that conserves the fuel-to-moderator ratio of the whole assembly in the previous calculations, i.e. accounting for 25 guide or instrument tube positions with reflective boundary conditions.

As for the irradiation history, three operating cycles, i.e. two cycles consisting of 420 days full power with end of cycle (EOC) burn-up of MOX equal to 16 GWd/teHM followed by 30 days downtime, and one cycle consisting of 420 days full power with EOC burn-up of MOX equal to 16 GWd/teHM followed by five years cooling, are considered. The complete Phase IV-B benchmark specification is given in Appendix A (the original Phase IV-B benchmark specification was slightly revised in March 2002 to clarify some issues which were ambiguous to participants). The specification of major actinides and fission products is consistent with previous burn-up credit benchmark exercises. For each of the two initial MOX fuels (the first recycle MOX and weapons disposition MOX) four plutonium contents and fuel enrichments are defined (low, medium, high and average). The average plutonium contents for the first recycle MOX and weapons disposition MOX are 8.0 w/o and 3.95 w/o, respectively, while the fuel enrichments for the first recycle MOX and weapons disposition MOX are 5.136 w/o and 3.709 w/o, respectively.

The participants are required to provide the following calculation results for all six cases:

- Actinide and fission product nuclide densities for EOC 1, 2, 3 and after five years cooling.
- In-core k_∞ at EOC 1, 2, 3 and after five years cooling.
- Average burn-up of pin types 1, 2 and 3 (low, medium and high enriched MOX fuel pins, respectively).

For the supercell calculations, it may be necessary to perform a number of iterations of the inventory calculation to produce the required MOX fuel assembly burn-up.

2. Participants and analysis methods

The following is a brief description of nuclear data and analysis codes employed by each participant. Additional comments provided by participants are also included. Table 2.1 summarises the data and codes used by the participants.

1) NUPEC, Japan

Institute: Institute for Nuclear Safety, NUPEC, Japan.

Participants: Shungo Sakurai, Susumu Mitake.

Neutron data library: E4LBL70 (L-library), based on ENDF/B-IV.

Neutron data processing code or method: CASLIB.

No. of neutron energy groups: 70 groups for pin cell, finally 16 groups for assembly.

Description of the code system: CASMO-4, a multi-group two-dimensional transport theory code for burn-up calculations on BWR and PWR assemblies. Some characteristics of this code are listed below:

(a) Nuclear data are collected in a library in 70 and 40 groups, and cover the energy range 0 to 10 MeV.

(b) CASMO can accommodate non-symmetric fuel bundles, while half, quadrant, or octant symmetry can be utilised.

(c) The two-dimensional calculation is performed in true heterogeneous geometry.

(d) The calculational sequence starts in a simplified geometry. Energy groups are then collapsed as spatial detail is increased.

(e) A predictor-corrector approach is used in the depletion calculation, which greatly reduces the number of burn-up steps necessary for a given accuracy.

(f) The output is flexible and gives few group cross-sections and reaction rates for any region of the assembly for use in overall reactor calculation.

(g) Discontinuity factors are calculated at the boundary between bundles and for reflector regions.

Geometry modelling: The transport calculation scheme and the corresponding geometry modelling are as follows: One-dimensional pin cell calculation (40 groups) is performed in annular model for each pin type. Each pin type is homogenised, and used for a two-dimensional response matrix (RM) calculation of the assembly in a rectangular geometry, to include the effects of the surroundings. Pin cell spectra are then modified by RM results, and the modified spectra are used for processing a several-group cross-section, with which a two-dimensional heterogeneous calculation of the entire assembly is done for the flux distribution throughout the lattice, by solving the transport equation using the method of characteristics.

Table 2.1. Analysis codes and methods

No.	Country	Institute	Participant	Nuclear data				Calculation			Remarks
				Origin	Library	No. of groups	Processing code	Code	Model	Convergence limits	
1	Japan	NUPEC	Sakurai, Mitake	ENDF/B-IV	E4LBL70 (L-library)	70	CASLIB	CASMO-4	1-D (pin cell, 70 group), 2-D (assembly, 16 group)	Flux: 5.0E-5, k_{eff}: 1.0E-4	CASMO-4: response matrix method
2	France	CEA	Thiollay	JEF-2.2	CEA-93	172	NJOY	DARWIN	2-D	k_{eff}: 1.0E-6	DARWIN code system based on APOLLO2 & PEPIN2 codes
3	Germany	GRS	Gmal, Moser, Hesse	JEF-2.2	KORLIB-V4, 99-standard library	83 (29 thermal)	RESMOD, HAMMER	KENOREST-2000, OREST99	3-D (KENO), 1-D (pin cell burn-up)	NA	No iteration employed to achieve target burn-up
4	Switzerland	PSI	Grimm	JEF-1	BOXLIB	70	ETOBOX	BOXER	2-D	Flux: 1.0E-4, k_{eff}: 1.0E-5	
5	UK	BNFL	O'Connor, Bowden, Thorne	JEF-2.2	"1997" WIMS library	172	NJOY & WILT	WIMS8A	2-D	None	172 group > 6 groups for CACTUS & BURNUP modules; WIMS8A: collision probabilistic method
6	Japan	JAERI (1)	Suyama	JENDL-3.2	MVP94.1	Continuous	LICEM	MVP-BURN	3-D	NA	MVP-BURN: continuous Monte Carlo burn-up code
7	Japan	JAERI (2)	Suyama	JENDL-3.2, JNDCFPV2	SWAT library, SRAC library	147	SWAT: RECENT, LINEAR, SIGMA 1, CRECTJ5, SRAC95: PROFGROUCH	SWAT (SRAC95 & ORIGEN2)	1-D	NA	SRAC95: collision probabilistic method
8	UK	DTLR	O'Connor	JEF-2.2	"1996" WIMS library	172	WIMS pre-processing modules	MONK8A	3-D	k_{eff}: 0.001 less	1 000 neutron per stage, 10 super-histories; decay chains for ^{238}Pu and Cm isotopes are omitted
9	USA	ORNL	De Hart, Sanders	ENDF/B-VI	scale.rev09. xn238	236	BONAMI/NITAWL	SAS2D (NEWT & ORIGEN-S)	2-D	Flux: 1.0E-4, k_{eff}: 1.0E-4	SAS2D is a developmental 2-D depletion sequence in SCALE. The final version will be released with SCALE5 under the name TRITON.

Omitted nuclides: ^{95}Mo, ^{99}Tc, ^{101}Ru.

Employed convergence limit for eigenvalue calculations: Convergence tolerance for relative change of flux: 5.0×10^{-5}, eigenvalue: 1.0×10^{-4} (default).

Other related information: Machine – SPARC Station 5 (Solaris 2.4).

References to the code system or library:

[1] E. Edenius, B.H. Forssen, C. Gragg, "The Physics Model of CASMO-4", Proc. Int. Topical Meeting on Advances in Mathematics, Computations and Reactor Physics, Vol. 2, pp. 10-11 1, ANS (1991).

2) *CEA, France*

Institute: CEA/DRN (France).

Participants: N. Thiollay, B. Roque.

Neutron data library: CEA-93 based on JEF-2.2 evaluations.

Neutron data processing code: Multi-group cross-sections and effective cross-sections processed by NJOY from JEF-2 file.

Neutron energy groups: 172 (X-MAS group structure).

Description of code system: The code system used is the DARWIN package based on the APOLLO2 and PEPIN2 codes. APOLLO2 is the new French code system used for LWRs and HCLWRs. APOLLO2 is a modular code which solves both the Boltzman integral equation and the integro-differential equation (S_n method). APOLLO2 allows the use of several collision probability methods (exact-2D P_{ij}, and multi-cell P_{ij} based on the interface current method) to solve the integral equation. The PEPIN2 program performs the nuclide depletion calculations. Different libraries feed this module:

(a) Neutronics data provided by the French transport code APOLLO2. These data are self-shielded cross-sections and neutron spectra.

(b) Nuclear constants (decay data, fission and (α,n) yields) and decay chains.

(c) Complementary cross-sections missing from the transport codes libraries, especially for activation products.

Geometry modelling: Exact heterogeneous geometry, each fuel pin is differentiated, fuel pin divided into four concentric zones. Thus, 36 depletion media are used (9 pins × 4 zones). Self-shielded cross-sections are calculated for every actinide in each concentric zone; a powerful and accurate matrix dilution formalism is used for resonant reaction rate calculation.

Omitted or substituted nuclides: The whole nuclides are available in CEA93 library.

Employed convergence limits: External convergence on k_{eff} = 1.E-6 dk/k.

Other information: ^{241}Am to ^{242m}Am branching ratio of 0.115 is used.

References:

[1] R. Sanchez, *et al*., "APOLLO2: A User-oriented, Portable, Modular Code for Multi-group Transport Assembly Calculations", *Nucl. Sci. and Eng*., 100, 352 (1988).

[2] P. Marimbeau, *et al*., "The DARWIN Fuel Cycle Package. Procedures for Material Balance Calculation and Qualification", ENC'98, Nice, France, 25-28 October 1998.

3) GRS, Germany

Institute: Gesellschaft für Anlagen- und Reaktorsicherheit GRS, Germany.

Participants: Bernhard Gmal, Ulrich Hesse, Eberhard F. Moser.

Neutron library: JEF-2.2 based library KORLIB-V4 for KENO-5a [2], 2001 standard library for OREST [3], HAMMER [4].

Neutron data processing code and method: Condensing KORLIB-V4 from 292-group library JEF-2.2 [6] by RESMOD code for the infinite dilution case. Resonance treatment is done by the HAMMER code using resonance parameters [7].

No. of neutron energy groups: 83, 32 thermal groups up to 1.13 eV (KENO-5a), PL order is 3.

Description of the code system: KENOREST Version 2001 [1] includes KENO-5a code for 3-D assembly calculations using the Monte Carlo method, coupled with the one-dimensional burn-up code system OREST01 (HAMMER-ORIGEN [5]) for single rod burn-up calculations. The coupling is realised using flux and reaction rate conservation with the FEC method [8] of GRS. The flux spectra and cross-section calculations for the fuel rods are performed by the HAMMER code (THERMOS-HAMLET) using the method of integral Boltzmann neutron transport calculation and Nordheim resonance treatment in the resonance region. The cross-sections are directly fed back to KENO.

Geometry modelling: 3-D for in-core k_{eff} calculations by KENO, 1-D for pin cell burn-up calculations.

Used nuclides: All nuclides of ORIGEN library.

Other information: K_∞ values are calculated automatically by the code system, taking into account more nuclides than those specified for the benchmark. Fifty-seven (57) nuclides were handled simultaneously. The remaining are treated as long-lived fission products. For ^{241}Am $\Rightarrow$ ^{242m}Am a branching ratio of 0.137 was used.

References:

[1] U. Hesse, *et al*., “KENOREST – A New Criticality and Inventory System Based on KENO and OREST”, ICNC99 Proceedings, Vol. 1, p. 48.

[2] L.M. Petrie, N.F. Landers, “KENO V.a., An Improved Monte Carlo Criticality Program with Supergrouping”, NUREG/CR-0200, Vol. 2, Section F11, ORNL, Tennessee 37831, March 1983.

[3] U. Hesse, W. Denk, H. Deitenbeck, “OREST – eine direkte Kopplung von HAMMER und ORIGEN zur Abbrandsimulation von LWR-Brennstoffen”, GRS-63 (GRS-erweiterte Version OREST-98), November 1986.

[4] J.E. Suich and H.C. Honeck, “The HAMMER System – Heterogeneous Analysis by Multi-group Methods of Exponentials and Reactors”, TID-4500, January 1967.

[5] M.J. Bell, “ORIGEN – The ORNL Isotope Generation and Depletion Code”, ORNL-4628, UC-32-Mathematics and Computers (GRS-Version 1990 für NEA Data Bank), May 1973.

[6] W. Bernnat, D. Lutz, J. Kleinert, M. Mattes, “Erstellung und Validierung von Wirkungsquerschnittsbibliotheken auf Basis der evaluierten Dateien JEF-2 und ENDF/B-VI für Kritikalitäts- und Reaktorauslegungs-Rechnungen sowie Störfallanalysen”, IKE 6-189, IKE Institut für Kerntechnik und Energiesysteme, Universität Stuttgart, September 1994.

[7] S.F. Mughabghab, “Neutron Resonance Parameters and Thermal Cross-sections”, Vol. 1, Brookhaven National Laboratory, Upton, New York, Academic Press, Inc., (1984).

[8] U. Hesse, K. Hummelsheim, “Detaillierte, dreidimensionale Abbrandrechnungen für ein SWR-Atriumbrennelement”, GRS-A-2116, December 1993.

4) *PSI, Switzerland*

Institute: Paul Scherrer Institute.

Participant: Peter Grimm.

Neutron data library: Cross-sections from JEF-1 (except ^{155}Gd from JENDL-2, zircaloy-2 from ENDF/B-4), processed by ETOBOX (code developed at PSI, Ref. [1]). Fission product yields from JEF-2 for thermal fission. Decay data for fission products are taken from Ref. [3], and for actinides from Ref. [4]. In the decay data 34 actinides (^{232}Th to ^{248}Cm), 55 explicit fission products, two pseudo fission products are taken into account.

Neutron energy group: 70 groups (69 group WIMS structure + 1 group 10-15 MeV, thermal cut-off 1.3 eV). Point data in resonance range (1.3 eV-907 eV) consists of typically 7 000-8 000 points. Tabulated resonance cross-sections are collapsed to groups for E > 907 eV. Thermal scattering matrix for hydrogen in water is taken from JEF-1 $S(\alpha,\beta)$ matrix.

Cell, transport and depletion code:

(a) BOXER – cell and two-dimensional transport and depletion code (developed at PSI, Ref. [2]). Resonance self-shielding: Pointwise two-region collision probability calculation (1.3 eV < E < 907 eV), tabular interpolation versus temperature and equivalent dilution cross-section for E > 907 eV, Dancoff factor corrected for 2-D array geometry by Monte Carlo method.

(b) Cell calculation: One-dimensional integral transport calculation in cylindrical geometry employing white boundary conditions or boundary source from a previously calculated cell. Fundamental mode spectrum (k_{eff} = 1) in 70 groups by B1 method for homogenised cell.

(c) Two-dimensional transport calculations: Transmission probability integral transport method in x-y geometry for homogenised cells, using first-order spherical harmonics expansions for mesh surface currents and linear space dependence of surface currents and source within meshes, P1 anisotropic scattering.

(d) Depletion calculation: Taylor series (fixed order), asymptotic densities for nuclides with high destruction rates, predictor-corrector method, density dependent one-group cross-sections within time step for ^{239}Pu and ^{240}Pu (approximated by rational function).

(e) Models and calculational options used: Cell calculation for all pin types (cylindricalised cells) with white boundary condition. Cell calculation for guide tubes with boundary source from high enrichment MOX cell. Cladding composition replaced by zircaloy-2, 3.8859E-2 atoms/barn*cm (sum of number densities for Zr + Fe + Cr in specifications).

(f) Energy group structure for two-dimensional transport calculation: 15 groups, upper boundaries 15, 6.07, 2.23 MeV, 821 keV, 907, 75.5, 16, 4, 1.3, 0.996, 0.625, 0.3, 0.14, 0.05 and 0.02 eV.

(g) Geometric model for 2-D transport calculations: Homogenised pin cells, one mesh per cell. Supercell: 2×2 assemblies with translational boundary conditions simulated by 2×2 quarter assemblies with reflective boundary.

Employed convergence limits: 1E-4 for fluxes, 1E-5 for eigenvalue.

Other information: Depletion with critical spectrum by search for material buckling at each burn-up step. Burn-up points in each cycle: 0, 0.1, 0.5, 1, 2, 4, 8, 12, 16 GWd/t from BOC (repeated three times).

References:

[1] J.M. Paratte, K. Foskolos, P. Grimm, J.M. Hollard, "ELCOS, The PSI Code System for LWR Core Analysis, Part I: User's Manual for the Library Preparation Code ETOBOX", PSI Report 96-02, January 1996.

[2] J.M. Paratte, P. Grimm, J.M. Hollard, "ELCOS, The PSI Code System for LWR Core Analysis, Part II: User's Manual for the Fuel Assembly Code BOXER", PSI Report 96-08, February 1996.

[3] M.E. Meek, B.F. Rider, "Compilation of Fission Product Yields", NEDO-12154-1, 74NED6 (1974).

[4] W. Seelmann-Eggebert, *et al*., "Karlsruhe Chart of the Nuclides", 5th edition, Kernforschungszentrum Karlsruhe (1981).

5) BNFL, United Kingdom

Institute: British Nuclear Fuels Ltd (BNFL).

Participants: Gregory O'Connor, Russell Bowden, Peter Thorne.

Neutron data library: 172-group "1997" WIMS library, Version 1, 20th June 1997. Xmas 172 group structure. Nuclear data source – JEF-2.2.

Neutron data processing code or method: WIMS8A processing codes – NJOY & WILT.

Neutron energy groups: 172-group structure condensed to six groups for final CACTUS and BURNUP modules.

Description of code system: WIMS8A, Release 0, is a two-dimensional deterministic code developed by AEA Technology.

Geometry modelling: Geometry modelled according to the benchmark, no simplifications made.

Omitted or substituted nuclides: No nuclides substituted or omitted from the calculations.

Employed convergence limits: None, WIMS8A is a deterministic code.

Other information: Calculations performed on a SunOS 5.7, processor type sun4u using the Solaris 2 operating system. ^{241}Am to ^{242m}Am branching ratio of 0.10 is used.

6) JAERI, Japan (1)

Institute: Japan Atomic Energy Research Institute (JAERI).

Participants: Kenya Suyama, Hiroki Mochizuki and Hiroshi Okuno.

Neutron data library: JENDL-3.2.

Neutron data processing code:

(a) SRAC95 libraries:
- PROF-GROUCH-GII [2] and TIMS-1 [3]: Fast group (10 MeV to 0.41399 eV): 74 groups.
- MCROSS-2 [3]: Resonance (961 eV to 0.41399 eV): 19 500 groups (for ultra fine resonance absorption calculation library).
- GASKET [4] and HEXSCAT [5]: Thermal (3.9279 eV to 1.0E-5 eV) and S(α,β): 48 groups.

(b) SWAT libraries:
- LINEAR, RECENT, SIGMA1 [6] and CRECTJ5 [7]: 147 groups. This SWAT library is for isotopes not included in SRAC95 libraries.

Neutron energy group: 107 groups(for eigenvalue problems). Overlapping groups exists in a resonance region (3.9279 to 0.41399 eV).

Description of code system:

(a) SWAT [8] is an integrated burn-up code system driving SRAC95 and ORIGEN2. In the SWAT calculation, SRAC95 evaluates effective cross-sections dependent on burn-up and burn-up calculation is conducted by ORIGEN2. SWAT includes original cross-section library "SWAT library" for use in burn-up calculation. This library is based on JENDL-3.2. For many isotopes, effective cross-sections are prepared by SRAC95. However, some isotopes are not treated in the SRAC95 calculation. To use the latest cross-section data in JENDL-3.2 for these isotopes, SWAT makes infinite diluted cross-section data from the "SWAT library". This function enables us to perform burn-up calculations using all cross-section data stored in JENDL-3.2. In the SWAT calculation, fission yield and decay constant data are also updated based on JNDC FP Library 2nd version [9].

(b) SRAC [1] is JAERI's Thermal Reactor Standard Code System. It contains many modules for neutronics calculation. SRAC95 is the latest version released in 1996. SRAC has been used for many reactor analyses. SRAC uses collision probability method to calculate group constants. A generalised Dancoff correction factor was introduced for infinite arrays of multi-region cells including several absorber lumps with different nuclide concentrations using the collision probability method. A fixed boundary source problem is available in the cell calculation using the collision probability method. It can endow a proper spectrum to an isolated cell that cannot have its own spectrum. A remarkable feature of SRAC is its ultra-fine resonance calculation using the collision probability method.

Geometry modelling: Square and cylinder divided by concentric circles (1-D calculation).

Omitted nuclides: None.

Employed convergence limit: 1.0E-5.

Other information: One-hundred seven (107) groups' effective group constants were calculated using the collision probability method in fixed source mode by SRAC95. We then treat the eigenvalue problem with the collision probability method using the constants of the 107 groups. Ultra-fine (15 000 groups) resonance calculation was selected for 961 eV to 3.9279 eV. This sequence is the standard method for calculating eigenvalues using the SRAC system. For ^{241}Am to ^{242m}Am, a branching ratio of 0.11 is used.

References:

[1] K. Okumura, *et al*., JAERI Data/Code 96-015 (1996), see also JAERI-1302 (1986).

[2] S. Hasegawa, JAERI-1248 (1978).

[3] H. Takano *et al*., JAERI-M 4721 (1978).

[4] J.U. Koppel, *et al*., GA-7417 (1966).

[5] Y.D. Naliboff, *et al*., GA-6026 (1964).

[6] D. Cullen, UCRL-50400, Vol. 17, Part B (1979).

[7] T. Nakagawa, JAERI Data/Code 99-41 (2000).

[8] K. Suyama, *et al*., JAERI Data/Code 2000-027 (2000).

[9] K. Tasaka, *et al*., JAERI-1320 (1980).

7) JAERI, Japan (2)

Institute: Japan Atomic Energy Research Institute (JAERI).

Participants: Kenya Suyama, Keisuke Okumura, Hiroshi Okuno and Masaru Ido* (* ITJ Inc.).

Neutron data library: JENDL-3.2.

Neutron data processing code: ART [4] is used to make temperature dependent libraries.

Neutron energy group: Continuous energy.

Description of code system: MVP-BURN [1] is a burn-up code system using the continuous-energy Monte Carlo code "MVP" [2] and the burn-up calculation routine of "SRAC95" [3].

Geometry modelling: Two-dimensional modelling specified in the benchmark specification.

Omitted nuclide: In burn-up chain data, ^{95}Mo, ^{110}Ag and ^{147}Sm are not included.

Employed convergence limit: None.

Other information: For ^{241}Am to ^{242m}Am, a branching ratio of 0.116 is used.

History information: Case-1 5000 history/cycle; 50 cycle (include 10 skip).
Case-2 5000 history/cycle; 50 cycle (include 10 skip).
Case-3 10000 history/cycle; 50 cycle (include 10 skip).
Case-4 10000 history/cycle; 50 cycle (include 10 skip).
Case-5 10000 history/cycle; 50 cycle (include 10 skip).
Case-6 10000 history/cycle; 50 cycle (include 10 skip).

Burn-up step: 2 GWd/t per step.

References:

[1] K. Okumura, *et al*., *J. Nucl. Sci. Technol.*,Vol. 32, pp. 128-138 (2000).

[2] T. Mori and M. Nakagawa, JAERI-Data/Code 94-007 (1994).

[3] K. Okumura, *et al*., JAERI Data/Code 96-015(1996), see also JAERI-1302 (1986).

[4] T. Mori, *et al*., Proc. Int. Conf. on Mathematics and Computation (M&C'99), Madrid, Vol. 2, p. 987 (1999).

8) DTLR, United Kingdom

Institute: Department for Transport, Local Government and the Regions (DTLR).

Participant: Gregory O'Connor.

Neutron data library: One-hundred seventy-two (172) group "1996" WIMS library, Version 3. Nuclear data source – JEF-2.2.

Neutron data processing code or method: WIMS pre-processing modules used.

Neutron energy groups: One-hundred seventy-two (172) group structure.

Description of code system: MONK8A, Release Update 1, developed by AEA Technology.

Geometry modelling: Geometry modelled according to the benchmark, no simplifications made.

Omitted or substituted nuclides: Decay chains for ^{238}Pu and Cm isotopes are omitted from the MONK8A code.

Employed convergence limits: Convergence of eigenvalue (k_{eff}) to less than 0.0010.

Other information: Three-dimensional Monte Carlo calculation using 1 000 neutrons per stage and 10 super-histories. Calculations performed on a Compaq DeskPro, with Pentium III processor and using WINDOWS-NT Version 4.0 operating system. ^{241}Am to ^{242m}Am branching ratio of 0.12 is used.

9) ORNL, USA

Institute: Oak Ridge National Laboratory.

Participants: Mark D. Hart, Charlotta Sanders.

Neutron data library: scale.rev09.xn238, version 9 of the SCALE 238-group ENDF/B-V library (contains ENDF/B-VI evaluations for O, N, and Eu nuclides).

Neutron data processing code or method: BONAMI/NITAWL.

Neutron energy groups: Two-hundred thirty-eight (238) group structure.

Description of code system: SAS2D is a developmental 2-D depletion sequence in SCALE 5. The final version will be released with SCALE 5 under the name TRITON. SAS2D used NEWT for 2-D transport calculations coupled with ORIGEN-S for independent depletion of each fuel region. NEWT is a generalised-geometry discrete ordinates solver.

Geometry modelling: NEWT employs arbitrary-polygon computational cells; all curved surfaces were approximated by high-order polygons (10 or more sides) with volumes conserved.

Omitted or substituted nuclides: None.

Employed convergence limits: Both flux and eigenvalue convergence limits set to 1E-4. In general, eigenvalues were converged on the order of 1E-6 before spatial convergence was achieved.

Other information: Reported results were obtained from calculations performed on a Compaq Alpha under OSF1 V4.0 compiled with the Compaq Fortran 95 compiler. Results were verified on a Macintosh G4-DP running OS X v10.1 and the Absoft F95 compiler. All calculations were performed with controlled but pre-released versions of SCALE 5 modules and data.

3. Results and discussion

All participants provided the required calculation results for all cases, except JAERI's analyses using the SWAT code system, which only covered results for Cases 5 and 6 (pin cell calculation model). The calculation results (raw data) submitted by the participants are tabulated in Appendix B. In the appendix, the average (mean) values and the two times relative standard deviation (TRSD, in %) values are also listed and graphically shown at the end of each table for all actinide and fission product nuclide densities.

The average (*Ave*), standard deviation (*SD*), relative standard deviation (*RSD*) and two times relative standard deviation (*TRSD*) are defined as follows:

$$Ave = \frac{1}{N}\sum_{i=1}^{I} N_i$$

$$SD = \frac{1}{I-1}\sum_{i=1}^{I}\left(N_i - Ave\right)^2$$

$$RSD = \frac{SD}{Ave}$$

$$TRSD = 2 \times RSD$$

Here, N_i is the atomic number density or other parameter of interest calculated by participant i (where the number of participants is denoted by I).

3.1 Infinite multiplication factor and reactivity change due to burn-up and cooling

Based on the calculation results shown in Appendix B, the average (mean) values of infinite multiplication factor (k_∞) and their standard deviations, the reactivity changes due to burn-up and cooling are summarised in Appendix C. In the appendix, the values of the k_∞ and reactivity changes are also shown in graphs for comparisons.

In the next discussion, Cases 1 and 2 are chosen since they represent the most complicated calculation model and it is expected that the range of the deviation of the calculation results would be the largest among other cases. The results for Cases 1 and 2 are shown in Table C.1 and Figure C.1 and Table C.2 and Figure C.2, respectively. The percentage relative difference in k_∞ and reactivity change values are obtained by comparing to the average values among the participants' results.

For Case 1 (first recycle MOX fuel) at the end of cycle 3, the minimum and maximum k_∞ values are 0.91013 (GRS) and 0.93210 (ORNL), and their relative differences from the average value are -1.28% and 1.11%, respectively. Therefore, the spread between the minimum and maximum values of k_∞ for the end of cycle 3 is around 2.4%. The percentages of standard deviation of the k_∞ as function of burn-up remains constant around 0.8%. As seen in Figure 1, the trend of the k_∞ values among participants after five years decay calculations is similar to the one at the end of cycle 3. At the end of five years cooling, the minimum and maximum k_∞ values are 0.89200 (GRS) and 0.92098 (ORNL), and their relative differences from the average value are -1.74% and 1.46%, respectively. Therefore, the spread between the minimum and maximum values of k_∞ after five years cooling is around 3.2%, which is larger than that for the end of cycle 3.

For Case 2 (weapons disposition MOX fuel where the ^{239}Pu is the main fissile material) at the end of cycle 3, the minimum and maximum k_∞ values are 0.88140 (GRS) and 0.91021 (ORNL), while their relative differences from the average value are -1.65% and 1.57%, respectively. Therefore, the spread between the minimum and maximum values of k_∞ for the end of cycle 3 is around 3.2%. These relative differences and the spread are slightly larger than the ones of the first recycle MOX fuel case. After five years cooling, the minimum and maximum k_∞ values are 0.86485 (GRS) and 0.90466 (ORNL), while their relative differences from the average value become -2.22% and 2.28%, respectively. Therefore, the spread between the minimum and maximum values of k_∞ after five years cooling is around 4.5%. Again, these relative differences and the spread are slightly larger than those of the first recycle MOX fuel case. Concerning the percentage of standard deviation of the k_∞ as function of burn-up, it can be observed that as fuel burn-up proceeds, the standard deviation also increases monotonically. This trend is not observed in the case of first recycle MOX fuel.

Concerning the results for other cases, as the calculation model becomes simpler, the spread of the k_∞ values among participants shows a decreasing trend. Consistent with the results of the most complicated cases (Cases 1 and 2), the weapons disposition MOX fuel cases showed relative larger k_∞ spreads than those of the first recycle MOX fuel cases.

Besides the k_∞ values, there is a strong incentive to investigate the differences on the reactivity change due to burn-up and cooling. It is expected that different parameters (effective cross-sections, half-lives, branching ratios and burn-up chains) used in the burn-up and cooling calculations would be reflected by these reactivity changes.

For Case 1 (first recycle MOX fuel), the reactivity swings due to burn-up during cycle 3 show minimum and maximum values of -7.3% (ORNL) and -8.7% (GRS), respectively, while their relative differences from the average values are -11.0% and 6.4%, respectively. The reactivity changes due to five years cooling (decay) show minimum and maximum values of -1.3% (ORNL) and -2.2% (GRS), while their relative differences from the average values are -23.6% and 31.7%, respectively. The relative differences of reactivity changes due to five years cooling show significantly larger values than those which come from burn-up. However, if we observe that the standard deviation for the total reactivity swing (burn-up and cooling effects) show only 5.3%, it can be concluded that the uncertainty of the total reactivity swing mainly comes from the burn-up calculations. At the end of five years cooling the spread of the total reactivity swing (burn-up and cooling) is about 3.3%.

Similar trends are also observed for Case 2 (^{239}Pu dominated case) although in a milder way. The minimum and maximum burn-up swings due to burn-up during cycle 3 of -9.7% and -10.8% are given by ORNL and GRS, respectively. Their relative differences from the average values (-6.8% and 3.9%) are slightly smaller than those of the first recycle MOX fuel case. In addition, the minimum and maximum reactivity changes due to five years cooling of -0.7% and -2.3% are given by ORNL and NUPEC, respectively. The relative differences for these reactivity changes are -54.6% and 57.3%, respectively, which are again significantly larger than those which come from burn-up. The standard deviation for the total reactivity swing (burn-up and cooling effects) of 5.2% is very close to that of the first recycle MOX fuel. At the end of five years cooling the spread of the total reactivity swing (burn-up and cooling) is about 3.6%.

As a general trend observed in all cases, the relative differences in reactivity change due to cooling are larger than those due to burn-up. However, for less complex cases, the standard deviations of the total burn-up swing do not significantly decrease.

3.2 Average burn-up and burn-up distribution

The calculation results for the fuel burn-up are summarised in Appendix D. Particularly, the intercomparison on the results for Cases 1 and 2 are shown in Table D.1 and Figure D.1 and Table D.2 and Figure D.2, respectively. It is expected that despite the variations on the high-, medium- and low-enriched pin fuel burn-up levels, their assembly averaged burn-up should produce the same values. In general, as the fuel burn-up proceeds the spread of the burn-up values among participants becomes larger, their absolute values are negligible. For Cases 3 and 4, there are practically no differences in the averaged burn-up values for high, medium, low and assembly averaged burn-up levels among the participants' results.

3.3 Additional analyses

Two participants have submitted additional analyses regarding various aspects of the Phase IV-B benchmark problem, the results of which are compiled in Appendix E.

3.3.1 Reactivity effect of ^{239}Pu

First, Dr. Greg O'Connor (DTLR) conducted analysis on the reactivity effect of ^{239}Pu using the MONK code. Details are presented in Appendix E.1.

The analysis of the participants' results showed that there was a spread in the final inventory prediction of the ^{239}Pu nuclide number density of about 9-10%. This spread did not appear to depend on the geometry of the system nor the type of MOX fuel used for the depletion calculation. It was then decided to use the participant's fuel spent MOX fuel inventory to calculate a k_∞ so that direct comparisons between each of the participants could be made. In order to do this, each MOX inventory was in turn put into the pin cell geometry and the same nuclear data (JEF-2.2) and code system (MONK) was used to calculate the system k_∞. A spread of about 3-4% was seen in the calculated k_∞. This spread was also independent of the geometry that the MOX fuel had been irradiated in.

A 9-10% spread in the predicted ^{239}Pu composition and a 3-4% spread in the depleted MOX fuel pin cell k_∞ is unexpectedly large and requires further investigation. The participants were therefore requested to re-examine their models to see if any of the approximations that were made could have an adverse affect on the final ^{239}Pu nuclide number density predicted. It is considered that if a better agreement could be achieved for the prediction of the ^{239}Pu nuclide between the participants, then a better agreement for the k_∞ of the MOX fuel inventory as a whole would occur.

It should be noted that the analyses were conducted based on the benchmark calculation results submitted before September 2001. At that point, the GRS calculation results had not yet been revised, i.e. the older results calculated with KENOREST-99 were used for the reactivity effect analysis. Furthermore, ORNL had not yet submitted their results and they were not included in the analysis. However, we believe that the conclusions drawn below would not change substantially if the latest results were used.

From the results of analysis, it can be concluded that the variation of ^{239}Pu nuclide densities among the participants' results yielded spreads of k_∞ values in the range from 3-4% depending on the calculational models and initial fuel compositions.

3.3.2 Burn-up zone number and burn-up step length effect

Second, Dr. Peter Grimm (PSI) carried out a sensitivity study of Case 6 using the BOXER code. Details are presented in Appendix E.2. Two numerical issues, that is, the radial subdivision of burn-up zones in the pellet region and the burn-up step length, were investigated as follows.

In one case, the fuel pellet was subdivided radially into five zones of equal cross-sectional areas and zone-wise self-shielding of the resonances was applied (in the standard model or base case, the fuel pellet was represented by a single zone). In the second case, the maximum length of the burn-up steps was reduced from 4 GWd/t to 2 GWd/t. The shorter steps at the beginning of each cycle of irradiation were retained.

From the results of the analysis above it can be concluded, at least for the BOXER code, that the number of burn-up zones and burn-up steps did not alter the benchmark calculation results in any significant manner. This also implies that the ^{239}Pu nuclide density variation was not due to these two numerical issues.

3.4 Actinide and fission product nuclide densities

Appendices F through K contain the comparison graphs for actinide and fission product nuclide densities for Cases 1 through 6.

The discussion concerning the intercomparison of actinide and fission product nuclide densities is again focused on Cases 1 and 2, which represent the most complicated calculation model. The relative differences of actinide and fission product nuclide densities from the average values at the end of cycle 1, cycle 3 and after five years cooling for Case 1 (first recycle MOX fuel) are shown in Figures F.1 to F.6 of Appendix F.

First, the results for end of cycle 3 are discussed. For uranium isotopes, a relatively large difference (about -85%) is found for the ^{234}U isotope submitted by DTLR, while the other participants submitted roughly the same values. For plutonium isotopes, a much better relative agreement among participants' results can be observed. Therefore, if the DTLR contribution is excluded then an excellent agreement can be achieved for both uranium and plutonium isotopes. A similar trend is also observed for ^{237}Np (about -80%, DTLR). For minor actinides, the relative differences among participants' results are observed within ±30%. Thus, for fissile isotopes which contribute significantly to the k_∞, a good agreement among participants' results are confirmed.

For important fission products at the end of cycle 3, relatively large differences are observed for ^{155}Gd, ^{109}Ag (-20%, NUPEC), ^{103}Rh (-11%, NUPEC) and ^{95}Mo (+9%, PSI). However, in the case of ^{109}Ag, if the contribution of NUPEC is excluded then a good agreement can be achieved among the participants' results. The relative differences of the actinide and fission product nuclide densities after five years cooling show similar trends inherited from the results at the end of cycle 3.

The results for the ^{239}Pu-dominated case (Case 2) are shown in Figures G.1 to G.6 of Appendix G. At the end of cycle 3, for uranium and plutonium isotopes, a good agreement among the participants' results can be achieved if the ^{234}U (relative difference of -22%) and ^{238}Pu (relative difference of -95%) contributions of DTLR are excluded. A similar trend is observed for ^{237}Np (-75%, DTLR). Other minor actinides show relative differences below ±30%. It is interesting to note that large relative differences of ^{238}Pu are found in these ^{239}Pu-dominated MOX fuel cases, which are not found in the first recycle MOX fuel cases.

Nevertheless, the relative differences for more simple calculation models (Cases 3 to 6), the trends and the magnitudes do not change significantly from Cases 1 and 2 discussed above.

4. Conclusion

Nine participants from seven countries undertook the calculations for the Phase IV-B Burn-up Credit Benchmark. The analysis codes used by participants covered both deterministic and stochastic neutron transport codes. The original nuclear data libraries used in the codes are ENDF/B (Version IV to VI), JEF (Version 2.2) and JENDL (Version 3.2). The deterministic codes employed the multi-group approach while the stochastic codes employed both the multi-group and continuous energy approaches. In the deterministic multi-group approach, some codes adopted an ultra-fine group structure for the resonance energy region. For stochastic multi-group codes, the pin cell and assembly geometries are treated almost without approximation, although a homogenisation step for producing effective group constants involved can be considered as an approximation.

In general, the benchmark calculation results submitted by each participant show good agreement and consistence. For the most complicated, i.e. the supercell modelling cases, the k_∞ spreads (maximum value minus minimum value) after five years cooling are found to be about 3% and 4% for the first recycle MOX and weapons disposition MOX fuels, respectively, while their total reactivity swing (due to burn-up and five years cooling) spreads are found to be about 3.3% and 3.6%, respectively. Other simpler calculational models show relatively smaller spreads. The k_∞ spreads for Pu-dominated MOX fuel (weapons disposition MOX fuel) are generally slightly larger than those for the first recycle MOX fuel. The spreads of reactivity swing due to five years cooling are significantly larger than those due to fuel burn-up.

From additional analysis on the effect of the number of burn-up zones in the fuel pellet and the burn-up step length, it can be deducted that these two numerical issues did not affect significantly the accuracy of the participants' benchmark calculation results.

From further analysis on the reactivity effect of ^{239}Pu, it can be seen that there is a relatively large discrepancy (~3-4%) between the highest and lowest neutron multiplication factors calculated from the MOX fuel compositions provided by the participants for the Phase IV-B Burn-up Credit Benchmark.

In terms of percentage relative difference from the mean value, ^{234}U (especially for first recycle MOX fuel), ^{238}Pu (especially for weapons disposition fuel) from the major actinides, and ^{237}Np from the minor actinides generally show relatively large deviations. For the percentage of the relative differences for fission products, ^{155}Gd, ^{109}Ag and ^{103}Rh show relatively large values.

REFERENCES

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Appendix A

PROBLEM SPECIFICATION FOR THE OECD/NEA NSC BURN-UP CREDIT BENCHMARK PHASE IV-B: MIXED OXIDE (MOX) FUELS*

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1. Introduction

Since 1991, the criticality working group of the NEA NSC (formerly the NEA CRP) has been investigating the methods and data associated with the calculation of burn-up credit in criticality safety assessments. During this period, consideration has been given to uranium oxide fuels in both pressurised water and boiling water reactors (PWRs and BWRs). These benchmark exercises, denoted as Phases I to III, have covered the calculation of fuel inventory and the calculation of reactivity in storage array and transport flask configurations. The international consensus approach to the benchmarks adopted by the working group generates a great deal of confidence in the assessment methods. Participation in these exercises has produced useful data and a deeper understanding of the issues associated with the calculation of burn-up credit.

The next challenge for the burn-up credit method lies in its application to mixed oxide (MOX) fuels, i.e. fuel containing a mixture of uranium and plutonium oxides. A comprehensive MOX benchmark study would contain all of the elements of the previous phases, but with the added difficulties associated with the non-unique specification of MOX fuels and the manner in which they would be utilised within existing thermal reactor designs. The definition of a universally attractive benchmark exercise is further complicated by the different incentives for adopting a MOX fuel strategy amongst the member countries of the group participants.

An initial benchmark exercise for MOX fuels has recently been undertaken by the burn-up credit working group established by the newly-formed OECD/NEA NSC Criticality Working Party [1]. This exercise, which was referred to as Phase IV-A, considered the calculation of infinite PWR fuel pin cell reactivity for fresh and irradiated MOX fuels. The benchmark was based upon fuel compositions provided by the benchmark organisers, which were derived using a simplified MOX-only representation of the core. This initial exercise considered the impact of different initial plutonium isotopic compositions in the MOX fuel, associated with first-generation MOX, weapons plutonium disposition and multiple MOX recycle.

The next step in the proposed benchmark programme is to address the calculation of irradiated MOX fuel compositions. The Phase IV-B benchmark specification proposed here is a first step in comparing methods for the calculation of isotopic inventories for the nuclides of interest to MOX fuel

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** Updated February 2002.*

burn-up credit. The benchmark participants are requested to perform inventory calculations for two MOX fuel cases appropriate to weapons plutonium disposition and first recycle MOX, using three modelling representations for the reactor core.

2. Parameters and case numbers

The spent fuel inventory is required for a total of six cases, covering two initial MOX fuel compositions and three calculational models. Participants are requested to provide the inventory of the major actinides and fission products, along with the curium isotopes for specified fuel pins within the MOX assembly.

In the context of this benchmark exercise, and consistent with previous benchmark problems, the term “major actinides” is taken to represent the following nuclides:

^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{237}Np, ^{241}Am, ^{243}Am

The term “all actinides” refers to the major actinides plus ^{242m}Am and the specified curium isotopes of ^{242}Cm, ^{243}Cm, ^{244}Cm and ^{245}Cm.

The fission products considered in this exercise are the 15 major fission product absorbers addressed in previous benchmarks, namely:

^{95}Mo, ^{99}Tc, ^{101}Ru, ^{103}Rh, ^{109}Ag, ^{133}Cs, ^{143}Nd, ^{145}Nd, ^{147}Sm, ^{149}Sm, ^{150}Sm, ^{151}Sm, ^{152}Sm, ^{153}Eu, ^{155}Gd

The selected parameters and case numbers are shown in Table 1.

3. MOX fuel compositions

The two initial MOX compositions selected for this study were chosen to represent the range of potential interest in MOX fuels within the working group. The proposed MOX fuels are representative of realistic MOX fuels that would be irradiated in a mixed UO_2-MOX PWR core, alongside UO_2 fuel assemblies with an initial enrichment of 4.3 w/o $^{235}U/U$. These MOX fuels consist of:

- A reference MOX fuel case, appropriate to a typical plutonium vector for material derived from the reprocessing of thermal reactor UO_2 fuels, often referred to as “first generation” MOX, referred to as MOX Case A.

- A MOX fuel case appropriate to the disposition of weapons plutonium in MOX, referred to as MOX Case B.

The plutonium isotopic compositions for the different MOX fuel cases are presented in Table 2. Note that the plutonium vector for the reference case, Case A, is different from that adopted in the Phase IV-A exercise. The weapons disposition case plutonium vector is consistent with that used in the Phase IV-A specification. In all cases, the uranium oxide component of the MOX is assumed to be depleted, with a ^{235}U content of 0.25 w/o $^{235}U/U$, which is typical of current MOX fuel fabrication. The uranium isotopic composition is shown in Table 3.

Due to the irradiation of the MOX fuel alongside UO_2 fuel assemblies, the MOX fuel design adopts an enrichment pinmap to counter power peaking in the outer MOX pins adjacent to the UO_2 fuel. The MOX fuel assembly geometry adopted for the Phase IV-B exercise is a 17×17 PWR fuel assembly with three enrichment zones, as shown in Figure 2. The initial MOX fuel enrichments for these zones for the two MOX fuel cases are shown in Tables 4 and 5.

The pre-irradiation fuel compositions for the two MOX fuel assemblies are shown in Tables 6 and 7 for the MOX Cases A and B, respectively.

4. Geometry data

Three calculational models are requested for the Phase IV-B exercise, covering;

- A supercell calculation for a MOX assembly together with three UO_2 fuel assemblies, as shown in Figure 1, with translational boundary conditions.

- A MOX-only core representation, as shown in Figure 2, with reflective boundary conditions.

- A simple MOX pin cell calculation, using the average MOX fuel composition, with pin cell geometry that conserves the fuel-to-moderator ratio of the whole assembly in the previous calculations, i.e. accounting for 25 guide or instrument tube positions, as shown in Figure 3, with reflective boundary conditions.

The assembly geometry relates to a typical 17×17 PWR fuel assembly, as detailed below.

Fuel pin pitch:	1.26 cm
Fuel pin radius:	0.475 cm
Fuel pellet radius:	0.410 cm
Cladding thickness:	0.065 cm (no air gap between fuel and cladding)

The assembly channel box or water buffer should not be modelled for the above calculations. In particular, the pitch between any two adjacent fuel pins should be constant across the entire supercell, with no variation across the cell boundaries.

The 24 guide tubes and one instrument tube shall be modelled as water-filled zircaloy tubes with the following dimensions:

Outer radius:	0.613 cm
Inner radius:	0.571 cm
Wall thickness:	0.042 cm

For the simplified MOX pin cell inventory calculations, the pin pitch should be modelled as 1.3127 cm.

5. Non-fissile material data

The non-fissile materials are as follows:

Cladding:	Zircaloy-2
Guide tubes:	Zircaloy-2
Coolant/moderator:	Light water, 600 ppm boron

For the purpose of the benchmark exercise, these materials should be modelled as specified in Table 8. A reduced-density zircaloy has been specified for the fuel pin cladding to take into account the air gap between the fuel and cladding. For simplicity, the guide tubes should also be modelled using this reduced-density zircaloy composition.

6. UO_2 fuel compositions

For the supercell calculations, the adjacent UO_2 fuel assemblies have an initial enrichment of 4.3 w/o $^{235}U/U$. The composition of the UO_2 fuel is presented in Table 9.

7. Irradiation histories

In order to attain a sensible comparison of results, the requested calculations should be performed to attain a constant target burn-up for the MOX fuel assembly of 48 GWd/teHM. For the supercell calculations it may be necessary to perform a number of iterations of the calculation to produce the required MOX fuel assembly burn-up. The MOX fuel assembly is irradiated over three operating cycles, as shown below.

Cycle 1: Downtime:	420 days full power, EOC burn-up of MOX = 16 GWd/teHM 30 days
Cycle 2: Downtime:	420 days full power, EOC burn-up of MOX = 32 GWd/teHM 30 days
Cycle 3: Cooling:	420 days full power, EOC burn-up of MOX = 48 GWd/teHM 0 years, 5 years

For the supercell calculations, the power of the four-assembly cell should be set to attain the target burn-up of the MOX assembly.

8. Material temperatures

Fuel temperature:	900 K
Cladding temperature:	620 K
Coolant/moderator temperature:	575 K

9. Specified format for submission of results

The results should be submitted via e-mail to the benchmark organisers, using the address shown on the front page of this specification. In order to facilitate the data manipulation, the participants are requested to submit their results in the following format:

1	Date
2	Institute
3	Contact person
4	E-mail address or telefax number of the contact person
5	Computer code
6	* Case 1 *
7	Nuclide density of ^{234}U for EOC1, EOC2, EOC3, 5 years cooling
8	Nuclide density of ^{235}U for EOC1, EOC2, EOC3, 5 years cooling
9	Nuclide density of ^{236}U for EOC1, EOC2, EOC3, 5 years cooling
10	Nuclide density of ^{238}U for EOC1, EOC2, EOC3, 5 years cooling
11	Nuclide density of ^{238}Pu for EOC1, EOC2, EOC3, 5 years cooling
12	Nuclide density of ^{239}Pu for EOC1, EOC2, EOC3, 5 years cooling
13	Nuclide density of ^{240}Pu for EOC1, EOC2, EOC3, 5 years cooling
14	Nuclide density of ^{241}Pu for EOC1, EOC2, EOC3, 5 years cooling
15	Nuclide density of ^{242}Pu for EOC1, EOC2, EOC3, 5 years cooling
16	Nuclide density of ^{237}Np for EOC1, EOC2, EOC3, 5 years cooling
17	Nuclide density of ^{241}Am for EOC1, EOC2, EOC3, 5 years cooling
18	Nuclide density of ^{242m}Am for EOC1, EOC2, EOC3, 5 years cooling
19	Nuclide density of ^{243}Am for EOC1, EOC2, EOC3, 5 years cooling
20	Nuclide density of ^{242}Cm for EOC1, EOC2, EOC3, 5 years cooling
21	Nuclide density of ^{243}Cm for EOC1, EOC2, EOC3, 5 years cooling
22	Nuclide density of ^{244}Cm for EOC1, EOC2, EOC3, 5 years cooling
23	Nuclide density of ^{245}Cm for EOC1, EOC2, EOC3, 5 years cooling
24	Nuclide density of ^{95}Mo for EOC1, EOC2, EOC3, 5 years cooling
25	Nuclide density of ^{99}Tc for EOC1, EOC2, EOC3, 5 years cooling
26	Nuclide density of ^{101}Ru for EOC1, EOC2, EOC3, 5 years cooling
27	Nuclide density of ^{103}Rh for EOC1, EOC2, EOC3, 5 years cooling
28	Nuclide density of ^{109}Ag for EOC1, EOC2, EOC3, 5 years cooling
29	Nuclide density of ^{133}Cs for EOC1, EOC2, EOC3, 5 years cooling
30	Nuclide density of ^{143}Nd for EOC1, EOC2, EOC3, 5 years cooling
31	Nuclide density of ^{145}Nd for EOC1, EOC2, EOC3, 5 years cooling
32	Nuclide density of ^{147}Sm for EOC1, EOC2, EOC3, 5 years cooling
33	Nuclide density of ^{149}Sm for EOC1, EOC2, EOC3, 5 years cooling
34	Nuclide density of ^{150}Sm for EOC1, EOC2, EOC3, 5 years cooling
35	Nuclide density of ^{151}Sm for EOC1, EOC2, EOC3, 5 years cooling
36	Nuclide density of ^{152}Sm for EOC1, EOC2, EOC3, 5 years cooling
37	Nuclide density of ^{153}Eu for EOC1, EOC2, EOC3, 5 years cooling
38	Nuclide density of ^{155}Gd for EOC1, EOC2, EOC3, 5 years cooling
39	In-core k_∞ at EOC1, EOC2, EOC3, 5 years cooling
40	Average burn-up (GWd/teHM) of pin types 1, 2, 3
41	* Case 2 *
42 to 75	As for items 7 to 40
76	* Case 3 *
77 to 110	As for items 7 to 40
111	* Case 4 *

112 to 145	As for items 7 to 40
146	* Case 5 *
147 to 179	As for items 7 to 39
180	* Case 6 *
181 to 213	As for items 7 to 39
214	Please describe your analysis environment here. It will be included in the Phase IV-B report. The description should include:

Institute and country
Participants
Neutron data library
Neutron data processing code or method
Neutron energy groups
Description of your code system
Geometry modelling
Omitted or substituted nuclides (if any)
Employed convergence limits, etc.
Other information (if any)

Additional information

The participants are requested to supply the smeared nuclide number densities for all the fuel pins within the MOX assembly.

EOC (end of cycle) defines the time period immediately after irradiation but before the downtime or cooling period.

The in-core k_∞ calculation is requested for the MOX-UO_2 supercell as a whole, not just for the individual MOX assembly within the supercell.

Table 1. Selected parameters and case numbers

Case #	MOX type	Calculational model
1	Case A (first recycle)	Supercell
2	Case B (weapons disposition)	Supercell
3	Case A (first recycle)	MOX assembly
4	Case B (weapons disposition)	MOX assembly
5	Case A (first recycle)	MOX pin cell
6	Case B (weapons disposition)	MOX pin cell

Table 2. Plutonium isotopic composition in fresh MOX fuel

Nuclide	Isotopic composition, w/o in Pu_{total}	
	MOX Case A	MOX Case B
^{238}Pu	2.5	0.05
^{239}Pu	54.7	93.6
^{240}Pu	26.1	6.0
^{241}Pu	9.5	0.3
^{242}Pu	7.2	0.05

Table 3. Uranium isotopic compositions in fresh MOX fuel

Nuclide	w/o in U_{total}
^{234}U	0.00119
^{235}U	0.25000
^{238}U	99.74881

Table 4. Initial MOX fuel enrichments – Case A

MOX fuel Case A (first recycle MOX) enrichment zones	MOX fuel plutonium content, w/o Pu_{total}/[U+Pu]	MOX fuel enrichment, w/o $Pu_{fissile}$/[U+Pu]
High	8.866	5.692
Medium	6.206	3.984
Low	4.894	3.142
Average	8.000	5.136

Table 5. Initial MOX fuel enrichments – Case B

MOX fuel Case B (weapons disposition) enrichment zones	MOX fuel plutonium content, w/o Pu_{total}/[U+Pu]	MOX fuel enrichment, w/o $Pu_{fissile}$/[U+Pu]
High	4.377	4.110
Medium	3.064	2.877
Low	2.416	2.269
Average	3.950	3.709

Table 6. Initial MOX fuel compositions – Case A

Nuclide	Atoms/barn.cm for given fuel pin			
	High	Medium	Low	Average (for pin cell calculation)
^{234}U	2.5718E-7	2.6436E-7	2.6789E-7	2.5952E-7
^{235}U	5.3798E-5	5.5300E-5	5.6040E-5	5.4287E-5
^{238}U	2.1194E-2	2.1786E-2	2.2077E-2	2.1387E-2
^{238}Pu	5.1677E-5	3.6128E-5	2.8473E-5	4.6610E-5
^{239}Pu	1.1259E-3	7.8717E-4	6.2038E-4	1.0156E-3
^{240}Pu	5.3500E-4	3.7403E-4	2.9478E-4	4.8255E-4
^{241}Pu	1.9392E-4	1.3557E-4	1.0685E-4	1.7491E-4
^{242}Pu	1.4636E-4	1.0233E-4	8.0644E-5	1.3201E-4
O	4.6602E-2	4.6553E-2	4.6529E-2	4.6586E-2

Table 7. Initial MOX fuel compositions – Case B

Nuclide	Atoms/barn.cm for given fuel pin			
	High	Medium	Low	Average (for pin cell calculation)
^{234}U	2.6928E-7	2.7281E-7	2.7455E-7	2.7043E-7
^{235}U	5.6330E-5	5.7069E-5	5.7433E-5	5.6570E-5
^{238}U	2.2191E-2	2.2482E-2	2.2626E-2	2.2286E-2
^{238}Pu	5.0917E-7	3.5621E-7	2.8080E-7	4.5941E-7
^{239}Pu	9.4917E-4	6.6404E-4	5.2345E-4	8.5640E-4
^{240}Pu	6.0591E-5	4.2389E-5	3.3414E-5	5.4669E-5
^{241}Pu	3.0169E-6	2.1106E-6	1.6638E-6	2.7221E-6
^{242}Pu	5.0074E-7	3.5032E-7	2.7615E-7	4.5180E-7
O	4.6524E-2	4.6498E-2	4.6486E-2	4.6515E-2

Table 8. Non-fissile material compositions

Nuclide	Atoms/barn.cm
Zircaloy-2 (5.8736 g/cm^3 – reduced density)	
Zr	3.8657E-2
Fe	1.3345E-4
Cr	6.8254E-5
Coolant/moderator (600 ppm boron, 0.7245 g/cm^3)	
H	4.8414E-2
O	2.4213E-2
^{10}B	4.7896E-6
^{11}B	1.9424E-5

Table 9. Initial composition for 4.3 w/o ^{235}U/U UO_2 fuel

Nuclide	Atoms/barn.cm
^{234}U	8.1248E-6
^{235}U	1.0113E-3
^{236}U	8.0558E-6
^{238}U	2.2206E-2
O	4.6467E-2

Figure 1. MOX-UO_2 supercell

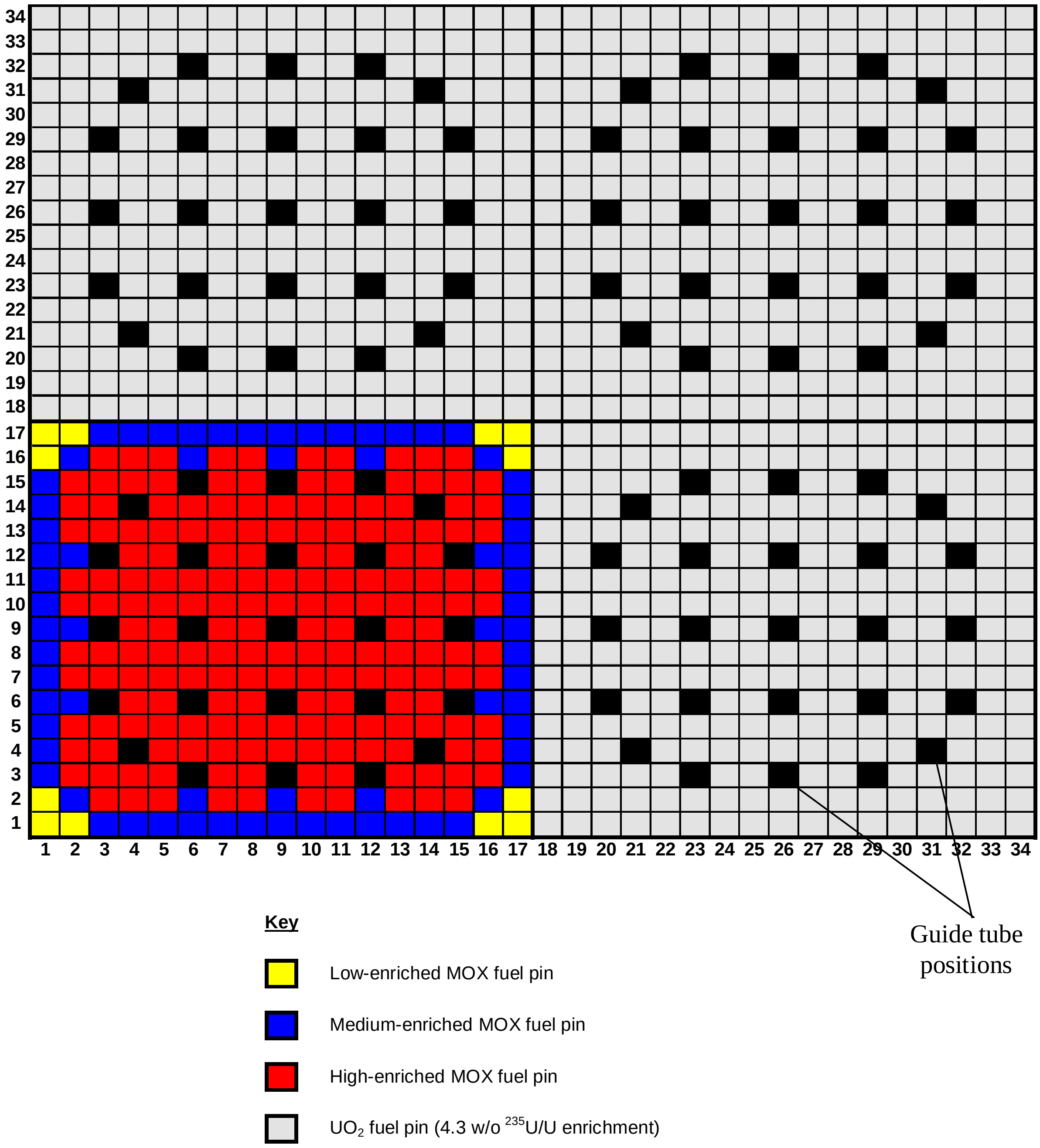
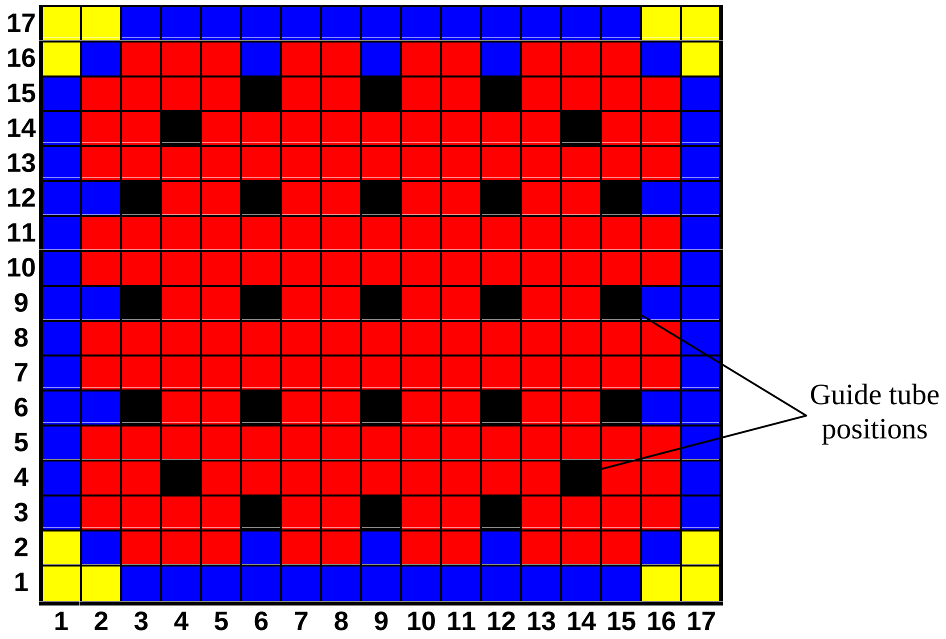


Figure 2. MOX fuel assembly



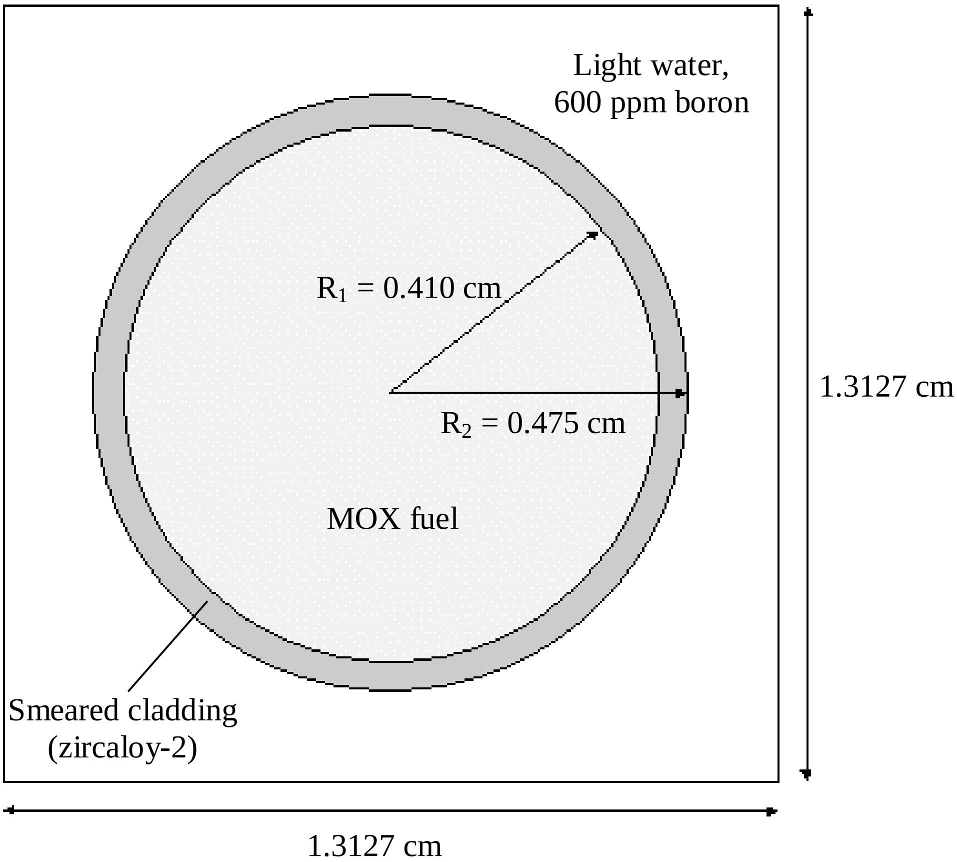
<u>**Key**</u>

Low-enriched MOX fuel pin

Medium-enriched MOX fuel pin

High-enriched MOX fuel pin

Figure 3. Simplified MOX pin cell



Appendix B

BENCHMARK CALCULATION RESULTS FROM EACH PARTICIPANT

Participants		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
		Supercell model		Assembly model		Pin cell model	
		First recycle	Weapons disposition	First recycle	Weapons disposition	First recycle	Weapons disposition
1	NUPEC	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
2	CEA	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
3	GRS	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
4	PSI	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
5	BNFL	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
6	JAERI (1)	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
7	JAERI (2)	–	–	–	–	Table B-5	Table B-6
8	DTLR	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
9	ORNL	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
	Mean	Table B-1	Table B-2	Table B-3	Table B-4	Table B-5	Table B-6
	TRSD	Table B-1 Figure B-1	Table B-2 Figure B-2	Table B-3 Figure B-3	Table B-4 Figure B-4	Table B-5 Figure B-5	Table B-6 Figure B-6

Table B.1. Benchmark calculation results for Case 1

Supercell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

NUPEC (Sakurai)
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8524E-07	8.3932E-07	1.0283E-06	2.6126E-06
U -235	4.3710E-05	3.4347E-05	2.6242E-05	2.6242E-05
U -236	2.4560E-06	4.3855E-06	5.8042E-06	5.8042E-06
U -238	2.1178E-02	2.0954E-02	2.0715E-02	2.0715E-02
Pu-238	4.0939E-05	3.8127E-05	3.7958E-05	4.0378E-05
Pu-239	7.8542E-04	6.0884E-04	4.7599E-04	4.7773E-04
Pu-240	4.7702E-04	4.5028E-04	4.0875E-04	4.1181E-04
Pu-241	2.1606E-04	2.3231E-04	2.2919E-04	1.7987E-04
Pu-242	1.3923E-04	1.5252E-04	1.6956E-04	1.6956E-04
Np-237	1.3580E-06	2.6734E-06	3.8624E-06	3.8624E-06
Am-241	8.7766E-06	1.5357E-05	1.8594E-05	6.7570E-05
Am-242m	1.2822E-07	3.0151E-07	3.9330E-07	3.8440E-07
Am-243	1.4810E-05	2.6992E-05	3.7275E-05	3.7275E-05
Cm-242	9.6640E-07	2.6105E-06	4.0298E-06	4.8625E-09
Cm-243	1.2072E-08	6.1798E-08	1.3368E-07	1.1908E-07
Cm-244	2.4042E-06	8.6253E-06	1.7529E-05	1.4476E-05
Cm-245	1.0678E-07	7.0294E-07	1.9244E-06	1.9244E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	1.9231E-05	3.5094E-05	4.7732E-05	4.7732E-05
Ag-109	4.7484E-06	8.3055E-06	1.0825E-05	1.0825E-05
Cs-133	2.3578E-05	4.4696E-05	6.3307E-05	6.3307E-05
Nd-143	1.6564E-05	3.1655E-05	4.4986E-05	4.4986E-05
Nd-145	1.1197E-05	2.1394E-05	3.0530E-05	3.0530E-05
Sm-147	8.3578E-07	2.5242E-06	4.2452E-06	1.0165E-05
Sm-149	3.9897E-07	3.7823E-07	3.3635E-07	3.9181E-07
Sm-150	5.0083E-06	1.0811E-05	1.6458E-05	1.6458E-05
Sm-151	1.4610E-06	1.7611E-06	1.8329E-06	1.7550E-06
Sm-152	2.9126E-06	5.2186E-06	6.6255E-06	6.6255E-06
Eu-153	2.2212E-06	5.4625E-06	8.6881E-06	8.6881E-06
Gd-155	1.5461E-08	2.5858E-08	3.7042E-08	9.6943E-07
k-infinity	1.09906	1.00024	0.92200	0.90332
High			49.259	
Medium			45.519	
Low			42.736	
Assembly Ave.			47.999	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8064E-07	8.3399E-07	1.0266E-06	2.6570E-06
U -235	4.3768E-05	3.4423E-05	2.6356E-05	2.6425E-05
U -236	2.4410E-06	4.3987E-06	5.8670E-06	6.0894E-06
U -238	2.1175E-02	2.0949E-02	2.0709E-02	2.0709E-02
Pu-238	4.1420E-05	3.8862E-05	3.8753E-05	4.0964E-05
Pu-239	7.8568E-04	6.1128E-04	4.7932E-04	4.8103E-04
Pu-240	4.8033E-04	4.5687E-04	4.1949E-04	4.2317E-04
Pu-241	2.1313E-04	2.2686E-04	2.2299E-04	1.7533E-04
Pu-242	1.3596E-04	1.4494E-04	1.5721E-04	1.5722E-04
Np-237	1.0813E-06	2.1871E-06	3.2075E-06	3.5935E-06
Am-241	8.6310E-06	1.4969E-05	1.8061E-05	6.5389E-05
Am-242m	1.3050E-07	2.9963E-07	3.8497E-07	3.7564E-07
Am-243	1.6186E-05	2.8928E-05	3.8986E-05	3.8987E-05
Cm-242	9.3646E-07	2.4993E-06	3.8112E-06	2.6086E-09
Cm-243	1.1849E-08	6.1160E-08	1.3260E-07	1.1814E-07
Cm-244	3.2416E-06	1.1383E-05	2.2413E-05	1.8511E-05
Cm-245	1.5100E-07	9.8455E-07	2.6008E-06	2.5998E-06
Mo-95	1.1850E-05	2.8825E-05	4.4890E-05	5.0859E-05
Tc-99	2.1988E-05	4.2477E-05	6.1275E-05	6.1508E-05
Ru-101	2.3067E-05	4.5251E-05	6.6508E-05	6.6510E-05
Rh-103	2.0151E-05	3.9381E-05	5.4669E-05	5.8105E-05
Ag-109	5.3218E-06	9.6595E-06	1.3251E-05	1.3267E-05
Cs-133	2.3969E-05	4.5767E-05	6.5005E-05	6.5551E-05
Nd-143	1.5472E-05	3.0170E-05	4.2990E-05	4.3861E-05
Nd-145	1.1523E-05	2.2227E-05	3.2065E-05	3.2075E-05
Sm-147	8.1638E-07	2.5195E-06	4.2263E-06	1.0876E-05
Sm-149	3.5412E-07	3.3601E-07	3.0399E-07	3.5851E-07
Sm-150	4.8468E-06	1.0353E-05	1.5757E-05	1.5757E-05
Sm-151	1.3378E-06	1.5926E-06	1.6622E-06	1.6106E-06
Sm-152	3.0790E-06	5.6120E-06	7.2949E-06	7.2964E-06
Eu-153	2.1959E-06	5.4051E-06	8.6766E-06	8.7269E-06
Gd-155	1.1253E-08	1.7261E-08	2.4446E-08	5.5919E-07
k-infinity	1.10154	1.00401	0.92554	0.91255
High			49.087	
Medium			45.867	
Low			43.415	
Assembly Ave.			48.000	

Table B.1. Benchmark calculation results for Case 1 (*cont.*)

Supercell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7790E-07	8.2630E-07	1.0110E-06	2.6720E-06
U -235	4.3660E-05	3.4310E-05	2.6270E-05	2.6340E-05
U -236	2.5080E-06	4.4700E-06	5.9060E-06	6.1330E-06
U -238	2.1170E-02	2.0950E-02	2.0700E-02	2.0700E-02
Pu-238	4.1600E-05	3.9170E-05	3.9170E-05	4.1250E-05
Pu-239	7.8290E-04	6.0740E-04	4.7910E-04	4.8090E-04
Pu-240	4.8470E-04	4.6400E-04	4.2650E-04	4.3020E-04
Pu-241	2.1340E-04	2.2890E-04	2.2740E-04	1.7960E-04
Pu-242	1.3550E-04	1.4450E-04	1.5690E-04	1.5690E-04
Np-237	1.2110E-06	2.4410E-06	3.5680E-06	3.9560E-06
Am-241	8.3990E-06	1.4560E-05	1.7620E-05	6.5010E-05
Am-242m	1.6740E-07	3.9830E-07	5.2390E-07	5.1210E-07
Am-243	1.6700E-05	2.9440E-05	3.9600E-05	3.9600E-05
Cm-242	9.1580E-07	2.4320E-06	3.6980E-06	2.8130E-09
Cm-243	1.1090E-08	5.7150E-08	1.2440E-07	1.1020E-07
Cm-244	3.3020E-06	1.1510E-05	2.2790E-05	1.8830E-05
Cm-245	1.3240E-07	8.6820E-07	2.3670E-06	2.3660E-06
Mo-95	1.1840E-05	2.8730E-05	4.4670E-05	5.0590E-05
Tc-99	2.3120E-05	4.4550E-05	6.4070E-05	6.4310E-05
Ru-101	2.2120E-05	4.3340E-05	6.3590E-05	6.3590E-05
Rh-103	1.9970E-05	3.8570E-05	5.3020E-05	5.6360E-05
Ag-109	6.0010E-06	1.0730E-05	1.4570E-05	1.4590E-05
Cs-133	2.4260E-05	4.6050E-05	6.5000E-05	6.5550E-05
Nd-143	1.5600E-05	3.0470E-05	4.3520E-05	4.4390E-05
Nd-145	1.1460E-05	2.2110E-05	3.1870E-05	3.1880E-05
Sm-147	8.1340E-07	2.5080E-06	4.2030E-06	1.0610E-05
Sm-149	3.7380E-07	3.5690E-07	3.2640E-07	3.8080E-07
Sm-150	4.8210E-06	1.0260E-05	1.5490E-05	1.5490E-05
Sm-151	1.4010E-06	1.7030E-06	1.8160E-06	1.7600E-06
Sm-152	3.2130E-06	6.0690E-06	8.0330E-06	8.0330E-06
Eu-153	2.0490E-06	5.0930E-06	8.3630E-06	8.4130E-06
Gd-155	1.0430E-08	1.9530E-08	3.1340E-08	7.2280E-07
k-infinity	1.09111	0.98840	0.91013	0.89200
High			49.124	
Medium			45.760	
Low			43.304	
Assembly Ave.			47.993	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7910E-07	8.3177E-07	1.0232E-06	2.6494E-06
U -235	4.3695E-05	3.4371E-05	2.6331E-05	2.6331E-05
U -236	2.4919E-06	4.4576E-06	5.9250E-06	5.9250E-06
U -238	2.1173E-02	2.0944E-02	2.0702E-02	2.0702E-02
Pu-238	4.1526E-05	3.8975E-05	3.8831E-05	4.0807E-05
Pu-239	7.9551E-04	6.2436E-04	4.9398E-04	4.9573E-04
Pu-240	4.7896E-04	4.5614E-04	4.1925E-04	4.2289E-04
Pu-241	2.1287E-04	2.2869E-04	2.2712E-04	1.7842E-04
Pu-242	1.3599E-04	1.4528E-04	1.5804E-04	1.5805E-04
Np-237	1.3757E-06	2.7896E-06	4.0853E-06	4.4907E-06
Am-241	8.7074E-06	1.5304E-05	1.8724E-05	6.7073E-05
Am-242m	1.8215E-07	4.2985E-07	5.6672E-07	5.5297E-07
Am-243	1.6059E-05	2.8581E-05	3.8750E-05	3.8750E-05
Cm-242	8.5881E-07	2.3065E-06	3.5681E-06	2.9476E-09
Cm-243	1.0979E-08	5.5733E-08	1.2044E-07	1.0693E-07
Cm-244	3.0796E-06	1.0628E-05	2.0932E-05	1.7286E-05
Cm-245	1.3875E-07	9.0357E-07	2.3965E-06	2.3955E-06
Mo-95	1.7668E-05	3.4354E-05	5.0032E-05	5.0032E-05
Tc-99	2.1802E-05	4.1958E-05	6.0330E-05	6.0540E-05
Ru-101	2.2860E-05	4.4864E-05	6.5942E-05	6.5942E-05
Rh-103	2.0022E-05	3.9317E-05	5.4823E-05	5.8180E-05
Ag-109	5.3534E-06	9.7520E-06	1.3470E-05	1.3470E-05
Cs-133	2.3868E-05	4.5627E-05	6.4922E-05	6.5373E-05
Nd-143	1.5449E-05	3.0111E-05	4.2982E-05	4.3750E-05
Nd-145	1.1483E-05	2.2185E-05	3.2078E-05	3.2078E-05
Sm-147	8.1314E-07	2.5253E-06	4.2632E-06	1.0940E-05
Sm-149	3.7987E-07	3.5730E-07	3.2318E-07	3.7432E-07
Sm-150	4.9301E-06	1.0722E-05	1.6656E-05	1.6656E-05
Sm-151	1.2979E-06	1.4575E-06	1.4413E-06	1.3886E-06
Sm-152	2.9403E-06	5.2119E-06	6.5217E-06	6.5217E-06
Eu-153	2.1966E-06	5.2911E-06	8.3073E-06	8.3539E-06
Gd-155	1.1705E-08	1.8487E-08	2.6472E-08	5.6243E-07
k-infinity	1.10163	1.00671	0.93077	0.91775
High	16.159	32.625	49.243	
Medium	15.708	30.787	45.546	
Low	15.220	29.266	42.809	
Assembly Ave.	16.000	31.999	47.998	

Table B.1. Benchmark calculation results for Case 1 (*cont.*)

Supercell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8219E-07	8.4278E-07	1.0475E-06	2.6962E-06
U -235	4.3630E-05	3.4382E-05	2.6459E-05	2.6532E-05
U -236	2.5000E-06	4.4443E-06	5.8866E-06	6.1034E-06
U -238	2.1160E-02	2.0921E-02	2.0670E-02	2.0670E-02
Pu-238	4.1363E-05	3.8944E-05	3.9095E-05	4.1433E-05
Pu-239	7.9775E-04	6.3265E-04	5.0815E-04	5.0998E-04
Pu-240	4.7323E-04	4.4696E-04	4.0884E-04	4.1260E-04
Pu-241	2.1799E-04	2.3414E-04	2.3173E-04	1.8219E-04
Pu-242	1.3592E-04	1.4554E-04	1.5849E-04	1.5849E-04
Np-237	1.0732E-06	2.1483E-06	3.1192E-06	3.1628E-06
Am-241	8.5844E-06	1.5179E-05	1.8653E-05	6.8190E-05
Am-242m	1.2011E-07	2.7275E-07	3.5513E-07	3.5513E-07
Am-243	1.6449E-05	2.8404E-05	3.7685E-05	3.7685E-05
Cm-242	1.0337E-06	2.6476E-06	3.9878E-06	1.6946E-09
Cm-243	1.4008E-08	6.7046E-08	1.4242E-07	1.2689E-07
Cm-244	3.6100E-06	1.1964E-05	2.2848E-05	1.8869E-05
Cm-245	1.8249E-07	1.1054E-06	2.8227E-06	2.8227E-06
Mo-95	1.1718E-05	2.9075E-05	4.5323E-05	5.1458E-05
Tc-99	2.2645E-05	4.3289E-05	6.2102E-05	6.2102E-05
Ru-101	2.3417E-05	4.5736E-05	6.7008E-05	6.7008E-05
Rh-103	2.0198E-05	3.9690E-05	5.5101E-05	5.8658E-05
Ag-109	5.4209E-06	9.7768E-06	1.3398E-05	1.3398E-05
Cs-133	2.4363E-05	4.6254E-05	6.5426E-05	6.5906E-05
Nd-143	1.5786E-05	3.0753E-05	4.3826E-05	4.4649E-05
Nd-145	1.1727E-05	2.2495E-05	3.2334E-05	3.2334E-05
Sm-147	7.8597E-07	2.4735E-06	4.1541E-06	1.0816E-05
Sm-149	3.6911E-07	3.5144E-07	3.2066E-07	3.7517E-07
Sm-150	4.9196E-06	1.0427E-05	1.5785E-05	1.5785E-05
Sm-151	1.3786E-06	1.6516E-06	1.7404E-06	1.6864E-06
Sm-152	3.0692E-06	5.5536E-06	7.1882E-06	7.1882E-06
Eu-153	2.2448E-06	5.4520E-06	8.6579E-06	8.7103E-06
Gd-155	1.0977E-08	1.7055E-08	2.3295E-08	6.0174E-07
k-infinity	1.075712	0.982246	0.913443	0.89595
High	16.456	33.122	49.864	
Medium	15.045	29.660	44.119	
Low	14.394	27.951	41.219	
Assembly Ave.	15.999	31.995	47.991	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.7958E-07	8.2810E-07	1.0134E-06	2.6285E-06
U-235	4.3835E-05	3.4592E-05	2.6613E-05	2.6684E-05
U-236	2.4263E-06	4.3667E-06	5.8165E-06	6.0346E-06
U-238	2.1177E-02	2.0950E-02	2.0708E-02	2.0708E-02
Pu-238	4.1341E-05	3.8611E-05	3.8395E-05	4.0553E-05
Pu-239	7.9086E-04	6.2025E-04	4.9265E-04	4.9438E-04
Pu-240	4.7589E-04	4.5070E-04	4.1148E-04	4.1516E-04
Pu-241	2.1803E-04	2.3527E-04	2.3426E-04	1.8395E-04
Pu-242	1.3548E-04	1.4492E-04	1.5771E-04	1.5771E-04
Np-237	1.0165E-06	2.0846E-06	3.1149E-06	3.5218E-06
Am-241	8.8083E-06	1.5735E-05	1.9564E-05	6.9009E-05
Am-242m	1.3239E-07	3.2041E-07	4.3472E-07	4.2492E-07
Am-243	1.6563E-05	2.8845E-05	3.8703E-05	3.8685E-05
Cm-242	8.9539E-07	2.4048E-06	3.7491E-06	2.6193E-09
Cm-243	1.1040E-08	5.7718E-08	1.2803E-07	1.1337E-07
Cm-244	3.3718E-06	1.1503E-05	2.2391E-05	1.8491E-05
Cm-245	1.6887E-07	1.0918E-06	2.9487E-06	2.9475E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2279E-05	4.2902E-05	6.1824E-05	6.1823E-05
Ru-101	2.1895E-05	4.3054E-05	6.3421E-05	6.3421E-05
Rh-103	2.2686E-05	4.0957E-05	5.5270E-05	5.5270E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4687E-05	4.6838E-05	6.6542E-05	6.6542E-05
Nd-143	1.5483E-05	3.0283E-05	4.3309E-05	4.4116E-05
Nd-145	1.1427E-05	2.2167E-05	3.2187E-05	3.2187E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	3.6625E-07	3.4439E-07	3.1280E-07	3.6247E-07
Sm-150	4.7933E-06	1.0349E-05	1.5961E-05	1.5961E-05
Sm-151	1.3500E-06	1.5294E-06	1.5248E-06	1.4673E-06
Sm-152	2.9665E-06	5.3280E-06	6.8139E-06	6.8139E-06
Eu-153	2.1622E-06	5.2466E-06	8.2078E-06	8.2078E-06
Gd-155	5.4402E-09	9.5325E-09	1.6100E-08	3.2870E-07
k-infinity	1.09525	0.99587	0.92144	0.91134
High			49.169	
Medium			45.702	
Low			43.071	
Assembly Ave.			47.999	

Table B.1. Benchmark calculation results for Case 1 (*cont.*)

Supercell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1385E-07	1.7623E-07	1.4410E-07	1.4410E-07
U-235	4.3482E-05	3.3915E-05	2.5581E-05	2.5648E-05
U-236	2.4890E-06	4.4477E-06	5.9047E-06	6.1215E-06
U-238	2.1173E-02	2.0944E-02	2.0701E-02	2.0701E-02
Pu-238	4.0543E-05	3.4633E-05	2.8948E-05	2.7827E-05
Pu-239	7.7611E-04	5.9519E-04	4.5956E-04	4.6130E-04
Pu-240	4.7807E-04	4.5226E-04	4.1087E-04	4.1065E-04
Pu-241	2.1479E-04	2.2846E-04	2.2318E-04	1.7547E-04
Pu-242	1.3652E-04	1.4636E-04	1.5946E-04	1.5946E-04
Np-237	9.8028E-08	3.4213E-07	6.6092E-07	6.7296E-07
Am-241	8.5633E-06	1.4878E-05	1.7791E-05	6.5500E-05
Am-242m	1.4010E-07	3.1234E-07	3.9535E-07	3.9535E-07
Am-243	1.5954E-05	2.7786E-05	3.7205E-05	3.7205E-05
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.2082E-05	2.9488E-05	4.5796E-05	5.1912E-05
Tc-99	2.2907E-05	4.3767E-05	6.2716E-05	6.2716E-05
Ru-101	2.3663E-05	4.6177E-05	6.7617E-05	6.7617E-05
Rh-103	2.0619E-05	4.0178E-05	5.5500E-05	5.9032E-05
Ag-109	5.5011E-06	9.9221E-06	1.3538E-05	1.3538E-05
Cs-133	2.4697E-05	4.6821E-05	6.6091E-05	6.6566E-05
Nd-143	1.5978E-05	3.0920E-05	4.3764E-05	4.4578E-05
Nd-145	1.1850E-05	2.2715E-05	3.2617E-05	3.2617E-05
Sm-147	8.2289E-07	2.5512E-06	4.2595E-06	1.0992E-05
Sm-149	3.5066E-07	3.2287E-07	2.8862E-07	3.4291E-07
Sm-150	4.9779E-06	1.0544E-05	1.5961E-05	1.5961E-05
Sm-151	1.3636E-06	1.5849E-06	1.6263E-06	1.5737E-06
Sm-152	3.1330E-06	5.6264E-06	7.1395E-06	7.1395E-06
Eu-153	2.2739E-06	5.5662E-06	8.9115E-06	8.9663E-06
Gd-155	1.1043E-08	1.5794E-08	2.0278E-08	5.7118E-07
k-infinity	1.0988	0.9991	0.9198	0.9082
High	16.149	32.600	49.211	
Medium	15.790	30.912	45.639	
Low	15.419	29.478	43.033	
Assembly Ave.	16.023	32.023	48.010	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 1 - First Recycle MOX, Supercell Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.74E-07	8.21E-07	9.99E-07	2.61E-06
U-235	4.3483E-05	3.4135E-05	2.6173E-05	2.6244E-05
U-236	2.6580E-06	4.6957E-06	6.1665E-06	6.3800E-06
U-238	2.1169E-02	2.0935E-02	2.0685E-02	2.0685E-02
Pu-238	4.1291E-05	3.8659E-05	3.8467E-05	4.0531E-05
Pu-239	7.9722E-04	6.3106E-04	5.0369E-04	5.0549E-04
Pu-240	4.7151E-04	4.4311E-04	4.0324E-04	4.0701E-04
Pu-241	2.1903E-04	2.3569E-04	2.3270E-04	1.8275E-04
Pu-242	1.3643E-04	1.4710E-04	1.6144E-04	1.6144E-04
Np-237	No Data	No Data	No Data	No Data
Am-241	8.8157E-06	1.5702E-05	1.9207E-05	6.8788E-05
Am-242m	1.8218E-07	4.2337E-07	5.5824E-07	5.4470E-07
Am-243	1.7998E-05	3.1914E-05	4.3158E-05	4.3158E-05
Cm-242	8.8745E-07	2.3593E-06	3.6478E-06	2.9728E-09
Cm-243	1.5111E-08	7.5461E-08	1.6067E-07	1.4232E-07
Cm-244	3.4367E-06	1.1760E-05	2.3187E-05	1.9165E-05
Cm-245	1.2484E-07	7.1867E-07	1.7283E-06	1.6927E-06
Mo-95	1.1785E-05	2.8661E-05	4.4374E-05	5.0200E-05
Tc-99	2.1884E-05	4.2035E-05	6.0037E-05	6.0267E-05
Ru-101	2.1841E-05	4.2765E-05	6.2716E-05	6.1971E-05
Rh-103	1.9565E-05	3.7699E-05	5.1278E-05	5.4538E-05
Ag-109	5.8663E-06	1.0325E-05	1.3675E-05	1.3695E-05
Cs-133	2.4079E-05	4.6140E-05	6.5456E-05	6.5970E-05
Nd-143	1.5471E-05	3.0255E-05	4.3034E-05	4.3377E-05
Nd-145	1.1337E-05	2.1824E-05	3.1394E-05	3.1404E-05
Sm-147	7.9312E-07	2.4287E-06	4.0189E-06	1.0189E-05
Sm-149	4.1234E-07	4.3411E-07	3.7033E-07	4.3038E-07
Sm-150	5.0900E-06	1.1157E-05	1.7129E-05	1.7129E-05
Sm-151	1.4768E-06	1.8803E-06	2.0382E-06	1.9734E-06
Sm-152	3.0123E-06	5.7684E-06	7.8515E-06	7.8532E-06
Eu-153	2.0841E-06	5.0518E-06	8.0835E-06	8.1326E-06
Gd-155	4.5514E-09	8.2604E-09	1.3669E-08	2.4772E-07
k-infinity	1.0938	0.9999	0.9321	0.9210

Table B.1. Benchmark calculation results for Case 1 (*cont.*)

Supercell model, first recycle MOX fuel

	Mean			
Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.3411E-07	7.4988E-07	9.1170E-07	2.3343E-06
U-235	4.3658E-05	3.4309E-05	2.6253E-05	2.6306E-05
U-236	2.4963E-06	4.4583E-06	5.9096E-06	6.0739E-06
U-238	2.1172E-02	2.0944E-02	2.0699E-02	2.0699E-02
Pu-238	4.1253E-05	3.8248E-05	3.7452E-05	3.9218E-05
Pu-239	7.8893E-04	6.1638E-04	4.8655E-04	4.8832E-04
Pu-240	4.7746E-04	4.5254E-04	4.1355E-04	4.1669E-04
Pu-241	2.1566E-04	2.3129E-04	2.2857E-04	1.7970E-04
Pu-242	1.3638E-04	1.4640E-04	1.5985E-04	1.5986E-04
Np-237	1.0305E-06	2.0952E-06	3.0883E-06	3.3229E-06
Am-241	8.6607E-06	1.5210E-05	1.8527E-05	6.7066E-05
Am-242m	1.4788E-07	3.4477E-07	4.5154E-07	4.4315E-07
Am-243	1.6340E-05	2.8861E-05	3.8920E-05	3.8918E-05
Cm-242	9.2772E-07	2.4657E-06	3.7846E-06	2.9312E-09
Cm-243	1.2307E-08	6.2295E-08	1.3461E-07	1.1956E-07
Cm-244	3.2066E-06	1.1053E-05	2.1727E-05	1.7947E-05
Cm-245	1.4359E-07	9.1073E-07	2.3983E-06	2.3927E-06
Mo-95	1.2824E-05	2.9856E-05	4.5848E-05	5.0842E-05
Tc-99	2.2375E-05	4.2997E-05	6.1765E-05	6.1895E-05
Ru-101	2.2695E-05	4.4455E-05	6.5257E-05	6.5151E-05
Rh-103	2.0305E-05	3.8861E-05	5.3424E-05	5.5984E-05
Ag-109	5.4590E-06	9.7815E-06	1.3247E-05	1.3255E-05
Cs-133	2.4188E-05	4.6024E-05	6.5219E-05	6.5596E-05
Nd-143	1.5725E-05	3.0577E-05	4.3551E-05	4.4213E-05
Nd-145	1.1501E-05	2.2140E-05	3.1884E-05	3.1888E-05
Sm-147	8.1153E-07	2.5043E-06	4.1957E-06	1.0655E-05
Sm-149	3.7564E-07	3.6016E-07	3.2279E-07	3.7705E-07
Sm-150	4.9234E-06	1.0578E-05	1.6150E-05	1.6150E-05
Sm-151	1.3833E-06	1.6450E-06	1.7103E-06	1.6519E-06
Sm-152	3.0407E-06	5.5485E-06	7.1835E-06	7.1839E-06
Eu-153	2.1785E-06	5.3210E-06	8.4870E-06	8.5249E-06
Gd-155	1.0108E-08	1.6472E-08	2.4080E-08	5.7040E-07

	Two Times Relative Standard Deviation (%)			
Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	48.47	61.85	68.11	75.86
U-235	0.57	1.19	2.32	2.32
U-236	5.74	4.61	3.80	5.52
U-238	0.05	0.10	0.14	0.14
Pu-238	1.69	7.81	18.47	23.54
Pu-239	1.96	4.20	6.59	6.58
Pu-240	1.73	2.85	3.65	3.79
Pu-241	2.29	3.00	3.68	3.58
Pu-242	1.78	3.57	5.23	5.23
Np-237	84.34	78.14	73.51	74.60
Am-241	3.34	5.31	7.28	4.75
Am-242m	34.26	36.04	37.60	36.39
Am-243	10.88	10.01	9.84	9.84
Cm-242	12.56	10.30	9.06	65.19
Cm-243	26.43	22.24	20.06	20.02
Cm-244	24.33	20.79	18.29	18.32
Cm-245	36.24	35.64	37.27	38.09
Mo-95	37.06	14.90	9.20	2.87
Tc-99	4.67	4.40	4.51	4.41
Ru-101	6.56	6.22	6.04	6.58
Rh-103	10.33	9.31	10.12	13.27
Ag-109	14.94	15.41	17.39	17.45
Cs-133	3.24	3.01	2.94	3.13
Nd-143	4.93	3.40	3.08	2.42
Nd-145	3.60	3.62	4.09	4.09
Sm-147	4.20	3.25	4.13	6.54
Sm-149	11.26	18.90	14.96	13.90
Sm-150	4.10	5.71	6.79	6.79
Sm-151	8.81	16.39	22.13	22.33
Sm-152	6.73	10.55	15.13	15.14
Eu-153	7.10	6.89	6.75	6.83
Gd-155	69.72	67.84	63.85	77.97

Table B.2. Benchmark calculation results for Case 2

Supercell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

NUPEC (Sakurai)
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2647E-07	1.9127E-07	1.7603E-07	4.0651E-07
U -235	4.1722E-05	2.8409E-05	1.7560E-05	1.7560E-05
U -236	3.1148E-06	5.4858E-06	6.9733E-06	6.9733E-06
U -238	2.2060E-02	2.1801E-02	2.1510E-02	2.1510E-02
Pu-238	6.7130E-07	1.9897E-06	4.6844E-06	6.2373E-06
Pu-239	5.5371E-04	3.5034E-04	2.3610E-04	2.3829E-04
Pu-240	1.4953E-04	1.8209E-04	1.7274E-04	1.7348E-04
Pu-241	5.7987E-05	9.4133E-05	1.0099E-04	7.9253E-05
Pu-242	5.6965E-06	2.1016E-05	4.2614E-05	4.2614E-05
Np-237	1.3896E-06	2.7551E-06	3.9277E-06	3.9277E-06
Am-241	1.3369E-06	3.6627E-06	4.8346E-06	2.6441E-05
Am-242m	1.7621E-08	6.1171E-08	8.3570E-08	8.1680E-08
Am-243	6.6326E-07	4.0732E-06	1.0743E-05	1.0743E-05
Cm-242	1.7423E-07	8.9807E-07	1.7958E-06	1.4316E-09
Cm-243	1.8207E-09	1.8584E-08	5.4326E-08	4.8390E-08
Cm-244	8.8154E-08	1.0150E-06	4.2987E-06	3.5499E-06
Cm-245	3.0724E-09	5.7729E-08	3.1922E-07	3.1922E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	1.7960E-05	3.1103E-05	3.9744E-05	3.9744E-05
Ag-109	3.7247E-06	6.6095E-06	8.6372E-06	8.6372E-06
Cs-133	2.3507E-05	4.4048E-05	6.1350E-05	6.1350E-05
Nd-143	1.6314E-05	3.0038E-05	4.0357E-05	4.0357E-05
Nd-145	1.1119E-05	2.1069E-05	2.9663E-05	2.9663E-05
Sm-147	7.9137E-07	2.2993E-06	3.6787E-06	8.8228E-06
Sm-149	2.1181E-07	1.8292E-07	1.5123E-07	2.1175E-07
Sm-150	5.1145E-06	1.0958E-05	1.6542E-05	1.6542E-05
Sm-151	9.4698E-07	9.7037E-07	9.5549E-07	9.1492E-07
Sm-152	3.0268E-06	5.0112E-06	6.0485E-06	6.0485E-06
Eu-153	2.2514E-06	5.5181E-06	8.3359E-06	8.3359E-06
Gd-155	7.2316E-09	1.0991E-08	1.4633E-08	9.0652E-07
k-infinity	1.10834	0.99068	0.89595	0.87758
High			50.264	
Medium			43.376	
Low			39.470	
Assembly Ave.			47.999	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2468E-07	1.8852E-07	1.7170E-07	3.9468E-07
U -235	4.1660E-05	2.8414E-05	1.7732E-05	1.7767E-05
U -236	3.0710E-06	5.4273E-06	6.9435E-06	7.0400E-06
U -238	2.2051E-02	2.1786E-02	2.1495E-02	2.1495E-02
Pu-238	6.1278E-07	1.7810E-06	4.2693E-06	5.7500E-06
Pu-239	5.5572E-04	3.5566E-04	2.4199E-04	2.4415E-04
Pu-240	1.5348E-04	1.8855E-04	1.8251E-04	1.8323E-04
Pu-241	5.6830E-05	9.2730E-05	1.0044E-04	7.8965E-05
Pu-242	5.6256E-06	2.0740E-05	4.1599E-05	4.1601E-05
Np-237	1.1082E-06	2.2405E-06	3.2286E-06	3.4080E-06
Am-241	1.2835E-06	3.5551E-06	4.7700E-06	2.6112E-05
Am-242m	1.7445E-08	6.0434E-08	8.3332E-08	8.1310E-08
Am-243	6.3237E-07	3.8417E-06	1.0115E-05	1.0120E-05
Cm-242	1.6448E-07	8.4820E-07	1.6848E-06	9.3199E-10
Cm-243	1.7614E-09	1.8281E-08	5.3831E-08	4.7962E-08
Cm-244	9.9810E-08	1.1346E-06	4.6584E-06	3.8479E-06
Cm-245	3.7153E-09	7.1144E-08	3.8688E-07	3.8673E-07
Mo-95	1.2252E-05	2.9558E-05	4.5500E-05	5.1545E-05
Tc-99	2.2186E-05	4.2424E-05	6.0380E-05	6.0614E-05
Ru-101	2.3067E-05	4.5085E-05	6.5949E-05	6.5951E-05
Rh-103	1.9091E-05	3.5320E-05	4.6043E-05	4.9443E-05
Ag-109	4.5528E-06	8.2231E-06	1.1194E-05	1.1209E-05
Cs-133	2.3979E-05	4.5172E-05	6.3014E-05	6.3560E-05
Nd-143	1.5242E-05	2.8589E-05	3.8504E-05	3.9377E-05
Nd-145	1.1459E-05	2.1899E-05	3.1178E-05	3.1188E-05
Sm-147	7.7939E-07	2.2993E-06	3.6452E-06	9.4909E-06
Sm-149	1.9559E-07	1.7219E-07	1.4639E-07	2.0722E-07
Sm-150	5.0123E-06	1.0716E-05	1.6243E-05	1.6243E-05
Sm-151	8.8833E-07	9.1210E-07	9.1111E-07	8.8829E-07
Sm-152	3.1634E-06	5.3065E-06	6.4865E-06	6.4871E-06
Eu-153	2.2501E-06	5.5885E-06	8.6890E-06	8.7476E-06
Gd-155	4.2019E-09	6.3500E-09	9.2050E-09	4.3046E-07
k-infinity	1.10649	0.99022	0.89605	0.88515
High			50.061	
Medium			43.775	
Low			40.343	
Assembly Ave.			48.000	

Table B.2. Benchmark calculation results for Case 2 (*cont.*)

Supercell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2240E-07	1.8530E-07	1.6920E-07	4.1460E-07
U -235	4.1600E-05	2.8450E-05	1.7900E-05	1.7940E-05
U -236	3.1150E-06	5.4290E-06	6.8580E-06	6.9500E-06
U -238	2.2050E-02	2.1790E-02	2.1490E-02	2.1490E-02
Pu-238	6.4380E-07	1.9240E-06	4.5910E-06	6.0960E-06
Pu-239	5.5440E-04	3.5770E-04	2.4960E-04	2.5180E-04
Pu-240	1.4910E-04	1.8080E-04	1.7310E-04	1.7380E-04
Pu-241	6.2650E-05	9.9360E-05	1.0640E-04	8.4030E-05
Pu-242	6.1550E-06	2.2170E-05	4.3770E-05	4.3770E-05
Np-237	1.2560E-06	2.5360E-06	3.6410E-06	3.8330E-06
Am-241	1.4090E-06	3.8070E-06	5.0550E-06	2.7250E-05
Am-242m	2.4750E-08	8.7300E-08	1.2120E-07	1.1850E-07
Am-243	6.7720E-07	4.0560E-06	1.0520E-05	1.0530E-05
Cm-242	1.7580E-07	8.8390E-07	1.7210E-06	1.0200E-09
Cm-243	1.8390E-09	1.8770E-08	5.4660E-08	4.8410E-08
Cm-244	9.9990E-08	1.1320E-06	4.6410E-06	3.8340E-06
Cm-245	3.0870E-09	5.9180E-08	3.2590E-07	3.2580E-07
Mo-95	1.2200E-05	2.9350E-05	4.5100E-05	5.1060E-05
Tc-99	2.3000E-05	4.3870E-05	6.2300E-05	6.2540E-05
Ru-101	2.2060E-05	4.3040E-05	6.2830E-05	6.2830E-05
Rh-103	1.9590E-05	3.5940E-05	4.6600E-05	4.9930E-05
Ag-109	5.6200E-06	9.7890E-06	1.2950E-05	1.2960E-05
Cs-133	2.4220E-05	4.5270E-05	6.2680E-05	6.3230E-05
Nd-143	1.5210E-05	2.8640E-05	3.8820E-05	3.9690E-05
Nd-145	1.1270E-05	2.1560E-05	3.0720E-05	3.0730E-05
Sm-147	7.7220E-07	2.2750E-06	3.6090E-06	9.2250E-06
Sm-149	2.0270E-07	1.8020E-07	1.5570E-07	2.1630E-07
Sm-150	4.9670E-06	1.0570E-05	1.5900E-05	1.5900E-05
Sm-151	9.1160E-07	9.6190E-07	9.8290E-07	9.5810E-07
Sm-152	3.3690E-06	5.9370E-06	7.5020E-06	7.5020E-06
Eu-153	2.0600E-06	5.1840E-06	8.2510E-06	8.3090E-06
Gd-155	4.7140E-09	8.7000E-09	1.2880E-08	6.5130E-07
k-infinity	1.09387	0.97408	0.88140	0.86485
High			50.204	
Medium			43.489	
Low			39.748	
Assembly Ave.			47.999	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2386E-07	1.8819E-07	1.7256E-07	4.0076E-07
U -235	4.1759E-05	2.8650E-05	1.8016E-05	1.8016E-05
U -236	3.1383E-06	5.5246E-06	7.0618E-06	7.0618E-06
U -238	2.2050E-02	2.1784E-02	2.1490E-02	2.1490E-02
Pu-238	6.7262E-07	1.9176E-06	4.5008E-06	5.8616E-06
Pu-239	5.6805E-04	3.7030E-04	2.5487E-04	2.5700E-04
Pu-240	1.5053E-04	1.8751E-04	1.8395E-04	1.8466E-04
Pu-241	5.5545E-05	9.2454E-05	1.0232E-04	8.0378E-05
Pu-242	5.3542E-06	1.9763E-05	4.0418E-05	4.0420E-05
Np-237	1.4227E-06	2.8725E-06	4.1219E-06	4.3157E-06
Am-241	1.2777E-06	3.5896E-06	4.9340E-06	2.6744E-05
Am-242m	2.4374E-08	8.6913E-08	1.2400E-07	1.2099E-07
Am-243	6.0396E-07	3.6175E-06	9.5804E-06	9.5850E-06
Cm-242	1.4878E-07	7.6949E-07	1.5677E-06	9.7733E-10
Cm-243	1.5933E-09	1.6100E-08	4.7370E-08	4.2055E-08
Cm-244	9.1365E-08	1.0011E-06	4.1074E-06	3.3921E-06
Cm-245	3.3533E-09	6.3840E-08	3.5290E-07	3.5275E-07
Mo-95	1.8217E-05	3.5124E-05	5.0596E-05	5.0596E-05
Tc-99	2.1945E-05	4.1801E-05	5.9307E-05	5.9516E-05
Ru-101	2.2892E-05	4.4777E-05	6.5513E-05	6.5513E-05
Rh-103	1.8778E-05	3.4868E-05	4.5647E-05	4.8927E-05
Ag-109	4.5974E-06	8.3276E-06	1.1406E-05	1.1406E-05
Cs-133	2.3864E-05	4.5045E-05	6.3030E-05	6.3476E-05
Nd-143	1.5194E-05	2.8532E-05	3.8587E-05	3.9346E-05
Nd-145	1.1411E-05	2.1837E-05	3.1165E-05	3.1165E-05
Sm-147	7.7817E-07	2.3155E-06	3.7018E-06	9.5953E-06
Sm-149	2.1179E-07	1.8361E-07	1.5513E-07	2.1162E-07
Sm-150	5.1184E-06	1.1148E-05	1.7306E-05	1.7306E-05
Sm-151	8.6327E-07	8.2289E-07	7.8068E-07	7.5212E-07
Sm-152	3.0224E-06	4.9178E-06	5.7906E-06	5.7906E-06
Eu-153	2.2564E-06	5.4256E-06	8.1691E-06	8.2211E-06
Gd-155	4.9241E-09	7.2911E-09	1.0183E-08	4.2557E-07
k-infinity	1.10934	0.99662	0.90549	0.8954
High	16.635	33.463	50.249	
Medium	14.729	29.036	43.408	
Low	13.451	26.345	39.493	
Assembly Ave.	15.999	31.999	47.998	

Table B.2. Benchmark calculation results for Case 2 (*cont.*)

Supercell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2664E-07	1.9280E-07	1.7856E-07	4.1138E-07
U -235	4.1561E-05	2.8436E-05	1.7913E-05	1.7950E-05
U -236	3.1023E-06	5.4346E-06	6.9246E-06	7.0196E-06
U -238	2.2040E-02	2.1766E-02	2.1463E-02	2.1463E-02
Pu-238	6.2586E-07	1.8497E-06	4.4472E-06	6.0066E-06
Pu-239	5.6323E-04	3.6921E-04	2.5896E-04	2.6123E-04
Pu-240	1.5016E-04	1.8461E-04	1.7968E-04	1.8040E-04
Pu-241	5.9781E-05	9.6415E-05	1.0489E-04	8.2464E-05
Pu-242	5.8668E-06	2.1132E-05	4.2233E-05	4.2233E-05
Np-237	1.0934E-06	2.1934E-06	3.1322E-06	3.1830E-06
Am-241	1.3483E-06	3.7153E-06	5.0397E-06	2.7461E-05
Am-242m	1.6348E-08	5.5841E-08	7.7794E-08	7.7794E-08
Am-243	6.8000E-07	3.9077E-06	9.8964E-06	9.8964E-06
Cm-242	1.8252E-07	9.1319E-07	1.7930E-06	7.6194E-10
Cm-243	2.0470E-09	2.0114E-08	5.8263E-08	5.1911E-08
Cm-244	1.1325E-07	1.2068E-06	4.7306E-06	3.9067E-06
Cm-245	4.4082E-09	7.8426E-08	4.0730E-07	4.0730E-07
Mo-95	1.2375E-05	2.9913E-05	4.5990E-05	5.2137E-05
Tc-99	2.2830E-05	4.3217E-05	6.1205E-05	6.1205E-05
Ru-101	2.3429E-05	4.5611E-05	6.6524E-05	6.6524E-05
Rh-103	1.9274E-05	3.5536E-05	4.6292E-05	4.9759E-05
Ag-109	4.6449E-06	8.3391E-06	1.1327E-05	1.1327E-05
Cs-133	2.4422E-05	4.5714E-05	6.3536E-05	6.4008E-05
Nd-143	1.5597E-05	2.9126E-05	3.9238E-05	4.0049E-05
Nd-145	1.1659E-05	2.2161E-05	3.1442E-05	3.1442E-05
Sm-147	7.7548E-07	2.2893E-06	3.6226E-06	9.4977E-06
Sm-149	1.9732E-07	1.7347E-07	1.4895E-07	2.0831E-07
Sm-150	5.0822E-06	1.0756E-05	1.6201E-05	1.6201E-05
Sm-151	9.0496E-07	9.3079E-07	9.3700E-07	9.1337E-07
Sm-152	3.1766E-06	5.2845E-06	6.4234E-06	6.4234E-06
Eu-153	2.3023E-06	5.6454E-06	8.6892E-06	8.7490E-06
Gd-155	4.1600E-09	5.8189E-09	7.4630E-09	4.5202E-07
k-infinity	1.091881	0.977179	0.889472	0.876575
High	16.799	33.661	50.423	
Medium	14.376	28.590	43.000	
Low	13.097	25.983	39.240	
Assembly Ave.	16.007	32.006	48.003	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2648E-07	1.9042E-07	1.7295E-07	3.9237E-07
U-235	4.2018E-05	2.8902E-05	1.8188E-05	1.8224E-05
U-236	2.9794E-06	5.2979E-06	6.8192E-06	6.9122E-06
U-238	2.2061E-02	2.1800E-02	2.1510E-02	2.1510E-02
Pu-238	6.0085E-07	1.7227E-06	4.1799E-06	5.6597E-06
Pu-239	5.5861E-04	3.6001E-04	2.4553E-04	2.4769E-04
Pu-240	1.4744E-04	1.8189E-04	1.7604E-04	1.7675E-04
Pu-241	5.8988E-05	9.5429E-05	1.0429E-04	8.1895E-05
Pu-242	5.7202E-06	2.0887E-05	4.2203E-05	4.2205E-05
Np-237	1.0043E-06	2.1374E-06	3.1286E-06	3.3136E-06
Am-241	1.3687E-06	3.8061E-06	5.1965E-06	2.7237E-05
Am-242m	1.8688E-08	6.6459E-08	9.5186E-08	9.3040E-08
Am-243	6.6062E-07	3.8639E-06	1.0009E-05	1.0005E-05
Cm-242	1.6249E-07	8.3571E-07	1.6895E-06	9.4218E-10
Cm-243	1.6382E-09	1.6767E-08	5.0626E-08	4.4829E-08
Cm-244	1.0632E-07	1.1507E-06	4.6519E-06	3.8417E-06
Cm-245	4.0822E-09	8.0007E-08	4.3971E-07	4.3953E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2164E-05	4.2344E-05	6.0405E-05	6.0404E-05
Ru-101	2.1791E-05	4.2780E-05	6.2817E-05	6.2817E-05
Rh-103	2.1806E-05	3.7087E-05	4.6733E-05	4.6733E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4659E-05	4.6295E-05	6.4902E-05	6.4902E-05
Nd-143	1.5079E-05	2.8386E-05	3.8443E-05	3.9235E-05
Nd-145	1.1204E-05	2.1599E-05	3.1011E-05	3.1011E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	1.9336E-07	1.6310E-07	1.4017E-07	1.9414E-07
Sm-150	4.8908E-06	1.0545E-05	1.6216E-05	1.6216E-05
Sm-151	8.7857E-07	8.3238E-07	7.9033E-07	7.6049E-07
Sm-152	3.1232E-06	5.2491E-06	6.2472E-06	6.2472E-06
Eu-153	2.1308E-06	5.1937E-06	7.9582E-06	7.9582E-06
Gd-155	2.3053E-09	4.3737E-09	6.8594E-09	3.1638E-07
k-infinity	1.11003	0.99169	0.8989	0.89068
High			50.210	
Medium			43.493	
Low			39.636	
Assembly Ave.			47.999	

Table B.2. Benchmark calculation results for Case 2 (*cont.*)

Supercell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 2 - Weapons Disposition MOX, Supercell Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1777E-07	1.7123E-07	1.3084E-07	1.3084E-07
U-235	4.1380E-05	2.7962E-05	1.7107E-05	1.7141E-05
U-236	3.1099E-06	5.4645E-06	6.9740E-06	7.0681E-06
U-238	2.2052E-02	2.1785E-02	2.1486E-02	2.1486E-02
Pu-238	3.7618E-07	2.9180E-07	2.1156E-07	2.0337E-07
Pu-239	5.4952E-04	3.4816E-04	2.3612E-04	2.3839E-04
Pu-240	1.5158E-04	1.8570E-04	1.7819E-04	1.7809E-04
Pu-241	5.9168E-05	9.4321E-05	1.0021E-04	7.8791E-05
Pu-242	5.8985E-06	2.1300E-05	4.2760E-05	4.2760E-05
Np-237	1.3220E-07	4.6200E-07	8.5124E-07	8.6985E-07
Am-241	1.3448E-06	3.6245E-06	4.7285E-06	2.6151E-05
Am-242m	1.9383E-08	6.4332E-08	8.5985E-08	8.5985E-08
Am-243	6.7214E-07	3.8848E-06	9.8997E-06	9.8997E-06
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.2544E-05	3.0174E-05	4.6294E-05	5.2457E-05
Tc-99	2.3013E-05	4.3525E-05	6.1633E-05	6.1633E-05
Ru-101	2.3607E-05	4.5914E-05	6.6977E-05	6.6977E-05
Rh-103	1.9497E-05	3.5797E-05	4.6279E-05	4.9750E-05
Ag-109	4.7011E-06	8.4041E-06	1.1373E-05	1.1373E-05
Cs-133	2.4636E-05	4.6066E-05	6.3984E-05	6.4454E-05
Nd-143	1.5703E-05	2.9159E-05	3.8929E-05	3.9738E-05
Nd-145	1.1750E-05	2.2310E-05	3.1640E-05	3.1640E-05
Sm-147	7.9311E-07	2.3345E-06	3.6639E-06	9.5653E-06
Sm-149	1.9078E-07	1.6422E-07	1.3821E-07	1.9879E-07
Sm-150	5.1171E-06	1.0828E-05	1.6335E-05	1.6335E-05
Sm-151	8.9098E-07	8.9805E-07	8.8311E-07	8.5891E-07
Sm-152	3.2578E-06	5.3516E-06	6.4255E-06	6.4255E-06
Eu-153	2.2908E-06	5.6965E-06	8.8064E-06	8.8680E-06
Gd-155	4.0258E-09	5.4178E-09	6.6596E-09	4.3518E-07
k-infinity	1.1077	0.9866	0.8919	0.8809
High	16.607	33.409	50.203	
Medium	14.792	29.079	43.503	
Low	13.560	26.568	39.802	
Assembly Ave.	16.001	31.983	48.004	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MC

Case 2 - Weapons Disposition MOX, Supercell Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3
U-234	2.2211E-07	1.8466E-07	1.6768E-07
U-235	4.1434E-05	2.8291E-05	1.7790E-05
U-236	3.2625E-06	5.6630E-06	7.1442E-06
U-238	2.2044E-02	2.1774E-02	2.1481E-02
Pu-238	6.2837E-07	1.8512E-06	4.4229E-06
Pu-239	5.6214E-04	3.6892E-04	2.5838E-04
Pu-240	1.4486E-04	1.7689E-04	1.7158E-04
Pu-241	6.5088E-05	9.9981E-05	1.0528E-04
Pu-242	6.2335E-06	2.2736E-05	4.4755E-05
Np-237	No Data	No Data	No Data
Am-241	1.3869E-06	3.9344E-06	5.2980E-06
Am-242m	2.5696E-08	9.5090E-08	1.3294E-07
Am-243	8.3571E-07	5.0554E-06	1.2645E-05
Cm-242	1.5641E-07	8.4206E-07	1.6636E-06
Cm-243	2.1335E-09	2.2758E-08	6.4938E-08
Cm-244	1.2301E-07	1.3732E-06	5.4560E-06
Cm-245	3.4084E-09	6.0532E-08	3.0205E-07
Mo-95	1.2326E-05	2.9614E-05	4.5510E-05
Tc-99	2.2076E-05	4.1919E-05	5.9283E-05
Ru-101	2.2093E-05	4.3173E-05	6.3146E-05
Rh-103	1.9331E-05	3.5215E-05	4.5256E-05
Ag-109	5.6368E-06	9.7565E-06	1.2723E-05
Cs-133	2.4419E-05	4.6094E-05	6.4523E-05
Nd-143	1.5263E-05	2.8688E-05	3.8805E-05
Nd-145	1.1298E-05	2.1588E-05	3.0745E-05
Sm-147	7.6562E-07	2.2354E-06	3.5257E-06
Sm-149	2.1604E-07	1.9491E-07	1.6484E-07
Sm-150	5.2588E-06	1.1399E-05	1.7317E-05
Sm-151	1.0169E-06	1.1205E-06	1.1576E-06
Sm-152	3.1916E-06	5.7529E-06	7.4948E-06
Eu-153	2.1331E-06	5.2255E-06	8.2058E-06
Gd-155	1.8351E-09	3.7797E-09	6.1876E-09
k-infinity	1.1113	0.9981	0.9102

Table B.2. Benchmark calculation results for Case 2 (*cont.*)

Supercell model, weapons disposition MOX fuel

	Mean			
Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2380E-07	1.8655E-07	1.6744E-07	3.6840E-07
U-235	4.1642E-05	2.8439E-05	1.7776E-05	1.7803E-05
U-236	3.1116E-06	5.4658E-06	6.9623E-06	7.0325E-06
U-238	2.2051E-02	2.1786E-02	2.1491E-02	2.1491E-02
Pu-238	6.0397E-07	1.6660E-06	3.9134E-06	5.2117E-06
Pu-239	5.5817E-04	3.6004E-04	2.4769E-04	2.4991E-04
Pu-240	1.4959E-04	1.8350E-04	1.7722E-04	1.7785E-04
Pu-241	5.9505E-05	9.5603E-05	1.0310E-04	8.1059E-05
Pu-242	5.8188E-06	2.1218E-05	4.2544E-05	4.2545E-05
Np-237	1.0581E-06	2.1710E-06	3.1473E-06	3.2644E-06
Am-241	1.3445E-06	3.7118E-06	4.9820E-06	2.6894E-05
Am-242m	2.0538E-08	7.2192E-08	1.0050E-07	9.8634E-08
Am-243	6.7816E-07	4.0375E-06	1.0426E-05	1.0429E-05
Cm-242	1.6639E-07	8.5580E-07	1.7022E-06	1.0159E-09
Cm-243	1.8333E-09	1.8768E-08	5.4859E-08	4.8723E-08
Cm-244	1.0313E-07	1.1448E-06	4.6491E-06	3.8410E-06
Cm-245	3.5895E-09	6.7265E-08	3.6199E-07	3.6188E-07
Mo-95	1.3319E-05	3.0622E-05	4.6498E-05	5.1545E-05
Tc-99	2.2459E-05	4.2729E-05	6.0645E-05	6.0776E-05
Ru-101	2.2706E-05	4.4340E-05	6.4822E-05	6.4823E-05
Rh-103	1.9416E-05	3.5108E-05	4.5324E-05	4.7858E-05
Ag-109	4.7825E-06	8.4927E-06	1.1373E-05	1.1378E-05
Cs-133	2.4213E-05	4.5463E-05	6.3377E-05	6.3754E-05
Nd-143	1.5450E-05	2.8895E-05	3.8960E-05	3.9680E-05
Nd-145	1.1396E-05	2.1753E-05	3.0946E-05	3.0949E-05
Sm-147	7.7933E-07	2.2926E-06	3.6353E-06	9.3184E-06
Sm-149	2.0242E-07	1.7683E-07	1.5008E-07	2.0971E-07
Sm-150	5.0701E-06	1.0865E-05	1.6508E-05	1.6508E-05
Sm-151	9.1269E-07	9.3112E-07	9.2478E-07	8.9647E-07
Sm-152	3.1664E-06	5.3513E-06	6.5523E-06	6.5524E-06
Eu-153	2.2094E-06	5.4347E-06	8.3881E-06	8.4316E-06
Gd-155	4.1747E-09	6.5903E-09	9.2588E-09	4.8164E-07

	Two Times Relative Standard Deviation (%)			
Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.71	7.28	18.14	52.29
U-235	0.96	1.90	3.70	3.71
U-236	5.02	3.78	3.00	2.81
U-238	0.06	0.11	0.14	0.14
Pu-238	31.63	67.42	76.89	77.98
Pu-239	2.16	4.82	7.49	7.44
Pu-240	3.49	4.18	5.23	5.18
Pu-241	10.37	5.91	4.68	4.89
Pu-242	9.82	8.52	6.17	6.17
Np-237	82.61	74.21	69.04	69.10
Am-241	6.84	6.97	8.14	4.62
Am-242m	36.70	41.77	43.66	42.51
Am-243	20.25	21.53	18.60	18.65
Cm-242	14.21	11.28	9.28	40.36
Cm-243	21.67	23.48	20.44	20.36
Cm-244	23.64	21.84	18.20	18.34
Cm-245	28.20	27.56	28.10	28.11
Mo-95	36.07	14.53	8.82	2.65
Tc-99	4.16	3.79	3.76	3.65
Ru-101	6.36	5.92	5.64	5.65
Rh-103	11.29	9.97	10.18	14.37
Ag-109	27.86	25.36	24.69	24.74
Cs-133	3.33	3.25	3.55	3.70
Nd-143	5.29	3.72	3.18	1.91
Nd-145	3.85	3.58	3.92	3.91
Sm-147	2.54	2.75	3.18	6.41
Sm-149	9.53	12.10	11.60	10.29
Sm-150	4.43	5.39	6.38	6.38
Sm-151	10.72	20.09	25.78	26.36
Sm-152	7.25	12.83	19.15	19.15
Eu-153	8.04	7.72	7.23	7.56
Gd-155	79.32	71.77	67.34	86.81

Table B.3. Benchmark calculation results for Case 3

Assembly model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

NUPEC (Sakurai)
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8095E-07	8.3192E-07	1.0211E-06	2.6288E-06
U -235	4.3790E-05	3.4621E-05	2.6722E-05	2.6722E-05
U -236	2.5154E-06	4.4450E-06	5.8461E-06	5.8461E-06
U -238	2.1160E-02	2.0923E-02	2.0675E-02	2.0675E-02
Pu-238	4.1019E-05	3.8424E-05	3.8550E-05	4.0961E-05
Pu-239	8.0416E-04	6.3755E-04	5.0850E-04	5.1029E-04
Pu-240	4.7385E-04	4.4805E-04	4.0953E-04	4.1275E-04
Pu-241	2.1858E-04	2.3660E-04	2.3550E-04	1.8481E-04
Pu-242	1.3785E-04	1.4982E-04	1.6558E-04	1.6558E-04
Np-237	1.5029E-06	2.8860E-06	4.0942E-06	4.0942E-06
Am-241	8.8242E-06	1.5561E-05	1.9061E-05	6.9385E-05
Am-242m	1.3421E-07	3.1898E-07	4.2146E-07	4.1192E-07
Am-243	1.5613E-05	2.7907E-05	3.8034E-05	3.8034E-05
Cm-242	9.7736E-07	2.6204E-06	4.0436E-06	5.0942E-09
Cm-243	1.2992E-08	6.4878E-08	1.3854E-07	1.2340E-07
Cm-244	2.6688E-06	9.2778E-06	1.8435E-05	1.5224E-05
Cm-245	1.2915E-07	8.1985E-07	2.1928E-06	2.1928E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	2.0509E-05	3.7469E-05	5.1041E-05	5.1041E-05
Ag-109	4.6603E-06	8.0989E-06	1.0524E-05	1.0524E-05
Cs-133	2.3463E-05	4.4403E-05	6.2829E-05	6.2829E-05
Nd-143	1.6594E-05	3.1809E-05	4.5385E-05	4.5385E-05
Nd-145	1.1183E-05	2.1322E-05	3.0386E-05	3.0386E-05
Sm-147	8.2700E-07	2.4742E-06	4.1395E-06	9.9452E-06
Sm-149	4.3945E-07	4.1781E-07	3.7238E-07	4.2796E-07
Sm-150	5.0215E-06	1.0870E-05	1.6535E-05	1.6535E-05
Sm-151	1.5281E-06	1.8767E-06	1.9755E-06	1.8916E-06
Sm-152	2.8187E-06	5.0468E-06	6.4242E-06	6.4242E-06
Eu-153	2.2411E-06	5.4745E-06	8.6655E-06	8.6655E-06
Gd-155	1.6769E-08	2.8935E-08	4.2299E-08	1.0081E-06
k-infinity	1.05978	1.00753	0.961	0.91857
High			50.966	
Medium			41.784	
Low			37.668	
Assembly Ave.			47.996	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7521E-07	8.2518E-07	1.0179E-06	2.6748E-06
U -235	4.3825E-05	3.4738E-05	2.6937E-05	2.7011E-05
U -236	2.5186E-06	4.4716E-06	5.9179E-06	6.1388E-06
U -238	2.1157E-02	2.0917E-02	2.0667E-02	2.0667E-02
Pu-238	4.1481E-05	3.9171E-05	3.9413E-05	4.1626E-05
Pu-239	8.0714E-04	6.4506E-04	5.1980E-04	5.2156E-04
Pu-240	4.7482E-04	4.5128E-04	4.1647E-04	4.2039E-04
Pu-241	2.1684E-04	2.3304E-04	2.3163E-04	1.8212E-04
Pu-242	1.3389E-04	1.4147E-04	1.5231E-04	1.5231E-04
Np-237	1.2206E-06	2.4144E-06	3.4853E-06	3.8866E-06
Am-241	8.6897E-06	1.5246E-05	1.8687E-05	6.7847E-05
Am-242m	1.3827E-07	3.2226E-07	4.2209E-07	4.1185E-07
Am-243	1.7356E-05	2.9837E-05	3.9436E-05	3.9436E-05
Cm-242	9.5415E-07	2.5215E-06	3.8393E-06	2.7151E-09
Cm-243	1.2966E-08	6.4908E-08	1.3889E-07	1.2375E-07
Cm-244	3.7951E-06	1.2517E-05	2.3817E-05	1.9671E-05
Cm-245	1.9612E-07	1.1882E-06	3.0345E-06	3.0333E-06
Mo-95	1.1834E-05	2.8767E-05	4.4787E-05	5.0765E-05
Tc-99	2.1921E-05	4.2288E-05	6.0943E-05	6.1176E-05
Ru-101	2.3054E-05	4.5186E-05	6.6364E-05	6.6366E-05
Rh-103	2.0064E-05	3.9239E-05	5.4581E-05	5.8014E-05
Ag-109	5.2444E-06	9.4844E-06	1.2993E-05	1.3008E-05
Cs-133	2.3867E-05	4.5475E-05	6.4493E-05	6.5039E-05
Nd-143	1.5508E-05	3.0346E-05	4.3452E-05	4.4325E-05
Nd-145	1.1518E-05	2.2191E-05	3.1988E-05	3.1999E-05
Sm-147	8.0249E-07	2.4525E-06	4.0902E-06	1.0607E-05
Sm-149	3.9254E-07	3.7684E-07	3.4511E-07	3.9940E-07
Sm-150	4.8280E-06	1.0327E-05	1.5706E-05	1.5706E-05
Sm-151	1.4035E-06	1.7138E-06	1.8212E-06	1.7636E-06
Sm-152	2.9820E-06	5.4446E-06	7.1033E-06	7.1049E-06
Eu-153	2.2080E-06	5.3823E-06	8.5860E-06	8.6362E-06
Gd-155	1.2599E-08	2.0400E-08	2.9866E-08	6.1487E-07
k-infinity	1.05624	0.99968	0.94869	0.90715
High			50.910	
Medium			41.960	
Low			37.612	
Assembly Ave.			48.000	

Table B.3. Benchmark calculation results for Case 3 (*cont.*)

Assembly model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7410E-07	8.2000E-07	1.0060E-06	2.6800E-06
U -235	4.3720E-05	3.4500E-05	2.6620E-05	2.6690E-05
U -236	2.5730E-06	4.5460E-06	5.9750E-06	6.2030E-06
U -238	2.1160E-02	2.0920E-02	2.0670E-02	2.0670E-02
Pu-238	4.1630E-05	3.9340E-05	3.9530E-05	4.1600E-05
Pu-239	7.9700E-04	6.2980E-04	5.0530E-04	5.0710E-04
Pu-240	4.8300E-04	4.6350E-04	4.2870E-04	4.3260E-04
Pu-241	2.1520E-04	2.3210E-04	2.3200E-04	1.8330E-04
Pu-242	1.3420E-04	1.4200E-04	1.5330E-04	1.5330E-04
Np-237	1.3020E-06	2.5890E-06	3.7460E-06	4.1420E-06
Am-241	8.4140E-06	1.4680E-05	1.7960E-05	6.6320E-05
Am-242m	1.7480E-07	4.1790E-07	5.5400E-07	5.4150E-07
Am-243	1.7340E-05	3.0030E-05	3.9880E-05	3.9880E-05
Cm-242	9.2900E-07	2.4410E-06	3.6990E-06	2.8840E-09
Cm-243	1.1940E-08	5.9910E-08	1.2840E-07	1.1370E-07
Cm-244	3.6100E-06	1.2230E-05	2.3690E-05	1.9570E-05
Cm-245	1.5290E-07	9.7280E-07	2.5940E-06	2.5930E-06
Mo-95	1.1820E-05	2.8660E-05	4.4550E-05	5.0480E-05
Tc-99	2.3060E-05	4.4400E-05	6.3850E-05	6.4090E-05
Ru-101	2.2080E-05	4.3230E-05	6.3400E-05	6.3400E-05
Rh-103	1.9910E-05	3.8470E-05	5.3000E-05	5.6340E-05
Ag-109	5.9460E-06	1.0640E-05	1.4480E-05	1.4490E-05
Cs-133	2.4160E-05	4.5810E-05	6.4660E-05	6.5210E-05
Nd-143	1.5610E-05	3.0560E-05	4.3780E-05	4.4650E-05
Nd-145	1.1440E-05	2.2040E-05	3.1760E-05	3.1770E-05
Sm-147	8.0330E-07	2.4620E-06	4.1200E-06	1.0470E-05
Sm-149	4.0260E-07	3.8580E-07	3.5390E-07	4.0810E-07
Sm-150	4.7960E-06	1.0210E-05	1.5410E-05	1.5410E-05
Sm-151	1.4590E-06	1.7990E-06	1.9340E-06	1.8740E-06
Sm-152	3.1530E-06	5.9850E-06	7.9580E-06	7.9580E-06
Eu-153	2.0380E-06	5.0480E-06	8.2780E-06	8.3280E-06
Gd-155	1.1250E-08	2.1620E-08	3.5120E-08	7.4640E-07
k-infinity	1.05910	0.99909	0.94752	0.90325
High			51.024	
Medium			41.680	
Low			37.377	
Assembly Ave.			47.997	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7512E-07	8.2480E-07	1.0163E-06	2.6658E-06
U -235	4.3762E-05	3.4601E-05	2.6747E-05	2.6747E-05
U -236	2.5521E-06	4.5243E-06	5.9787E-06	5.9787E-06
U -238	2.1158E-02	2.0917E-02	2.0666E-02	2.0666E-02
Pu-238	4.1593E-05	3.9255E-05	3.9412E-05	4.1388E-05
Pu-239	8.1074E-04	6.4958E-04	5.2512E-04	5.2693E-04
Pu-240	4.7491E-04	4.5167E-04	4.1661E-04	4.2046E-04
Pu-241	2.1629E-04	2.3380E-04	2.3378E-04	1.8365E-04
Pu-242	1.3464E-04	1.4278E-04	1.5439E-04	1.5440E-04
Np-237	1.6560E-06	3.2139E-06	4.5652E-06	4.9848E-06
Am-241	8.7832E-06	1.5571E-05	1.9269E-05	6.9036E-05
Am-242m	1.9036E-07	4.5414E-07	6.0712E-07	5.9239E-07
Am-243	1.6873E-05	2.9412E-05	3.9308E-05	3.9308E-05
Cm-242	8.7154E-07	2.3253E-06	3.5893E-06	3.0594E-09
Cm-243	1.1794E-08	5.8709E-08	1.2551E-07	1.1143E-07
Cm-244	3.4364E-06	1.1486E-05	2.2112E-05	1.8261E-05
Cm-245	1.6672E-07	1.0442E-06	2.7028E-06	2.7017E-06
Mo-95	1.7651E-05	3.4297E-05	4.9929E-05	4.9929E-05
Tc-99	2.1756E-05	4.1811E-05	6.0068E-05	6.0280E-05
Ru-101	2.2850E-05	4.4807E-05	6.5815E-05	6.5815E-05
Rh-103	2.0010E-05	3.9289E-05	5.4843E-05	5.8208E-05
Ag-109	5.2895E-06	9.6113E-06	1.3270E-05	1.3270E-05
Cs-133	2.3804E-05	4.5422E-05	6.4563E-05	6.5015E-05
Nd-143	1.5493E-05	3.0263E-05	4.3346E-05	4.4116E-05
Nd-145	1.1482E-05	2.2157E-05	3.2015E-05	3.2015E-05
Sm-147	8.0328E-07	2.4740E-06	4.1579E-06	1.0734E-05
Sm-149	4.1087E-07	3.8950E-07	3.5594E-07	4.0707E-07
Sm-150	4.9297E-06	1.0740E-05	1.6679E-05	1.6679E-05
Sm-151	1.3420E-06	1.5306E-06	1.5340E-06	1.4779E-06
Sm-152	2.8608E-06	5.0602E-06	6.3335E-06	6.3335E-06
Eu-153	2.2088E-06	5.2837E-06	8.2452E-06	8.2917E-06
Gd-155	1.2702E-08	2.0676E-08	3.0586E-08	6.0623E-07
k-infinity	1.06088	1.00618	0.95837	0.91826
High	17.057	34.053	50.978	
Medium	13.789	27.708	41.776	
Low	12.294	24.805	37.546	
Assembly Ave.	15.999	31.998	47.997	

Table B.3. Benchmark calculation results for Case 3 (*cont.*)

Assembly model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8216E-07	8.4354E-07	1.0509E-06	2.7220E-06
U -235	4.3925E-05	3.4893E-05	2.7129E-05	2.7206E-05
U -236	2.4858E-06	4.4215E-06	5.8610E-06	6.0776E-06
U -238	2.1155E-02	2.0911E-02	2.0657E-02	2.0657E-02
Pu-238	4.1519E-05	3.9292E-05	3.9688E-05	4.1989E-05
Pu-239	8.1275E-04	6.5524E-04	5.3435E-04	5.3613E-04
Pu-240	4.7109E-04	4.4499E-04	4.0836E-04	4.1217E-04
Pu-241	2.1962E-04	2.3790E-04	2.3767E-04	1.8687E-04
Pu-242	1.3484E-04	1.4345E-04	1.5546E-04	1.5546E-04
Np-237	1.1137E-06	2.2000E-06	3.1690E-06	3.2112E-06
Am-241	8.7598E-06	1.5505E-05	1.9170E-05	6.9979E-05
Am-242m	1.2244E-07	2.8821E-07	3.8216E-07	3.8216E-07
Am-243	1.6599E-05	2.8469E-05	3.7589E-05	3.7589E-05
Cm-242	9.8523E-07	2.6022E-06	3.9739E-06	1.6887E-09
Cm-243	1.3460E-08	6.7246E-08	1.4425E-07	1.2852E-07
Cm-244	3.7079E-06	1.2184E-05	2.3116E-05	1.9090E-05
Cm-245	1.9252E-07	1.1630E-06	2.9692E-06	2.9692E-06
Mo-95	1.1831E-05	2.8749E-05	4.4723E-05	5.0684E-05
Tc-99	2.2143E-05	4.2478E-05	6.1086E-05	6.1086E-05
Ru-101	2.2911E-05	4.4911E-05	6.5963E-05	6.5963E-05
Rh-103	2.0046E-05	3.9167E-05	5.4464E-05	5.7890E-05
Ag-109	5.2685E-06	9.5331E-06	1.3103E-05	1.3103E-05
Cs-133	2.3862E-05	4.5380E-05	6.4309E-05	6.4769E-05
Nd-143	1.5564E-05	3.0397E-05	4.3537E-05	4.4326E-05
Nd-145	1.1481E-05	2.2101E-05	3.1845E-05	3.1845E-05
Sm-147	8.0039E-07	2.4435E-06	4.0718E-06	1.0589E-05
Sm-149	3.9039E-07	3.7535E-07	3.4617E-07	3.9778E-07
Sm-150	4.7829E-06	1.0197E-05	1.5486E-05	1.5486E-05
Sm-151	1.4076E-06	1.7200E-06	1.8340E-06	1.7758E-06
Sm-152	2.9513E-06	5.3829E-06	7.0072E-06	7.0072E-06
Eu-153	2.1852E-06	5.3132E-06	8.4552E-06	8.5048E-06
Gd-155	1.2846E-08	1.9899E-08	2.7185E-08	6.2682E-07
k-infinity	1.049756	0.996539	0.949737	0.904088
High	17.071	34.069	50.988	
Medium	13.769	27.690	41.778	
Low	12.219	24.696	37.443	
Assembly Ave.	16.000	32.000	48.000	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.7489E-07	8.1934E-07	9.9952E-07	2.6318E-06
U-235	4.3905E-05	3.4829E-05	2.7040E-05	2.7116E-05
U-236	2.4930E-06	4.4327E-06	5.8628E-06	6.0806E-06
U-238	2.1161E-02	2.0922E-02	2.0671E-02	2.0671E-02
Pu-238	4.1368E-05	3.8820E-05	3.8846E-05	4.0979E-05
Pu-239	8.0812E-04	6.4771E-04	5.2533E-04	5.2711E-04
Pu-240	4.7323E-04	4.4755E-04	4.1078E-04	4.1461E-04
Pu-241	2.2011E-04	2.3979E-04	2.4058E-04	1.8891E-04
Pu-242	1.3438E-04	1.4244E-04	1.5431E-04	1.5432E-04
Np-237	1.1770E-06	2.3545E-06	3.4219E-06	3.8393E-06
Am-241	8.8762E-06	1.5982E-05	2.0066E-05	7.0845E-05
Am-242m	1.3756E-07	3.3843E-07	4.6346E-07	4.5301E-07
Am-243	1.6980E-05	2.9426E-05	3.8845E-05	3.8826E-05
Cm-242	8.9099E-07	2.4047E-06	3.7415E-06	2.6841E-09
Cm-243	1.1641E-08	6.0687E-08	1.3377E-07	1.1845E-07
Cm-244	3.6913E-06	1.2231E-05	2.3240E-05	1.9193E-05
Cm-245	1.9877E-07	1.2348E-06	3.2335E-06	3.2321E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2221E-05	4.2680E-05	6.1468E-05	6.1467E-05
Ru-101	2.1875E-05	4.2980E-05	6.3251E-05	6.3251E-05
Rh-103	2.2642E-05	4.0914E-05	5.5357E-05	5.5357E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4597E-05	4.6602E-05	6.6172E-05	6.6172E-05
Nd-143	1.5549E-05	3.0426E-05	4.3648E-05	4.4443E-05
Nd-145	1.1427E-05	2.2143E-05	3.2104E-05	3.2104E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	3.9305E-07	3.7427E-07	3.4182E-07	3.9065E-07
Sm-150	4.7807E-06	1.0332E-05	1.5946E-05	1.5946E-05
Sm-151	1.4002E-06	1.6091E-06	1.6197E-06	1.5586E-06
Sm-152	2.9006E-06	5.2213E-06	6.6175E-06	6.6175E-06
Eu-153	2.1559E-06	5.1923E-06	8.1650E-06	8.1650E-06
Gd-155	5.8811E-09	1.0585E-08	1.8072E-08	3.3400E-07
k-infinity	1.05541	0.99749	0.95292	0.91676
High			51.004	
Medium			41.700	
Low			37.577	
Assembly Ave.			47.997	

Table B.3. Benchmark calculation results for Case 3 (*cont.*)

Assembly model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 3 - First Recycle MOX, Assembly Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1279E-07	1.7413E-07	1.4169E-07	1.4169E-07
U-235	4.3857E-05	3.4629E-05	2.6596E-05	2.6668E-05
U-236	2.5018E-06	4.4578E-06	5.9076E-06	6.1256E-06
U-238	2.1163E-02	2.0927E-02	2.0678E-02	2.0678E-02
Pu-238	4.0713E-05	3.5013E-05	2.9577E-05	2.8432E-05
Pu-239	8.0065E-04	6.3327E-04	5.0368E-04	5.0542E-04
Pu-240	4.7507E-04	4.5051E-04	4.1309E-04	4.1287E-04
Pu-241	2.1644E-04	2.3299E-04	2.3107E-04	1.8167E-04
Pu-242	1.3502E-04	1.4305E-04	1.5441E-04	1.5441E-04
Np-237	1.0400E-07	3.6114E-07	6.9348E-07	7.0645E-07
Am-241	8.6941E-06	1.5252E-05	1.8616E-05	6.8011E-05
Am-242m	1.4390E-07	3.3587E-07	4.3633E-07	4.3633E-07
Am-243	1.6074E-05	2.7797E-05	3.6793E-05	3.6793E-05
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.1828E-05	2.8749E-05	4.4743E-05	5.0706E-05
Tc-99	2.2139E-05	4.2498E-05	6.1130E-05	6.1130E-05
Ru-101	2.2897E-05	4.4899E-05	6.5960E-05	6.5960E-05
Rh-103	2.0073E-05	3.9256E-05	5.4560E-05	5.7983E-05
Ag-109	5.2687E-06	9.5091E-06	1.2998E-05	1.2998E-05
Cs-133	2.3866E-05	4.5420E-05	6.4368E-05	6.4828E-05
Nd-143	1.5552E-05	3.0350E-05	4.3375E-05	4.4163E-05
Nd-145	1.1477E-05	2.2103E-05	3.1849E-05	3.1849E-05
Sm-147	8.0403E-07	2.4617E-06	4.1041E-06	1.0635E-05
Sm-149	3.7767E-07	3.5930E-07	3.2302E-07	3.7494E-07
Sm-150	4.7846E-06	1.0201E-05	1.5508E-05	1.5508E-05
Sm-151	1.3972E-06	1.6804E-06	1.7554E-06	1.6976E-06
Sm-152	2.9625E-06	5.3781E-06	6.8758E-06	6.8758E-06
Eu-153	2.1826E-06	5.3538E-06	8.6212E-06	8.6716E-06
Gd-155	1.2499E-08	1.8707E-08	2.4619E-08	6.0517E-07
k-infinity	1.0590	1.0046	0.9510	0.9108
High	17.074	34.090	51.019	
Medium	13.747	27.624	41.689	
Low	12.292	24.747	37.473	
Assembly Ave.	16.000	32.000	48.000	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MO

Case 3 - First Recycle MOX, Assembly Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3
U-234	5.7170E-07	8.1280E-07	9.9100E-07
U-235	4.3730E-05	3.4590E-05	2.6800E-05
U-236	2.6190E-06	4.6370E-06	6.1140E-06
U-238	2.1160E-02	2.0910E-02	2.0660E-02
Pu-238	4.1300E-05	3.8680E-05	3.8550E-05
Pu-239	8.0920E-04	6.5000E-04	5.2840E-04
Pu-240	4.7570E-04	4.5190E-04	4.1650E-04
Pu-241	2.1670E-04	2.3410E-04	2.3350E-04
Pu-242	1.3480E-04	1.4340E-04	1.5550E-04
Np-237	No Data	No Data	No Data
Am-241	8.7380E-06	1.5530E-05	1.9330E-05
Am-242m	1.7520E-07	3.9650E-07	5.2310E-07
Am-243	1.8260E-05	3.1620E-05	4.2000E-05
Cm-242	8.8600E-07	2.3350E-06	3.5650E-06
Cm-243	1.4560E-08	7.0660E-08	1.4820E-07
Cm-244	3.9610E-06	1.3050E-05	2.4950E-05
Cm-245	1.7670E-07	9.7210E-07	2.2540E-06
Mo-95	1.1690E-05	2.8330E-05	4.3990E-05
Tc-99	2.1760E-05	4.1850E-05	6.0140E-05
Ru-101	2.1640E-05	4.2320E-05	6.1990E-05
Rh-103	1.9630E-05	3.8240E-05	5.2980E-05
Ag-109	5.7460E-06	1.0050E-05	1.3310E-05
Cs-133	2.3870E-05	4.5670E-05	6.5030E-05
Nd-143	1.5350E-05	2.9970E-05	4.2830E-05
Nd-145	1.1260E-05	2.1670E-05	3.1200E-05
Sm-147	7.8960E-07	2.4130E-06	4.0280E-06
Sm-149	4.2340E-07	4.1990E-07	3.8520E-07
Sm-150	5.1050E-06	1.1350E-05	1.7660E-05
Sm-151	1.5140E-06	1.8870E-06	2.0110E-06
Sm-152	2.7790E-06	5.1250E-06	6.7300E-06
Eu-153	2.1290E-06	5.1290E-06	8.1310E-06
Gd-155	4.3940E-09	7.9700E-09	1.3920E-08
k-infinity	1.0627E+00	1.0117E+00	9.6610E-01

Table B.3. Benchmark calculation results for Case 3 (*cont.*)

Assembly model, first recycle MOX fuel

	Mean					Two Times Relative Standard Deviation (%)			
Nuclide	**End of Cycle 1**	**End of Cycle 2**	**End of Cycle 3**	**5 Years Cooling**	**Nuclide**	**End of Cycle 1**	**End of Cycle 2**	**End of Cycle 3**	**5 Years Cooling**
U-234	5.3087E-07	7.4396E-07	9.0555E-07	2.3439E-06	U-234	48.44	61.95	68.28	75.99
U-235	4.3814E-05	3.4675E-05	2.6824E-05	2.6879E-05	U-235	0.35	0.77	1.45	1.55
U-236	2.5323E-06	4.4920E-06	5.9329E-06	6.0982E-06	U-236	3.62	3.25	2.99	4.77
U-238	2.1159E-02	2.0918E-02	2.0668E-02	2.0668E-02	U-238	0.02	0.05	0.07	0.07
Pu-238	4.1328E-05	3.8499E-05	3.7946E-05	3.9688E-05	Pu-238	1.53	7.52	17.98	23.04
Pu-239	8.0622E-04	6.4353E-04	5.1881E-04	5.2060E-04	Pu-239	1.31	2.79	4.45	4.45
Pu-240	4.7521E-04	4.5118E-04	4.1501E-04	4.1831E-04	Pu-240	1.46	2.45	3.10	3.28
Pu-241	2.1747E-04	2.3504E-04	2.3447E-04	1.8434E-04	Pu-241	1.61	2.33	2.81	2.66
Pu-242	1.3495E-04	1.4355E-04	1.5566E-04	1.5566E-04	Pu-242	1.82	3.65	5.33	5.32
Np-237	1.1537E-06	2.2884E-06	3.3107E-06	3.5521E-06	Np-237	86.81	80.15	75.17	76.59
Am-241	8.7224E-06	1.5416E-05	1.9020E-05	6.8812E-05	Am-241	3.20	4.86	6.50	4.07
Am-242m	1.5209E-07	3.5904E-07	4.7621E-07	4.6744E-07	Am-242m	32.14	31.83	32.50	31.34
Am-243	1.6887E-05	2.9312E-05	3.8985E-05	3.8983E-05	Am-243	9.69	8.60	8.20	8.20
Cm-242	9.2775E-07	2.4643E-06	3.7788E-06	2.9962E-09	Cm-242	9.92	9.76	9.69	68.54
Cm-243	1.2765E-08	6.3857E-08	1.3679E-07	1.2149E-07	Cm-243	16.54	13.53	11.94	12.09
Cm-244	3.5529E-06	1.1854E-05	2.2766E-05	1.8806E-05	Cm-244	23.74	20.70	18.38	18.43
Cm-245	1.7327E-07	1.0564E-06	2.7115E-06	2.7107E-06	Cm-245	29.65	27.95	29.12	29.12
Mo-95	1.2776E-05	2.9592E-05	4.5454E-05	5.0389E-05	Mo-95	37.40	15.62	9.73	1.71
Tc-99	2.2143E-05	4.2572E-05	6.1241E-05	6.1371E-05	Tc-99	4.03	4.09	4.12	4.16
Ru-101	2.2472E-05	4.4048E-05	6.4678E-05	6.4678E-05	Ru-101	5.21	5.29	5.40	5.41
Rh-103	2.0360E-05	3.9006E-05	5.3853E-05	5.6380E-05	Rh-103	9.36	5.16	5.26	8.53
Ag-109	5.3462E-06	9.5610E-06	1.2954E-05	1.2959E-05	Ag-109	15.39	16.10	18.36	18.40
Cs-133	2.3936E-05	4.5523E-05	6.4553E-05	6.4926E-05	Cs-133	2.73	2.66	2.85	2.96
Nd-143	1.5653E-05	3.0515E-05	4.3669E-05	4.4382E-05	Nd-143	4.96	3.60	3.43	2.25
Nd-145	1.1409E-05	2.1966E-05	3.1643E-05	3.1647E-05	Nd-145	2.11	2.80	3.66	3.66
Sm-147	8.0430E-07	2.4544E-06	4.1016E-06	1.0469E-05	Sm-147	2.78	1.74	2.12	5.14
Sm-149	4.0375E-07	3.8735E-07	3.5294E-07	4.0626E-07	Sm-149	9.93	11.05	10.83	10.62
Sm-150	4.8785E-06	1.0528E-05	1.6116E-05	1.6116E-05	Sm-150	5.17	7.98	9.77	9.77
Sm-151	1.4314E-06	1.7271E-06	1.8106E-06	1.7482E-06	Sm-151	8.90	14.39	18.64	18.77
Sm-152	2.9260E-06	5.3305E-06	6.8812E-06	6.8815E-06	Sm-152	7.95	11.47	14.84	14.85
Eu-153	2.1686E-06	5.2721E-06	8.3934E-06	8.4302E-06	Eu-153	5.80	5.34	5.12	5.11
Gd-155	1.1118E-08	1.8599E-08	2.7708E-08	5.9725E-07	Gd-155	72.66	70.68	65.34	79.23

Table B.4. Benchmark calculation results for Case 4

Assembly model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

NUPEC (Sakurai)
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2489E-07	1.8995E-07	1.7589E-07	4.1077E-07
U -235	4.1886E-05	2.8836E-05	1.8119E-05	1.8119E-05
U -236	3.1382E-06	5.4858E-06	6.9682E-06	6.9682E-06
U -238	2.2047E-02	2.1783E-02	2.1493E-02	2.1493E-02
Pu-238	6.9514E-07	2.0530E-06	4.7927E-06	6.3483E-06
Pu-239	5.6667E-04	3.6608E-04	2.4767E-04	2.4983E-04
Pu-240	1.4844E-04	1.8284E-04	1.7629E-04	1.7703E-04
Pu-241	5.8503E-05	9.5303E-05	1.0323E-04	8.1013E-05
Pu-242	5.5899E-06	2.0439E-05	4.1587E-05	4.1587E-05
Np-237	1.4806E-06	2.8656E-06	4.0198E-06	4.0198E-06
Am-241	1.3539E-06	3.7297E-06	4.9896E-06	2.7076E-05
Am-242m	1.8243E-08	6.3564E-08	8.7686E-08	8.5703E-08
Am-243	6.7704E-07	4.0541E-06	1.0616E-05	1.0616E-05
Cm-242	1.7563E-07	8.9591E-07	1.8030E-06	1.4676E-09
Cm-243	1.8987E-09	1.8809E-08	5.4576E-08	4.8613E-08
Cm-244	9.3251E-08	1.0277E-06	4.2633E-06	3.5206E-06
Cm-245	3.4298E-09	6.0866E-08	3.2603E-07	3.2603E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	1.9154E-05	3.3166E-05	4.2315E-05	4.2315E-05
Ag-109	3.6778E-06	6.5223E-06	8.5551E-06	8.5551E-06
Cs-133	2.3439E-05	4.3917E-05	6.1230E-05	6.1230E-05
Nd-143	1.6346E-05	3.0200E-05	4.0746E-05	4.0746E-05
Nd-145	1.1117E-05	2.1048E-05	2.9641E-05	2.9642E-05
Sm-147	7.8701E-07	2.2794E-06	3.6527E-06	8.7798E-06
Sm-149	2.2432E-07	1.9268E-07	1.5771E-07	2.1788E-07
Sm-150	5.1388E-06	1.1001E-05	1.6585E-05	1.6585E-05
Sm-151	9.8132E-07	1.0140E-06	9.9233E-07	9.5019E-07
Sm-152	2.9780E-06	4.9499E-06	6.0104E-06	6.0104E-06
Eu-153	2.2657E-06	5.5211E-06	8.3324E-06	8.3324E-06
Gd-155	7.6886E-09	1.1850E-08	1.5641E-08	9.2307E-07
k-infinity	1.08996	0.98919	0.9067	0.87071
High			50.826	
Medium			42.112	
Low			37.988	
Assembly Ave.			47.998	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2268E-07	1.8685E-07	1.7150E-07	4.0146E-07
U -235	4.1782E-05	2.8835E-05	1.8347E-05	1.8383E-05
U -236	3.1085E-06	5.4368E-06	6.9372E-06	7.0341E-06
U -238	2.2040E-02	2.1771E-02	2.1477E-02	2.1477E-02
Pu-238	6.3679E-07	1.8655E-06	4.4319E-06	5.9258E-06
Pu-239	5.6844E-04	3.7243E-04	2.5722E-04	2.5938E-04
Pu-240	1.5008E-04	1.8624E-04	1.8298E-04	1.8370E-04
Pu-241	5.8471E-05	9.4698E-05	1.0336E-04	8.1267E-05
Pu-242	5.6826E-06	2.0404E-05	4.0667E-05	4.0669E-05
Np-237	1.1931E-06	2.3677E-06	3.3710E-06	3.5558E-06
Am-241	1.3382E-06	3.6692E-06	4.9773E-06	2.6942E-05
Am-242m	1.8833E-08	6.4226E-08	8.9282E-08	8.7116E-08
Am-243	6.7308E-07	3.8908E-06	1.0038E-05	1.0043E-05
Cm-242	1.7322E-07	8.6302E-07	1.7043E-06	9.5553E-10
Cm-243	1.9336E-09	1.9018E-08	5.4980E-08	4.8986E-08
Cm-244	1.1230E-07	1.1914E-06	4.7127E-06	3.8927E-06
Cm-245	4.4313E-09	7.8480E-08	4.0901E-07	4.0885E-07
Mo-95	1.2240E-05	2.9529E-05	4.5478E-05	5.1528E-05
Tc-99	2.2143E-05	4.2323E-05	6.0253E-05	6.0488E-05
Ru-101	2.3058E-05	4.5057E-05	6.5908E-05	6.5909E-05
Rh-103	1.8998E-05	3.5198E-05	4.6069E-05	4.9468E-05
Ag-109	4.5115E-06	8.1430E-06	1.1100E-05	1.1117E-05
Cs-133	2.3911E-05	4.5017E-05	6.2823E-05	6.3369E-05
Nd-143	1.5270E-05	2.8750E-05	3.8945E-05	3.9818E-05
Nd-145	1.1454E-05	2.1882E-05	3.1166E-05	3.1176E-05
Sm-147	7.7069E-07	2.2668E-06	3.5994E-06	9.4128E-06
Sm-149	2.0718E-07	1.8318E-07	1.5608E-07	2.1661E-07
Sm-150	5.0222E-06	1.0730E-05	1.6254E-05	1.6254E-05
Sm-151	9.1880E-07	9.5700E-07	9.5939E-07	9.3466E-07
Sm-152	3.1096E-06	5.2341E-06	6.4285E-06	6.4291E-06
Eu-153	2.2606E-06	5.5763E-06	8.6528E-06	8.7110E-06
Gd-155	4.5552E-09	7.0455E-09	1.0167E-08	4.4857E-07
k-infinity	1.07981	0.97923	0.89724	0.86897
High			50.693	
Medium			42.430	
Low			38.272	
Assembly Ave.			48.000	

Table B.4. Benchmark calculation results for Case 4 (*cont.*)

Assembly model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2110E-07	1.8430E-07	1.6920E-07	4.1870E-07
U -235	4.1730E-05	2.8760E-05	1.8320E-05	1.8360E-05
U -236	3.1450E-06	5.4490E-06	6.8740E-06	6.9670E-06
U -238	2.2040E-02	2.1780E-02	2.1480E-02	2.1480E-02
Pu-238	6.5860E-07	1.9740E-06	4.6860E-06	6.1990E-06
Pu-239	5.6280E-04	3.6890E-04	2.5970E-04	2.6190E-04
Pu-240	1.4800E-04	1.8070E-04	1.7470E-04	1.7540E-04
Pu-241	6.3690E-05	1.0080E-04	1.0850E-04	8.5710E-05
Pu-242	6.1170E-06	2.1840E-05	4.3080E-05	4.3090E-05
Np-237	1.3080E-06	2.6090E-06	3.7180E-06	3.9130E-06
Am-241	1.4360E-06	3.8820E-06	5.2020E-06	2.7840E-05
Am-242m	2.5820E-08	9.0760E-08	1.2680E-07	1.2390E-07
Am-243	6.9570E-07	4.0710E-06	1.0460E-05	1.0460E-05
Cm-242	1.7950E-07	8.9090E-07	1.7320E-06	1.0380E-09
Cm-243	1.9360E-09	1.9230E-08	5.5420E-08	4.9080E-08
Cm-244	1.0630E-07	1.1590E-06	4.6520E-06	3.8430E-06
Cm-245	3.4090E-09	6.2490E-08	3.3530E-07	3.3510E-07
Mo-95	1.2190E-05	2.9310E-05	4.5060E-05	5.1020E-05
Tc-99	2.2950E-05	4.3780E-05	6.2220E-05	6.2460E-05
Ru-101	2.2030E-05	4.2980E-05	6.2750E-05	6.2750E-05
Rh-103	1.9520E-05	3.5860E-05	4.6640E-05	4.9970E-05
Ag-109	5.5840E-06	9.7410E-06	1.2920E-05	1.2940E-05
Cs-133	2.4150E-05	4.5140E-05	6.2570E-05	6.3120E-05
Nd-143	1.5220E-05	2.8740E-05	3.9090E-05	3.9960E-05
Nd-145	1.1260E-05	2.1530E-05	3.0690E-05	3.0700E-05
Sm-147	7.6540E-07	2.2520E-06	3.5820E-06	9.1890E-06
Sm-149	2.1150E-07	1.8810E-07	1.6230E-07	2.2260E-07
Sm-150	4.9650E-06	1.0560E-05	1.5880E-05	1.5880E-05
Sm-151	9.3720E-07	9.9610E-07	1.0180E-06	9.9180E-07
Sm-152	3.3370E-06	5.9030E-06	7.4850E-06	7.4860E-06
Eu-153	2.0570E-06	5.1650E-06	8.2240E-06	8.2810E-06
Gd-155	4.9510E-09	9.2390E-09	1.3650E-08	6.6030E-07
k-infinity	1.07112	0.97149	0.89143	0.85771
High			50.880	
Medium			42.005	
Low			37.786	
Assembly Ave.			47.999	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2277E-07	1.8773E-07	1.7389E-07	4.1220E-07
U -235	4.1893E-05	2.8976E-05	1.8467E-05	1.8467E-05
U -236	3.1612E-06	5.5340E-06	7.0634E-06	7.0634E-06
U -238	2.2041E-02	2.1771E-02	2.1475E-02	2.1475E-02
Pu-238	7.1826E-07	2.0587E-06	4.7483E-06	6.1143E-06
Pu-239	5.7659E-04	3.8221E-04	2.6621E-04	2.6835E-04
Pu-240	1.4884E-04	1.8618E-04	1.8437E-04	1.8510E-04
Pu-241	5.6781E-05	9.4093E-05	1.0450E-04	8.2092E-05
Pu-242	5.3572E-06	1.9550E-05	3.9815E-05	3.9817E-05
Np-237	1.6488E-06	3.1897E-06	4.4424E-06	4.6418E-06
Am-241	1.3107E-06	3.6796E-06	5.0976E-06	2.7372E-05
Am-242m	2.5523E-08	9.0795E-08	1.3037E-07	1.2721E-07
Am-243	6.2689E-07	3.6612E-06	9.5680E-06	9.5725E-06
Cm-242	1.5269E-07	7.7886E-07	1.5821E-06	9.9962E-10
Cm-243	1.6814E-09	1.6565E-08	4.8232E-08	4.2821E-08
Cm-244	9.8505E-08	1.0390E-06	4.1608E-06	3.4362E-06
Cm-245	3.7729E-09	6.8602E-08	3.6845E-07	3.6830E-07
Mo-95	1.8204E-05	3.5096E-05	5.0570E-05	5.0570E-05
Tc-99	2.1917E-05	4.1730E-05	5.9218E-05	5.9428E-05
Ru-101	2.2886E-05	4.4753E-05	6.5473E-05	6.5473E-05
Rh-103	1.8759E-05	3.4846E-05	4.5724E-05	4.9009E-05
Ag-109	4.5638E-06	8.2657E-06	1.1337E-05	1.1337E-05
Cs-133	2.3826E-05	4.4954E-05	6.2922E-05	6.3369E-05
Nd-143	1.5229E-05	2.8666E-05	3.8911E-05	3.9671E-05
Nd-145	1.1409E-05	2.1824E-05	3.1154E-05	3.1154E-05
Sm-147	7.7250E-07	2.2924E-06	3.6688E-06	9.5399E-06
Sm-149	2.2140E-07	1.9215E-07	1.6259E-07	2.1896E-07
Sm-150	5.1364E-06	1.1182E-05	1.7344E-05	1.7344E-05
Sm-151	8.8308E-07	8.4937E-07	8.0820E-07	7.7864E-07
Sm-152	2.9780E-06	4.8514E-06	5.7314E-06	5.7314E-06
Eu-153	2.2659E-06	5.4184E-06	8.1399E-06	8.1917E-06
Gd-155	5.2200E-09	7.8677E-09	1.0954E-08	4.3899E-07
k-infinity	1.08652	0.9878	0.9089	0.88219
High	17.066	34.025	50.810	
Medium	13.778	27.782	42.156	
Low	12.229	24.821	37.984	
Assembly Ave.	15.999	31.999	47.998	

Table B.4. Benchmark calculation results for Case 4 (*cont.*)

Assembly model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2681E-07	1.9333E-07	1.7954E-07	4.1232E-07
U -235	4.1982E-05	2.9122E-05	1.8682E-05	1.8722E-05
U -236	3.0518E-06	5.3642E-06	6.8672E-06	6.9628E-06
U -238	2.2041E-02	2.1767E-02	2.1467E-02	2.1467E-02
Pu-238	6.2846E-07	1.8518E-06	4.4601E-06	6.0037E-06
Pu-239	5.7398E-04	3.8246E-04	2.7064E-04	2.7284E-04
Pu-240	1.4813E-04	1.8362E-04	1.8074E-04	1.8143E-04
Pu-241	5.9326E-05	9.6950E-05	1.0700E-04	8.4129E-05
Pu-242	5.6011E-06	2.0249E-05	4.0773E-05	4.0773E-05
Np-237	1.0952E-06	2.1916E-06	3.1297E-06	3.1791E-06
Am-241	1.3614E-06	3.7729E-06	5.1960E-06	2.8071E-05
Am-242m	1.6636E-08	5.7737E-08	8.2007E-08	8.2007E-08
Am-243	6.5506E-07	3.7568E-06	9.5691E-06	9.5691E-06
Cm-242	1.7814E-07	8.9231E-07	1.7772E-06	7.5522E-10
Cm-243	1.9809E-09	1.9657E-08	5.7552E-08	5.1277E-08
Cm-244	1.0996E-07	1.1590E-06	4.5467E-06	3.7549E-06
Cm-245	4.3221E-09	7.6141E-08	3.9752E-07	3.9752E-07
Mo-95	1.2221E-05	2.9474E-05	4.5373E-05	5.1407E-05
Tc-99	2.2330E-05	4.2455E-05	6.0333E-05	6.0333E-05
Ru-101	2.2919E-05	4.4802E-05	6.5544E-05	6.5544E-05
Rh-103	1.8952E-05	3.5072E-05	4.5918E-05	4.9307E-05
Ag-109	4.5308E-06	8.1690E-06	1.1145E-05	1.1145E-05
Cs-133	2.3900E-05	4.4922E-05	6.2654E-05	6.3114E-05
Nd-143	1.5317E-05	2.8804E-05	3.9099E-05	3.9889E-05
Nd-145	1.1410E-05	2.1784E-05	3.1021E-05	3.1021E-05
Sm-147	7.6910E-07	2.2614E-06	3.5863E-06	9.4028E-06
Sm-149	2.0313E-07	1.7988E-07	1.5538E-07	2.1272E-07
Sm-150	4.9560E-06	1.0540E-05	1.5938E-05	1.5938E-05
Sm-151	9.1986E-07	9.5685E-07	9.6623E-07	9.4117E-07
Sm-152	3.0866E-06	5.1849E-06	6.3364E-06	6.3364E-06
Eu-153	2.2378E-06	5.5158E-06	8.5389E-06	8.5964E-06
Gd-155	4.5396E-09	6.3794E-09	8.1414E-09	4.5655E-07
k-infinity	1.07323	0.976022	0.899025	0.86913
High	17.074	34.023	50.786	
Medium	13.767	27.795	42.215	
Low	12.184	24.805	38.059	
Assembly Ave.	16.000	32.000	48.000	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2364E-07	1.8683E-07	1.6964E-07	3.9604E-07
U-235	4.2085E-05	2.9257E-05	1.8791E-05	1.8830E-05
U-236	3.0287E-06	5.3234E-06	6.8091E-06	6.9037E-06
U-238	2.2047E-02	2.1778E-02	2.1482E-02	2.1482E-02
Pu-238	6.2601E-07	1.8103E-06	4.3559E-06	5.8335E-06
Pu-239	5.7245E-04	3.7993E-04	2.6701E-04	2.6921E-04
Pu-240	1.4610E-04	1.8164E-04	1.7898E-04	1.7969E-04
Pu-241	6.0151E-05	9.7797E-05	1.0802E-04	8.4824E-05
Pu-242	5.6789E-06	2.0411E-05	4.1060E-05	4.1062E-05
Np-237	1.1353E-06	2.3127E-06	3.3378E-06	3.5299E-06
Am-241	1.4016E-06	3.9280E-06	5.4746E-06	2.8303E-05
Am-242m	1.9417E-08	7.0454E-08	1.0295E-07	1.0063E-07
Am-243	6.6831E-07	3.8708E-06	9.9119E-06	9.9072E-06
Cm-242	1.6373E-07	8.3570E-07	1.6941E-06	9.6253E-10
Cm-243	1.7527E-09	1.7631E-08	5.2481E-08	4.6472E-08
Cm-244	1.1088E-07	1.1758E-06	4.6160E-06	3.8120E-06
Cm-245	4.6024E-09	8.6913E-08	4.7115E-07	4.7096E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2098E-05	4.2149E-05	6.0094E-05	6.0093E-05
Ru-101	2.1769E-05	4.2699E-05	6.2654E-05	6.2654E-05
Rh-103	2.1765E-05	3.7099E-05	4.7011E-05	4.7011E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4574E-05	4.6063E-05	6.4442E-05	6.4442E-05
Nd-143	1.5109E-05	2.8545E-05	3.8908E-05	3.9700E-05
Nd-145	1.1196E-05	2.1563E-05	3.0945E-05	3.0945E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	2.0462E-07	1.7759E-07	1.5161E-07	2.0516E-07
Sm-150	4.9051E-06	1.0577E-05	1.6275E-05	1.6275E-05
Sm-151	9.0334E-07	8.7707E-07	8.4064E-07	8.0890E-07
Sm-152	3.0423E-06	5.0496E-06	6.0177E-06	6.0177E-06
Eu-153	2.1650E-06	5.2481E-06	7.9849E-06	7.9849E-06
Gd-155	2.4393E-09	4.9156E-09	7.6758E-09	3.2182E-07
k-infinity	1.0833	0.98167	0.90121	0.87964
High			50.821	
Medium			42.126	
Low			37.996	
Assembly Ave.			47.999	

Table B.4. Benchmark calculation results for Case 4 (*cont.*)

Assembly model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1683E-07	1.7098E-07	1.3174E-07	1.3174E-07
U-235	4.1925E-05	2.8940E-05	1.8338E-05	1.8375E-05
U-236	3.0599E-06	5.3820E-06	6.8813E-06	6.9765E-06
U-238	2.2049E-02	2.1783E-02	2.1489E-02	2.1489E-02
Pu-238	3.7913E-07	2.9817E-07	2.2123E-07	2.1267E-07
Pu-239	5.6883E-04	3.7324E-04	2.5841E-04	2.6059E-04
Pu-240	1.4828E-04	1.8388E-04	1.8036E-04	1.8026E-04
Pu-241	5.8644E-05	9.5369E-05	1.0407E-04	8.1825E-05
Pu-242	5.5326E-06	1.9815E-05	3.9825E-05	3.9825E-05
Np-237	1.3364E-07	4.5945E-07	8.5608E-07	8.7398E-07
Am-241	1.3518E-06	3.7222E-06	5.0446E-06	2.7293E-05
Am-242m	1.9671E-08	6.7410E-08	9.4312E-08	9.4312E-08
Am-243	6.3924E-07	3.6779E-06	9.3994E-06	9.3994E-06
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.2181E-05	2.9386E-05	4.5261E-05	5.1284E-05
Tc-99	2.2262E-05	4.2356E-05	6.0238E-05	6.0238E-05
Ru-101	2.2844E-05	4.4663E-05	6.5384E-05	6.5384E-05
Rh-103	1.8913E-05	3.5045E-05	4.5840E-05	4.9219E-05
Ag-109	4.5144E-06	8.1505E-06	1.1103E-05	1.1103E-05
Cs-133	2.3833E-05	4.4838E-05	6.2582E-05	6.3041E-05
Nd-143	1.5268E-05	2.8685E-05	3.8821E-05	3.9608E-05
Nd-145	1.1377E-05	2.1732E-05	3.0962E-05	3.0962E-05
Sm-147	7.6965E-07	2.2723E-06	3.6097E-06	9.4445E-06
Sm-149	1.9930E-07	1.7336E-07	1.4821E-07	2.0599E-07
Sm-150	4.9387E-06	1.0500E-05	1.5895E-05	1.5895E-05
Sm-151	9.1057E-07	9.3611E-07	9.3065E-07	9.0435E-07
Sm-152	3.0892E-06	5.2026E-06	6.3070E-06	6.3070E-06
Eu-153	2.2238E-06	5.4932E-06	8.5580E-06	8.6158E-06
Gd-155	4.4452E-09	6.0856E-09	7.5729E-09	4.4276E-07
k-infinity	1.0821	0.9835	0.9009	0.8744
High	17.071	34.031	50.809	
Medium	13.767	27.770	42.158	
Low	12.238	24.837	38.036	
Assembly Ave.	16.000	32.000	48.000	

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 4 - Weapons Disposition MOX, Assembly Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.22E-07	1.84E-07	1.67E-07	3.93E-07
U-235	4.18E-05	2.89E-05	1.86E-05	1.86E-05
U-236	3.19E-06	5.56E-06	7.07E-06	7.17E-06
U-238	2.20E-02	2.18E-02	2.15E-02	2.15E-02
Pu-238	6.37E-07	1.86E-06	4.39E-06	5.80E-06
Pu-239	5.72E-04	3.83E-04	2.72E-04	2.74E-04
Pu-240	1.46E-04	1.81E-04	1.80E-04	1.81E-04
Pu-241	6.38E-05	9.87E-05	1.06E-04	8.34E-05
Pu-242	5.93E-06	2.15E-05	4.23E-05	4.23E-05
Np-237	No Data	No Data	No Data	No Data
Am-241	1.35E-06	3.88E-06	5.37E-06	2.80E-05
Am-242m	2.47E-08	8.99E-08	1.28E-07	1.25E-07
Am-243	8.01E-07	4.73E-06	1.17E-05	1.17E-05
Cm-242	1.55E-07	8.19E-07	1.62E-06	1.02E-09
Cm-243	2.03E-09	2.09E-08	5.92E-08	5.24E-08
Cm-244	1.31E-07	1.41E-06	5.42E-06	4.49E-06
Cm-245	4.45E-09	7.61E-08	3.69E-07	3.69E-07
Mo-95	1.22E-05	2.93E-05	4.50E-05	5.09E-05
Tc-99	2.19E-05	4.19E-05	5.95E-05	5.98E-05
Ru-101	2.19E-05	4.27E-05	6.23E-05	6.23E-05
Rh-103	1.92E-05	3.52E-05	4.58E-05	4.91E-05
Ag-109	5.54E-06	9.57E-06	1.25E-05	1.25E-05
Cs-133	2.42E-05	4.58E-05	6.43E-05	6.48E-05
Nd-143	1.51E-05	2.85E-05	3.87E-05	3.95E-05
Nd-145	1.12E-05	2.14E-05	3.05E-05	3.05E-05
Sm-147	7.65E-07	2.26E-06	3.59E-06	9.27E-06
Sm-149	2.18E-07	1.97E-07	1.69E-07	2.31E-07
Sm-150	5.27E-06	1.16E-05	1.79E-05	1.79E-05
Sm-151	1.02E-06	1.09E-06	1.10E-06	1.07E-06
Sm-152	2.96E-06	5.06E-06	6.28E-06	6.28E-06
Eu-153	2.19E-06	5.33E-06	8.23E-06	8.28E-06
Gd-155	1.80E-09	3.81E-09	6.30E-09	2.30E-07
k-infinity	1.096727	1.001136	0.9247713	

Table B.4. Benchmark calculation results for Case 4 (*cont.*)

Assembly model, weapons disposition MOX fuel

	Mean					Two Times Relative Standard Deviation (%)			
Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling	Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2254E-07	1.8552E-07	1.6734E-07	3.7202E-07	U-234	2.64	7.10	17.83	52.41
U-235	4.1882E-05	2.8956E-05	1.8455E-05	1.8484E-05	U-235	0.57	1.13	2.38	2.47
U-236	3.1107E-06	5.4420E-06	6.9338E-06	7.0052E-06	U-236	3.75	3.05	2.73	2.31
U-238	2.2043E-02	2.1775E-02	2.1479E-02	2.1479E-02	U-238	0.03	0.06	0.08	0.08
Pu-238	6.2240E-07	1.7209E-06	4.0108E-06	5.3052E-06	Pu-238	33.36	67.72	76.82	77.88
Pu-239	5.7026E-04	3.7599E-04	2.6232E-04	2.6451E-04	Pu-239	1.55	3.54	6.16	6.13
Pu-240	1.4795E-04	1.8331E-04	1.7981E-04	1.8045E-04	Pu-240	1.93	2.29	3.55	3.54
Pu-241	5.9915E-05	9.6715E-05	1.0560E-04	8.3026E-05	Pu-241	8.45	4.73	3.97	4.19
Pu-242	5.6855E-06	2.0520E-05	4.1138E-05	4.1140E-05	Pu-242	8.31	7.50	5.56	5.57
Np-237	1.1421E-06	2.2851E-06	3.2678E-06	3.3876E-06	Np-237	85.21	76.71	70.67	70.92
Am-241	1.3632E-06	3.7827E-06	5.1686E-06	2.7612E-05	Am-241	5.68	5.29	6.92	3.66
Am-242m	2.1102E-08	7.4352E-08	1.0519E-07	1.0323E-07	Am-242m	34.49	37.20	38.34	37.19
Am-243	6.7953E-07	3.9645E-06	1.0159E-05	1.0161E-05	Am-243	15.79	17.49	14.98	15.03
Cm-242	1.6823E-07	8.5368E-07	1.7017E-06	1.0276E-09	Cm-242	13.29	10.42	9.36	41.91
Cm-243	1.8879E-09	1.8836E-08	5.4639E-08	4.8527E-08	Cm-243	13.32	14.95	13.03	13.05
Cm-244	1.0894E-07	1.1660E-06	4.6251E-06	3.8211E-06	Cm-244	22.27	21.66	17.65	17.79
Cm-245	4.0595E-09	7.2793E-08	3.8238E-07	3.8227E-07	Cm-245	25.08	25.57	25.78	25.77
Mo-95	1.3208E-05	3.0351E-05	4.6129E-05	5.1122E-05	Mo-95	37.07	15.33	9.46	1.39
Tc-99	2.2234E-05	4.2378E-05	6.0268E-05	6.0399E-05	Tc-99	3.15	3.18	3.18	3.24
Ru-101	2.2481E-05	4.3946E-05	6.4293E-05	6.4293E-05	Ru-101	5.03	5.00	5.02	5.02
Rh-103	1.9405E-05	3.5191E-05	4.5670E-05	4.8176E-05	Rh-103	10.10	6.21	6.25	10.47
Ag-109	4.7032E-06	8.3656E-06	1.1233E-05	1.1241E-05	Ag-109	28.26	25.60	24.76	24.86
Cs-133	2.3978E-05	4.5076E-05	6.2934E-05	6.3306E-05	Cs-133	2.77	2.85	3.24	3.35
Nd-143	1.5361E-05	2.8859E-05	3.9151E-05	3.9864E-05	Nd-143	5.26	3.83	3.36	1.93
Nd-145	1.1302E-05	2.1594E-05	3.0760E-05	3.0764E-05	Nd-145	2.23	2.56	3.29	3.29
Sm-147	7.7128E-07	2.2685E-06	3.6133E-06	9.2905E-06	Sm-147	1.94	1.25	1.88	5.45
Sm-149	2.1117E-07	1.8554E-07	1.5780E-07	2.1641E-07	Sm-149	8.68	9.03	8.25	7.97
Sm-150	5.0410E-06	1.0832E-05	1.6504E-05	1.6504E-05	Sm-150	5.01	7.12	8.87	8.87
Sm-151	9.3465E-07	9.5931E-07	9.5156E-07	9.2221E-07	Sm-151	9.80	15.82	19.59	20.27
Sm-152	3.0726E-06	5.1798E-06	6.3241E-06	6.3244E-06	Sm-152	7.91	12.36	16.50	16.51
Eu-153	2.2080E-06	5.4090E-06	8.3320E-06	8.3743E-06	Eu-153	6.46	5.42	5.57	5.89
Gd-155	4.4549E-09	7.1489E-09	1.0013E-08	4.9020E-07	Gd-155	80.34	70.83	65.17	87.28

Table B.5. Benchmark calculation results for Case 5

Pin cell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

NUPEC (Sakurai)
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8084E-07	8.3177E-07	1.0213E-06	2.6333E-06
U -235	4.3864E-05	3.4740E-05	2.6867E-05	2.6867E-05
U -236	2.5080E-06	4.4354E-06	5.8372E-06	5.8372E-06
U -238	2.1159E-02	2.0921E-02	2.0673E-02	2.0673E-02
Pu-238	4.1033E-05	3.8471E-05	3.8653E-05	4.1073E-05
Pu-239	8.0476E-04	6.3899E-04	5.1067E-04	5.1247E-04
Pu-240	4.7299E-04	4.4657E-04	4.0782E-04	4.1107E-04
Pu-241	2.1950E-04	2.3807E-04	2.3723E-04	1.8617E-04
Pu-242	1.3761E-04	1.4943E-04	1.6503E-04	1.6503E-04
Np-237	1.5130E-06	2.9047E-06	4.1208E-06	4.1208E-06
Am-241	8.8471E-06	1.5636E-05	1.9194E-05	6.9889E-05
Am-242m	1.3502E-07	3.2214E-07	4.2705E-07	4.1739E-07
Am-243	1.5770E-05	2.8150E-05	3.8314E-05	3.8314E-05
Cm-242	9.7912E-07	2.6278E-06	4.0576E-06	5.1450E-09
Cm-243	1.3039E-08	6.5168E-08	1.3925E-07	1.2403E-07
Cm-244	2.7069E-06	9.3993E-06	1.8645E-05	1.5398E-05
Cm-245	1.3158E-07	8.3563E-07	2.2350E-06	2.2350E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	1.9154E-05	3.4981E-05	4.7669E-05	4.7669E-05
Ag-109	4.6574E-06	8.0911E-06	1.0511E-05	1.0511E-05
Cs-133	2.3459E-05	4.4390E-05	6.2807E-05	6.2807E-05
Nd-143	1.6599E-05	3.1831E-05	4.5443E-05	4.5443E-05
Nd-145	1.1182E-05	2.1321E-05	3.0383E-05	3.0383E-05
Sm-147	8.2666E-07	2.4721E-06	4.1352E-06	9.9349E-06
Sm-149	4.4534E-07	4.2426E-07	3.7872E-07	4.3430E-07
Sm-150	5.0180E-06	1.0869E-05	1.6537E-05	1.6537E-05
Sm-151	1.5364E-06	1.8913E-06	1.9944E-06	1.9097E-06
Sm-152	2.8106E-06	5.0332E-06	6.4074E-06	6.4074E-06
Eu-153	2.2413E-06	5.4754E-06	8.6687E-06	8.6687E-06
Gd-155	1.6944E-08	2.9317E-08	4.2985E-08	1.0112E-06
k-infinity	1.05958	1.00783	0.96162	0.91903

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7518E-07	8.2531E-07	1.0185E-06	2.6800E-06
U -235	4.3895E-05	3.4850E-05	2.7070E-05	2.7146E-05
U -236	2.5101E-06	4.4600E-06	5.9070E-06	6.1270E-06
U -238	2.1157E-02	2.0915E-02	2.0665E-02	2.0665E-02
Pu-238	4.1493E-05	3.9218E-05	3.9512E-05	4.1739E-05
Pu-239	8.0777E-04	6.4641E-04	5.2177E-04	5.2354E-04
Pu-240	4.7408E-04	4.4999E-04	4.1497E-04	4.1893E-04
Pu-241	2.1760E-04	2.3437E-04	2.3317E-04	1.8332E-04
Pu-242	1.3375E-04	1.4125E-04	1.5202E-04	1.5202E-04
Np-237	1.2315E-06	2.4339E-06	3.5113E-06	3.9151E-06
Am-241	8.7059E-06	1.5299E-05	1.8780E-05	6.8267E-05
Am-242m	1.3926E-07	3.2545E-07	4.2724E-07	4.1687E-07
Am-243	1.7428E-05	2.9938E-05	3.9541E-05	3.9542E-05
Cm-242	9.5729E-07	2.5312E-06	3.8557E-06	2.7353E-09
Cm-243	1.3011E-08	6.5147E-08	1.3945E-07	1.2425E-07
Cm-244	3.8185E-06	1.2584E-05	2.3924E-05	1.9760E-05
Cm-245	1.9772E-07	1.1981E-06	3.0596E-06	3.0584E-06
Mo-95	1.1834E-05	2.8768E-05	4.4789E-05	5.0768E-05
Tc-99	2.1921E-05	4.2288E-05	6.0943E-05	6.1177E-05
Ru-101	2.3056E-05	4.5189E-05	6.6369E-05	6.6371E-05
Rh-103	2.0063E-05	3.9238E-05	5.4582E-05	5.8015E-05
Ag-109	5.2410E-06	9.4789E-06	1.2984E-05	1.3001E-05
Cs-133	2.3867E-05	4.5475E-05	6.4495E-05	6.5041E-05
Nd-143	1.5512E-05	3.0367E-05	4.3506E-05	4.4378E-05
Nd-145	1.1519E-05	2.2195E-05	3.1996E-05	3.2007E-05
Sm-147	8.0254E-07	2.4527E-06	4.0911E-06	1.0610E-05
Sm-149	3.9684E-07	3.8152E-07	3.4973E-07	4.0397E-07
Sm-150	4.8237E-06	1.0322E-05	1.5699E-05	1.5699E-05
Sm-151	1.4104E-06	1.7249E-06	1.8347E-06	1.7767E-06
Sm-152	2.9765E-06	5.4380E-06	7.0974E-06	7.0990E-06
Eu-153	2.2065E-06	5.3786E-06	8.5816E-06	8.6318E-06
Gd-155	1.2724E-08	2.0654E-08	3.0314E-08	6.1876E-07
k-infinity	1.05638	1.00028	0.94969	0.90789

Table B.5. Benchmark calculation results for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7390E-07	8.1910E-07	1.0040E-06	2.6830E-06
U -235	4.3770E-05	3.4580E-05	2.6720E-05	2.6790E-05
U -236	2.5710E-06	4.5490E-06	5.9820E-06	6.2090E-06
U -238	2.1160E-02	2.0920E-02	2.0670E-02	2.0670E-02
Pu-238	4.1630E-05	3.9380E-05	3.9620E-05	4.1700E-05
Pu-239	7.9790E-04	6.3320E-04	5.1180E-04	5.1360E-04
Pu-240	4.8240E-04	4.6230E-04	4.2730E-04	4.3130E-04
Pu-241	2.1590E-04	2.3330E-04	2.3360E-04	1.8460E-04
Pu-242	1.3400E-04	1.4160E-04	1.5260E-04	1.5260E-04
Np-237	1.3090E-06	2.6110E-06	3.7860E-06	4.1850E-06
Am-241	8.4230E-06	1.4720E-05	1.8050E-05	6.6740E-05
Am-242m	1.7620E-07	4.2330E-07	5.6520E-07	5.5250E-07
Am-243	1.7450E-05	3.0220E-05	4.0090E-05	4.0090E-05
Cm-242	9.3220E-07	2.4490E-06	3.7070E-06	2.9140E-09
Cm-243	1.2060E-08	6.0610E-08	1.3000E-07	1.1510E-07
Cm-244	3.6470E-06	1.2370E-05	2.3970E-05	1.9800E-05
Cm-245	1.5500E-07	9.9070E-07	2.6510E-06	2.6500E-06
Mo-95	1.1810E-05	2.8650E-05	4.4510E-05	5.0440E-05
Tc-99	2.3060E-05	4.4370E-05	6.3790E-05	6.4030E-05
Ru-101	2.2080E-05	4.3210E-05	6.3350E-05	6.3350E-05
Rh-103	1.9900E-05	3.8440E-05	5.2950E-05	5.6300E-05
Ag-109	5.9410E-06	1.0630E-05	1.4450E-05	1.4470E-05
Cs-133	2.4150E-05	4.5770E-05	6.4570E-05	6.5110E-05
Nd-143	1.5610E-05	3.0570E-05	4.3820E-05	4.4690E-05
Nd-145	1.1440E-05	2.2030E-05	3.1730E-05	3.1740E-05
Sm-147	8.0230E-07	2.4540E-06	4.0980E-06	1.0420E-05
Sm-149	4.0900E-07	3.9450E-07	3.6470E-07	4.1880E-07
Sm-150	4.7900E-06	1.0200E-05	1.5390E-05	1.5390E-05
Sm-151	1.4670E-06	1.8210E-06	1.9730E-06	1.9110E-06
Sm-152	3.1440E-06	5.9670E-06	7.9310E-06	7.9320E-06
Eu-153	2.0370E-06	5.0400E-06	8.2540E-06	8.3040E-06
Gd-155	1.1390E-08	2.2130E-08	3.6390E-08	7.5280E-07
k-infinity	1.05753	0.99969	0.94775	0.90424

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.7451E-07	8.2334E-07	1.0143E-06	2.6703E-06
U -235	4.3846E-05	3.4757E-05	2.6960E-05	2.6960E-05
U -236	2.5433E-06	4.5073E-06	5.9546E-06	5.9546E-06
U -238	2.1154E-02	2.0911E-02	2.0656E-02	2.0656E-02
Pu-238	4.1611E-05	3.9325E-05	3.9568E-05	4.1548E-05
Pu-239	8.1399E-04	6.5607E-04	5.3433E-04	5.3615E-04
Pu-240	4.7332E-04	4.4906E-04	4.1367E-04	4.1760E-04
Pu-241	2.1779E-04	2.3621E-04	2.3678E-04	1.8601E-04
Pu-242	1.3422E-04	1.4202E-04	1.5327E-04	1.5328E-04
Np-237	1.7017E-06	3.2952E-06	4.6763E-06	5.1020E-06
Am-241	8.8276E-06	1.5719E-05	1.9549E-05	6.9954E-05
Am-242m	1.9164E-07	4.6059E-07	6.2035E-07	6.0530E-07
Am-243	1.7166E-05	2.9817E-05	3.9722E-05	3.9722E-05
Cm-242	8.7188E-07	2.3298E-06	3.5996E-06	3.0974E-09
Cm-243	1.1771E-08	5.8650E-08	1.2551E-07	1.1143E-07
Cm-244	3.5238E-06	1.1748E-05	2.2551E-05	1.8624E-05
Cm-245	1.7345E-07	1.0794E-06	2.7890E-06	2.7879E-06
Mo-95	1.7651E-05	3.4298E-05	4.9935E-05	4.9935E-05
Tc-99	2.1747E-05	4.1769E-05	5.9979E-05	6.0190E-05
Ru-101	2.2854E-05	4.4815E-05	6.5833E-05	6.5833E-05
Rh-103	2.0008E-05	3.9281E-05	5.4840E-05	5.8207E-05
Ag-109	5.2754E-06	9.5680E-06	1.3187E-05	1.3187E-05
Cs-133	2.3792E-05	4.5374E-05	6.4465E-05	6.4918E-05
Nd-143	1.5501E-05	3.0301E-05	4.3448E-05	4.4219E-05
Nd-145	1.1484E-05	2.2157E-05	3.2012E-05	3.2012E-05
Sm-147	8.0207E-07	2.4663E-06	4.1407E-06	1.0679E-05
Sm-149	4.1898E-07	3.9909E-07	3.6638E-07	4.1752E-07
Sm-150	4.9266E-06	1.0738E-05	1.6680E-05	1.6680E-05
Sm-151	1.3525E-06	1.5504E-06	1.5610E-06	1.5039E-06
Sm-152	2.8545E-06	5.0487E-06	6.3219E-06	6.3219E-06
Eu-153	2.2060E-06	5.2821E-06	8.2482E-06	8.2946E-06
Gd-155	1.2903E-08	2.1169E-08	3.1416E-08	6.1314E-07
k-infinity	1.05824	1.00469	0.95812	0.91803

Table B.5. Benchmark calculation results for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	5.8173E-07	8.4286E-07	1.0507E-06	2.7318E-06
U -235	4.3992E-05	3.5018E-05	2.7303E-05	2.7381E-05
U -236	2.4860E-06	4.4200E-06	5.8573E-06	6.0717E-06
U -238	2.1153E-02	2.0907E-02	2.0650E-02	2.0650E-02
Pu-238	4.1549E-05	3.9399E-05	3.9912E-05	4.2241E-05
Pu-239	8.1491E-04	6.5992E-04	5.4123E-04	5.4301E-04
Pu-240	4.6913E-04	4.4158E-04	4.0417E-04	4.0808E-04
Pu-241	2.2160E-04	2.4088E-04	2.4109E-04	1.8955E-04
Pu-242	1.3448E-04	1.4285E-04	1.5462E-04	1.5462E-04
Np-237	1.1228E-06	2.2164E-06	3.1907E-06	3.2333E-06
Am-241	8.7984E-06	1.5623E-05	1.9374E-05	7.0912E-05
Am-242m	1.2446E-07	2.9497E-07	3.9343E-07	3.9343E-07
Am-243	1.6877E-05	2.8845E-05	3.7972E-05	3.7972E-05
Cm-242	9.9445E-07	2.6283E-06	4.0126E-06	1.7052E-09
Cm-243	1.3679E-08	6.8280E-08	1.4628E-07	1.3033E-07
Cm-244	3.8188E-06	1.2504E-05	2.3645E-05	1.9527E-05
Cm-245	2.0087E-07	1.2114E-06	3.0878E-06	3.0878E-06
Mo-95	1.1829E-05	2.8736E-05	4.4695E-05	5.0655E-05
Tc-99	2.2134E-05	4.2443E-05	6.1017E-05	6.1017E-05
Ru-101	2.2908E-05	4.4898E-05	6.5934E-05	6.5934E-05
Rh-103	2.0023E-05	3.9084E-05	5.4311E-05	5.7737E-05
Ag-109	5.2623E-06	9.5146E-06	1.3070E-05	1.3070E-05
Cs-133	2.3848E-05	4.5327E-05	6.4206E-05	6.4666E-05
Nd-143	1.5569E-05	3.0421E-05	4.3607E-05	4.4395E-05
Nd-145	1.1478E-05	2.2091E-05	3.1827E-05	3.1827E-05
Sm-147	7.9856E-07	2.4333E-06	4.0493E-06	1.0540E-05
Sm-149	4.0123E-07	3.8730E-07	3.5838E-07	4.0998E-07
Sm-150	4.7747E-06	1.0189E-05	1.5476E-05	1.5476E-05
Sm-151	1.4206E-06	1.7470E-06	1.8715E-06	1.8119E-06
Sm-152	2.9340E-06	5.3464E-06	6.9602E-06	6.9602E-06
Eu-153	2.1872E-06	5.3129E-06	8.4448E-06	8.4944E-06
Gd-155	1.3180E-08	2.0696E-08	2.8532E-08	6.3896E-07
k-infinity	1.046356	0.99422	0.948532	0.902327

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.7674E-07	8.2417E-07	1.0104E-06	2.6517E-06
U-235	4.4033E-05	3.5022E-05	2.7246E-05	2.7321E-05
U-236	2.4587E-06	4.3851E-06	5.8225E-06	6.0374E-06
U-238	2.1163E-02	2.0926E-02	2.0678E-02	2.0678E-02
Pu-238	4.1411E-05	3.8924E-05	3.9037E-05	4.1208E-05
Pu-239	8.0586E-04	6.4392E-04	5.2014E-04	5.2189E-04
Pu-240	4.7096E-04	4.4348E-04	4.0523E-04	4.0915E-04
Pu-241	2.2213E-04	2.4263E-04	2.4322E-04	1.9099E-04
Pu-242	1.3386E-04	1.4194E-04	1.5361E-04	1.5362E-04
Np-237	1.1980E-06	2.4006E-06	3.4718E-06	3.8940E-06
Am-241	8.9233E-06	1.6103E-05	2.0219E-05	7.1556E-05
Am-242m	1.3865E-07	3.4202E-07	4.6768E-07	4.5714E-07
Am-243	1.7326E-05	2.9697E-05	3.9337E-05	3.9318E-05
Cm-242	8.9644E-07	2.4302E-06	3.7877E-06	2.7136E-09
Cm-243	1.1524E-08	5.9884E-08	1.3248E-07	1.1731E-07
Cm-244	3.7747E-06	1.2467E-05	2.3756E-05	1.9618E-05
Cm-245	1.9906E-07	1.2293E-06	3.2016E-06	3.2003E-06
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2252E-05	4.2776E-05	6.1703E-05	6.1702E-05
Ru-101	2.1885E-05	4.3018E-05	6.3341E-05	6.3341E-05
Rh-103	2.2625E-05	4.0850E-05	5.5201E-05	5.5201E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4632E-05	4.6720E-05	6.6431E-05	6.6431E-05
Nd-143	1.5558E-05	3.0453E-05	4.3697E-05	4.4492E-05
Nd-145	1.1439E-05	2.2181E-05	3.2186E-05	3.2186E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	3.9542E-07	3.7180E-07	3.3921E-07	3.8781E-07
Sm-150	4.7723E-06	1.0321E-05	1.5922E-05	1.5922E-05
Sm-151	1.4063E-06	1.6159E-06	1.6182E-06	1.5571E-06
Sm-152	2.9165E-06	5.2763E-06	6.7572E-06	6.7572E-06
Eu-153	2.1374E-06	5.1535E-06	8.0958E-06	8.0958E-06
Gd-155	5.8504E-09	1.0411E-08	1.7652E-08	3.2685E-07
k-infinity	1.05829	1.00398	0.95731	0.9194

Table B.5. Benchmark calculation results for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

JAERI (Suyama)
SWAT, JENDL-3.2, 107 Groups

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.7716E-07	8.2829E-07	1.0212E-06	2.6544E-06
U-235	4.3940E-05	3.4871E-05	2.7049E-05	2.7125E-05
U-236	2.4750E-06	4.3989E-06	5.8205E-06	6.0383E-06
U-238	2.1158E-02	2.0916E-02	2.0663E-02	2.0663E-02
Pu-238	4.1338E-05	3.8798E-05	3.8877E-05	4.1048E-05
Pu-239	8.0781E-04	6.4616E-04	5.2255E-04	5.2434E-04
Pu-240	4.7220E-04	4.4641E-04	4.0930E-04	4.1303E-04
Pu-241	2.2055E-04	2.3989E-04	2.4014E-04	1.8881E-04
Pu-242	1.3440E-04	1.4279E-04	1.5489E-04	1.5490E-04
Np-237	1.3796E-06	2.7310E-06	3.9438E-06	4.3721E-06
Am-241	8.9667E-06	1.6186E-05	2.0330E-05	7.1293E-05
Am-242m	1.2868E-07	3.1706E-07	4.3384E-07	4.2330E-07
Am-243	1.6982E-05	2.9401E-05	3.9098E-05	3.9098E-05
Cm-242	8.8698E-07	2.4103E-06	3.7718E-06	2.7359E-09
Cm-243	1.1362E-08	5.9208E-08	1.3153E-07	1.1648E-07
Cm-244	3.5708E-06	1.1848E-05	2.2690E-05	1.8742E-05
Cm-245	1.8392E-07	1.1369E-06	2.9373E-06	2.9361E-06
Mo-95	1.1845E-05	2.8802E-05	4.4862E-05	5.0817E-05
Tc-99	2.2857E-05	4.4183E-05	6.3758E-05	6.3995E-05
Ru-101	2.2025E-05	4.3296E-05	6.3734E-05	6.3735E-05
Rh-103	1.9935E-05	3.8958E-05	5.4075E-05	5.7421E-05
Ag-109	5.8559E-06	1.0448E-05	1.4129E-05	1.4146E-05
Cs-133	2.4246E-05	4.6481E-05	6.6275E-05	6.6828E-05
Nd-143	1.5570E-05	3.0540E-05	4.3803E-05	4.4677E-05
Nd-145	1.1460E-05	2.2206E-05	3.2183E-05	3.2193E-05
Sm-147	8.0963E-07	2.5150E-06	4.2564E-06	1.0881E-05
Sm-149	3.7922E-07	3.5398E-07	3.2095E-07	3.6854E-07
Sm-150	4.7168E-06	1.0099E-05	1.5511E-05	1.5511E-05
Sm-151	1.3942E-06	1.5991E-06	1.6021E-06	1.5539E-06
Sm-152	3.1161E-06	6.0181E-06	8.0933E-06	8.0942E-06
Eu-153	1.9376E-06	4.6131E-06	7.3474E-06	7.3910E-06
Gd-155	5.8090E-09	9.7642E-09	1.5839E-08	3.0670E-07
k-infinity	1.06295	1.01043	0.96399	0.92710

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1267E-07	1.7417E-07	1.4183E-07	1.4183E-07
U-235	4.3950E-05	3.4811E-05	2.6823E-05	2.6897E-05
U-236	2.4595E-06	4.3804E-06	5.8106E-06	6.0274E-06
U-238	2.1163E-02	2.0926E-02	2.0677E-02	2.0677E-02
Pu-238	4.0745E-05	3.5105E-05	2.9717E-05	2.8567E-05
Pu-239	8.0233E-04	6.3651E-04	5.0862E-04	5.1037E-04
Pu-240	4.7414E-04	4.4900E-04	4.1101E-04	4.1080E-04
Pu-241	2.1727E-04	2.3444E-04	2.3311E-04	1.8327E-04
Pu-242	1.3492E-04	1.4290E-04	1.5403E-04	1.5403E-04
Np-237	1.0228E-07	3.5575E-07	6.8203E-07	6.9531E-07
Am-241	8.7100E-06	1.5340E-05	1.8775E-05	6.8607E-05
Am-242m	1.4538E-07	3.3988E-07	4.4536E-07	4.4536E-07
Am-243	1.6268E-05	2.7992E-05	3.7050E-05	3.7050E-05
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.1798E-05	2.8648E-05	4.4574E-05	5.0519E-05
Tc-99	2.2077E-05	4.2326E-05	6.0899E-05	6.0899E-05
Ru-101	2.2835E-05	4.4730E-05	6.5722E-05	6.5722E-05
Rh-103	2.0022E-05	3.9101E-05	5.4354E-05	5.7768E-05
Ag-109	5.2504E-06	9.4713E-06	1.2966E-05	1.2966E-05
Cs-133	2.3797E-05	4.5228E-05	6.4116E-05	6.4574E-05
Nd-143	1.5517E-05	3.0266E-05	4.3291E-05	4.4077E-05
Nd-145	1.1448E-05	2.2027E-05	3.1745E-05	3.1745E-05
Sm-147	8.0216E-07	2.4547E-06	4.0912E-06	1.0602E-05
Sm-149	3.8487E-07	3.6286E-07	3.2940E-07	3.8115E-07
Sm-150	4.7637E-06	1.0157E-05	1.5435E-05	1.5435E-05
Sm-151	1.4025E-06	1.6903E-06	1.7732E-06	1.7146E-06
Sm-152	2.9517E-06	5.3471E-06	6.8483E-06	6.8483E-06
Eu-153	2.1714E-06	5.3311E-06	8.5688E-06	8.6193E-06
Gd-155	1.2697E-08	1.9065E-08	2.5256E-08	6.0942E-07
k-infinity	1.0561	1.0016	0.9517	0.9112

Table B.5. Benchmark calculation results for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 5 - First Recycle MOX, Pincell Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	5.7150E-07	8.1010E-07	9.9030E-07	2.6210E-06
U-235	4.3770E-05	3.4640E-05	2.6890E-05	2.6970E-05
U-236	2.6320E-06	4.6630E-06	6.1380E-06	6.3570E-06
U-238	2.1150E-02	2.0910E-02	2.0650E-02	2.0650E-02
Pu-238	4.1340E-05	3.8870E-05	3.8910E-05	4.0910E-05
Pu-239	8.1010E-04	6.5570E-04	5.3350E-04	5.3530E-04
Pu-240	4.7380E-04	4.4700E-04	4.1190E-04	4.1620E-04
Pu-241	2.1860E-04	2.3740E-04	2.3640E-04	1.8560E-04
Pu-242	1.3460E-04	1.4290E-04	1.5530E-04	1.5530E-04
Np-237	No Data	No Data	No Data	No Data
Am-241	8.8020E-06	1.5660E-05	1.9540E-05	6.9890E-05
Am-242m	1.7750E-07	4.0500E-07	5.3490E-07	5.2190E-07
Am-243	1.8450E-05	3.1880E-05	4.2050E-05	4.2050E-05
Cm-242	8.9190E-07	2.3600E-06	3.5980E-06	2.8920E-09
Cm-243	1.4770E-08	7.2810E-08	1.5120E-07	1.3380E-07
Cm-244	4.0210E-06	1.3550E-05	2.5540E-05	2.1110E-05
Cm-245	1.8310E-07	1.0360E-06	2.3510E-06	2.3500E-06
Mo-95	1.1740E-05	2.8430E-05	4.4160E-05	4.9980E-05
Tc-99	2.1860E-05	4.1950E-05	6.0300E-05	6.0530E-05
Ru-101	2.1740E-05	4.2510E-05	6.2310E-05	6.2310E-05
Rh-103	1.9720E-05	3.8230E-05	5.2990E-05	5.6250E-05
Ag-109	5.7700E-06	1.0080E-05	1.3380E-05	1.3390E-05
Cs-133	2.3980E-05	4.5760E-05	6.5190E-05	6.5710E-05
Nd-143	1.5430E-05	3.0130E-05	4.3110E-05	4.3930E-05
Nd-145	1.1310E-05	2.1760E-05	3.1350E-05	3.1360E-05
Sm-147	7.9160E-07	2.3970E-06	4.0040E-06	1.0280E-05
Sm-149	4.3300E-07	4.2920E-07	3.9210E-07	4.5110E-07
Sm-150	5.1230E-06	1.1450E-05	1.7790E-05	1.7790E-05
Sm-151	1.5340E-06	1.9250E-06	2.0520E-06	1.9870E-06
Sm-152	2.7870E-06	5.0920E-06	6.7310E-06	6.7320E-06
Eu-153	2.1330E-06	5.1610E-06	8.1540E-06	8.2020E-06
Gd-155	4.4830E-09	8.2730E-09	1.4350E-08	2.3940E-07
k-infinity	1.0608	1.0104	0.9654	0.9281

Table B.5. Benchmark calculation results for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

	Mean			
Nuclide	**End of Cycle 1**	**End of Cycle 2**	**End of Cycle 3**	**5 Years Cooling**
U-234	5.3603E-07	7.5323E-07	9.1918E-07	2.3853E-06
U-235	4.3896E-05	3.4810E-05	2.6992E-05	2.7051E-05
U-236	2.5160E-06	4.4666E-06	5.9033E-06	6.0733E-06
U-238	2.1157E-02	2.0917E-02	2.0665E-02	2.0665E-02
Pu-238	4.1350E-05	3.8610E-05	3.8201E-05	4.0004E-05
Pu-239	8.0727E-04	6.4632E-04	5.2273E-04	5.2452E-04
Pu-240	4.7367E-04	4.4838E-04	4.1171E-04	4.1513E-04
Pu-241	2.1899E-04	2.3747E-04	2.3719E-04	1.8648E-04
Pu-242	1.3465E-04	1.4307E-04	1.5504E-04	1.5504E-04
Np-237	1.1947E-06	2.3686E-06	3.4228E-06	3.6897E-06
Am-241	8.7782E-06	1.5587E-05	1.9312E-05	6.9679E-05
Am-242m	1.5075E-07	3.5893E-07	4.7945E-07	4.7035E-07
Am-243	1.7080E-05	2.9549E-05	3.9242E-05	3.9240E-05
Cm-242	9.2628E-07	2.4708E-06	3.7988E-06	2.9923E-09
Cm-243	1.2652E-08	6.3720E-08	1.3696E-07	1.2159E-07
Cm-244	3.6102E-06	1.2059E-05	2.3090E-05	1.9072E-05
Cm-245	1.7809E-07	1.0897E-06	2.7890E-06	2.7882E-06
Mo-95	1.2644E-05	2.9476E-05	4.5361E-05	5.0445E-05
Tc-99	2.2239E-05	4.2763E-05	6.1549E-05	6.1692E-05
Ru-101	2.2423E-05	4.3958E-05	6.4574E-05	6.4575E-05
Rh-103	2.0161E-05	3.8685E-05	5.3441E-05	5.6063E-05
Ag-109	5.4067E-06	9.6603E-06	1.3085E-05	1.3093E-05
Cs-133	2.3974E-05	4.5614E-05	6.4728E-05	6.5121E-05
Nd-143	1.5652E-05	3.0542E-05	4.3747E-05	4.4478E-05
Nd-145	1.1418E-05	2.1996E-05	3.1712E-05	3.1717E-05
Sm-147	8.0444E-07	2.4556E-06	4.1082E-06	1.0493E-05
Sm-149	4.0710E-07	3.8939E-07	3.5551E-07	4.0813E-07
Sm-150	4.8565E-06	1.0483E-05	1.6049E-05	1.6049E-05
Sm-151	1.4360E-06	1.7294E-06	1.8089E-06	1.7473E-06
Sm-152	2.9434E-06	5.3963E-06	7.0164E-06	7.0169E-06
Eu-153	2.1397E-06	5.1942E-06	8.2626E-06	8.3002E-06
Gd-155	1.0664E-08	1.7942E-08	2.6970E-08	5.6858E-07

	Two Times Relative Standard Deviation (%)			
Nuclide	**End of Cycle 1**	**End of Cycle 2**	**End of Cycle 3**	**5 Years Cooling**
U-234	45.26	57.71	63.53	70.59
U-235	0.42	0.87	1.44	1.52
U-236	4.56	4.15	3.64	4.89
U-238	0.04	0.07	0.10	0.10
Pu-238	1.41	7.00	16.80	21.55
Pu-239	1.34	2.89	4.41	4.40
Pu-240	1.55	2.62	3.34	3.44
Pu-241	1.92	2.70	3.08	2.94
Pu-242	1.74	3.44	5.02	5.02
Np-237	80.17	74.27	69.97	71.44
Am-241	3.61	5.64	7.46	4.49
Am-242m	32.39	31.50	31.81	30.89
Am-243	8.91	7.95	7.26	7.26
Cm-242	10.00	9.23	9.01	64.54
Cm-243	18.78	15.83	12.71	12.87
Cm-244	22.05	20.00	17.46	17.49
Cm-245	27.25	24.59	25.32	25.31
Mo-95	34.93	14.45	8.95	1.42
Tc-99	4.27	4.60	4.76	4.86
Ru-101	4.80	4.77	4.80	4.80
Rh-103	9.59	8.12	8.59	11.78
Ag-109	15.76	16.22	17.99	18.07
Cs-133	2.79	3.03	3.45	3.58
Nd-143	4.59	3.29	3.10	1.99
Nd-145	1.85	2.62	3.55	3.55
Sm-147	2.55	2.73	3.62	5.46
Sm-149	10.74	13.16	12.99	12.81
Sm-150	5.63	8.59	10.08	10.08
Sm-151	8.84	15.11	20.20	20.22
Sm-152	8.39	13.61	17.56	17.57
Eu-153	8.98	9.80	9.65	9.58
Gd-155	79.74	77.89	71.87	85.83

Table B.6. Benchmark calculation results for Case 6

Pin cell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

NUPEC (Sakurai) - CASLIB
CASLIB - E4LBL70 (L-libraray), based on ENDF/B-IV

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2492E-07	1.9005E-07	1.7617E-07	4.1247E-07
U -235	4.1989E-05	2.8987E-05	1.8278E-05	1.8278E-05
U -236	3.1260E-06	5.4716E-06	6.9587E-06	6.9587E-06
U -238	2.2046E-02	2.1781E-02	2.1491E-02	2.1491E-02
Pu-238	6.9659E-07	2.0619E-06	4.8226E-06	6.3862E-06
Pu-239	5.6732E-04	3.6748E-04	2.4971E-04	2.5188E-04
Pu-240	1.4812E-04	1.8219E-04	1.7565E-04	1.7640E-04
Pu-241	5.8961E-05	9.6096E-05	1.0419E-04	8.1768E-05
Pu-242	5.5993E-06	2.0466E-05	4.1569E-05	4.1570E-05
Np-237	1.4893E-06	2.8823E-06	4.0447E-06	4.0447E-06
Am-241	1.3658E-06	3.7679E-06	5.0551E-06	2.7347E-05
Am-242m	1.8425E-08	6.4470E-08	8.9284E-08	8.7265E-08
Am-243	6.7804E-07	4.0632E-06	1.0656E-05	1.0656E-05
Cm-242	1.7631E-07	9.0049E-07	1.8125E-06	1.4845E-09
Cm-243	1.9052E-09	1.8903E-08	5.4912E-08	4.8912E-08
Cm-244	9.3405E-08	1.0295E-06	4.2714E-06	3.5273E-06
Cm-245	3.4410E-09	6.1184E-08	3.2868E-07	3.2868E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	No Data	No Data	No Data	No Data
Ru-101	No Data	No Data	No Data	No Data
Rh-103	1.7890E-05	3.1049E-05	3.9850E-05	3.9850E-05
Ag-109	3.6780E-06	6.5225E-06	8.5543E-06	8.5543E-06
Cs-133	2.3438E-05	4.3917E-05	6.1235E-05	6.1235E-05
Nd-143	1.6353E-05	3.0236E-05	4.0850E-05	4.0850E-05
Nd-145	1.1117E-05	2.1050E-05	2.9650E-05	2.9650E-05
Sm-147	7.8713E-07	2.2802E-06	3.6547E-06	8.7839E-06
Sm-149	2.2690E-07	1.9511E-07	1.6003E-07	2.2015E-07
Sm-150	5.1371E-06	1.1001E-05	1.6592E-05	1.6592E-05
Sm-151	9.8717E-07	1.0213E-06	1.0016E-06	9.5904E-07
Sm-152	2.9745E-06	4.9459E-06	6.0038E-06	6.0038E-06
Eu-153	2.2652E-06	5.5243E-06	8.3438E-06	8.3438E-06
Gd-155	7.7676E-09	1.1987E-08	1.5904E-08	9.2647E-07
k-infinity	1.09068	0.99041	0.90879	0.87288

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

CEA (Thiollay)
APOLLO2/PEPIN2 - CEA-93 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2275E-07	1.8700E-07	1.7182E-07	4.0303E-07
U -235	4.1872E-05	2.8961E-05	1.8473E-05	1.8511E-05
U -236	3.0966E-06	5.4237E-06	6.9283E-06	7.0249E-06
U -238	2.2039E-02	2.1769E-02	2.1475E-02	2.1475E-02
Pu-238	6.3841E-07	1.8739E-06	4.4576E-06	5.9577E-06
Pu-239	5.6892E-04	3.7343E-04	2.5861E-04	2.6077E-04
Pu-240	1.4994E-04	1.8591E-04	1.8259E-04	1.8331E-04
Pu-241	5.8744E-05	9.5277E-05	1.0413E-04	8.1868E-05
Pu-242	5.6718E-06	2.0381E-05	4.0636E-05	4.0638E-05
Np-237	1.2022E-06	2.3835E-06	3.3924E-06	3.5785E-06
Am-241	1.3444E-06	3.6928E-06	5.0215E-06	2.7149E-05
Am-242m	1.8973E-08	6.4946E-08	9.0567E-08	8.8369E-08
Am-243	6.7149E-07	3.8849E-06	1.0031E-05	1.0035E-05
Cm-242	1.7358E-07	8.6605E-07	1.7117E-06	9.6197E-10
Cm-243	1.9348E-09	1.9058E-08	5.5161E-08	4.9147E-08
Cm-244	1.1197E-07	1.1882E-06	4.7019E-06	3.8838E-06
Cm-245	4.4235E-09	7.8332E-08	4.0863E-07	4.0846E-07
Mo-95	1.2240E-05	2.9530E-05	4.5484E-05	5.1535E-05
Tc-99	2.2144E-05	4.2327E-05	6.0263E-05	6.0498E-05
Ru-101	2.3060E-05	4.5060E-05	6.5915E-05	6.5917E-05
Rh-103	1.9001E-05	3.5205E-05	4.6093E-05	4.9492E-05
Ag-109	4.5097E-06	8.1395E-06	1.1097E-05	1.1113E-05
Cs-133	2.3912E-05	4.5022E-05	6.2837E-05	6.3383E-05
Nd-143	1.5276E-05	2.8780E-05	3.9024E-05	3.9897E-05
Nd-145	1.1456E-05	2.1887E-05	3.1179E-05	3.1189E-05
Sm-147	7.7098E-07	2.2681E-06	3.6030E-06	9.4211E-06
Sm-149	2.0901E-07	1.8496E-07	1.5778E-07	2.1825E-07
Sm-150	5.0204E-06	1.0729E-05	1.6256E-05	1.6256E-05
Sm-151	9.2298E-07	9.6215E-07	9.6574E-07	9.4082E-07
Sm-152	3.1071E-06	5.2319E-06	6.4269E-06	6.4277E-06
Eu-153	2.2596E-06	5.5757E-06	8.6544E-06	8.7125E-06
Gd-155	4.5932E-09	7.1188E-09	1.0295E-08	4.5104E-07
k-infinity	1.08089	0.98056	0.89916	0.87082

Table B.6. Benchmark calculation results for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

GRS (Gmal)
KENOREST-2001 - KORLIB-V4 based on JEF2.2 evaluations

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2160E-07	1.8460E-07	1.6930E-07	4.1870E-07
U -235	4.1810E-05	2.8810E-05	1.8320E-05	1.8360E-05
U -236	3.1200E-06	5.4320E-06	6.8640E-06	6.9560E-06
U -238	2.2050E-02	2.1780E-02	2.1480E-02	2.1480E-02
Pu-238	6.5350E-07	1.9650E-06	4.6800E-06	6.1960E-06
Pu-239	5.5970E-04	3.6620E-04	2.5830E-04	2.6050E-04
Pu-240	1.4820E-04	1.8020E-04	1.7370E-04	1.7440E-04
Pu-241	6.3710E-05	1.0090E-04	1.0840E-04	8.5620E-05
Pu-242	6.1210E-06	2.1940E-05	4.3250E-05	4.3250E-05
Np-237	1.2920E-06	2.5940E-06	3.7070E-06	3.9010E-06
Am-241	1.4340E-06	3.8800E-06	5.1900E-06	2.7800E-05
Am-242m	2.5700E-08	9.0640E-08	1.2650E-07	1.2370E-07
Am-243	6.9090E-07	4.0790E-06	1.0500E-05	1.0510E-05
Cm-242	1.7900E-07	8.9310E-07	1.7350E-06	1.0380E-09
Cm-243	1.9160E-09	1.9240E-08	5.5550E-08	4.9200E-08
Cm-244	1.0450E-07	1.1570E-06	4.6700E-06	3.8580E-06
Cm-245	3.3140E-09	6.2060E-08	3.3570E-07	3.3560E-07
Mo-95	1.2190E-05	2.9310E-05	4.5050E-05	5.1010E-05
Tc-99	2.2960E-05	4.3790E-05	6.2210E-05	6.2450E-05
Ru-101	2.2030E-05	4.2980E-05	6.2750E-05	6.2750E-05
Rh-103	1.9540E-05	3.5860E-05	4.6600E-05	4.9940E-05
Ag-109	5.5940E-06	9.7470E-06	1.2920E-05	1.2930E-05
Cs-133	2.4160E-05	4.5150E-05	6.2560E-05	6.3100E-05
Nd-143	1.5220E-05	2.8720E-05	3.9060E-05	3.9930E-05
Nd-145	1.1260E-05	2.1530E-05	3.0690E-05	3.0700E-05
Sm-147	7.6710E-07	2.2550E-06	3.5830E-06	9.1880E-06
Sm-149	2.1020E-07	1.8730E-07	1.6160E-07	2.2190E-07
Sm-150	4.9640E-06	1.0560E-05	1.5880E-05	1.5880E-05
Sm-151	9.3350E-07	9.9170E-07	1.0150E-06	9.8920E-07
Sm-152	3.3440E-06	5.9060E-06	7.4850E-06	7.4850E-06
Eu-153	2.0570E-06	5.1670E-06	8.2250E-06	8.2820E-06
Gd-155	4.9030E-09	9.1660E-09	1.3590E-08	6.5950E-07
k-infinity	1.07057	0.96996	0.89012	0.85692

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

PSI (Grimm)
BOXER/ETOBOX - JEF-1/JEF-2

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2260E-07	1.8754E-07	1.7399E-07	4.1485E-07
U -235	4.2013E-05	2.9191E-05	1.8752E-05	1.8752E-05
U -236	3.1463E-06	5.5072E-06	7.0291E-06	7.0291E-06
U -238	2.2038E-02	2.1765E-02	2.1467E-02	2.1467E-02
Pu-238	7.2527E-07	2.0838E-06	4.8067E-06	6.1788E-06
Pu-239	5.7981E-04	3.8829E-04	2.7378E-04	2.7594E-04
Pu-240	1.4792E-04	1.8476E-04	1.8322E-04	1.8395E-04
Pu-241	5.7546E-05	9.5358E-05	1.0642E-04	8.3603E-05
Pu-242	5.3826E-06	1.9557E-05	3.9631E-05	3.9633E-05
Np-237	1.6938E-06	3.2645E-06	4.5453E-06	4.7485E-06
Am-241	1.3316E-06	3.7493E-06	5.2376E-06	2.7921E-05
Am-242m	2.5882E-08	9.2764E-08	1.3466E-07	1.3139E-07
Am-243	6.2852E-07	3.6669E-06	9.5721E-06	9.5766E-06
Cm-242	1.5362E-07	7.8303E-07	1.5904E-06	1.0140E-09
Cm-243	1.6848E-09	1.6585E-08	4.8291E-08	4.2872E-08
Cm-244	9.8738E-08	1.0411E-06	4.1598E-06	3.4354E-06
Cm-245	3.8026E-09	6.9096E-08	3.7125E-07	3.7110E-07
Mo-95	1.8204E-05	3.5100E-05	5.0594E-05	5.0594E-05
Tc-99	2.1909E-05	4.1694E-05	5.9150E-05	5.9361E-05
Ru-101	2.2890E-05	4.4765E-05	6.5504E-05	6.5504E-05
Rh-103	1.8776E-05	3.4904E-05	4.5884E-05	4.9175E-05
Ag-109	4.5541E-06	8.2345E-06	1.1276E-05	1.1276E-05
Cs-133	2.3817E-05	4.4918E-05	6.2865E-05	6.3312E-05
Nd-143	1.5241E-05	2.8729E-05	3.9107E-05	3.9869E-05
Nd-145	1.1412E-05	2.1830E-05	3.1169E-05	3.1169E-05
Sm-147	7.7166E-07	2.2874E-06	3.6614E-06	9.5113E-06
Sm-149	2.2509E-07	1.9656E-07	1.6747E-07	2.2382E-07
Sm-150	5.1385E-06	1.1188E-05	1.7357E-05	1.7357E-05
Sm-151	8.9053E-07	8.6180E-07	8.2491E-07	7.9473E-07
Sm-152	2.9745E-06	4.8501E-06	5.7378E-06	5.7378E-06
Eu-153	2.2645E-06	5.4188E-06	8.1493E-06	8.2008E-06
Gd-155	5.2990E-09	8.0615E-09	1.1333E-08	4.4447E-07
k-infinity	1.08547	0.98849	0.91182	0.88549

Table B.6. Benchmark calculation results for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

BNFL (O'Connor, Bowden, Thorne)
WIMS8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U -234	2.2667E-07	1.9319E-07	1.7972E-07	4.1533E-07
U -235	4.2091E-05	2.9305E-05	1.8909E-05	1.8949E-05
U -236	3.0441E-06	5.3527E-06	6.8548E-06	6.9496E-06
U -238	2.2039E-02	2.1764E-02	2.1462E-02	2.1462E-02
Pu-238	6.3169E-07	1.8722E-06	4.5168E-06	6.0764E-06
Pu-239	5.7554E-04	3.8586E-04	2.7522E-04	2.7743E-04
Pu-240	1.4753E-04	1.8234E-04	1.7935E-04	1.8005E-04
Pu-241	6.0148E-05	9.8292E-05	1.0865E-04	8.5426E-05
Pu-242	5.6373E-06	2.0330E-05	4.0779E-05	4.0779E-05
Np-237	1.1014E-06	2.2032E-06	3.1460E-06	3.1956E-06
Am-241	1.3793E-06	3.8253E-06	5.2863E-06	2.8513E-05
Am-242m	1.7007E-08	5.9282E-08	8.4632E-08	8.4632E-08
Am-243	6.6223E-07	3.7965E-06	9.6492E-06	9.6492E-06
Cm-242	1.8077E-07	9.0383E-07	1.7960E-06	7.6323E-10
Cm-243	2.0181E-09	1.9983E-08	5.8331E-08	5.1971E-08
Cm-244	1.1172E-07	1.1784E-06	4.6121E-06	3.8089E-06
Cm-245	4.4295E-09	7.8257E-08	4.0880E-07	4.0880E-07
Mo-95	1.2218E-05	2.9463E-05	4.5358E-05	5.1393E-05
Tc-99	2.2323E-05	4.2429E-05	6.0285E-05	6.0285E-05
Ru-101	2.2917E-05	4.4793E-05	6.5527E-05	6.5527E-05
Rh-103	1.8938E-05	3.5019E-05	4.5843E-05	4.9231E-05
Ag-109	4.5284E-06	8.1589E-06	1.1126E-05	1.1126E-05
Cs-133	2.3890E-05	4.4884E-05	6.2584E-05	6.3044E-05
Nd-143	1.5324E-05	2.8846E-05	3.9231E-05	4.0021E-05
Nd-145	1.1408E-05	2.1779E-05	3.1015E-05	3.1015E-05
Sm-147	7.6789E-07	2.2548E-06	3.5738E-06	9.3754E-06
Sm-149	2.0734E-07	1.8430E-07	1.5978E-07	2.1708E-07
Sm-150	4.9543E-06	1.0541E-05	1.5942E-05	1.5942E-05
Sm-151	9.2938E-07	9.7205E-07	9.8562E-07	9.5981E-07
Sm-152	3.0739E-06	5.1618E-06	6.3095E-06	6.3095E-06
Eu-153	2.2405E-06	5.5188E-06	8.5376E-06	8.5950E-06
Gd-155	4.6479E-09	6.5994E-09	8.4943E-09	4.6371E-07
k-infinity	1.071937	0.975801	0.900202	0.870159

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

JAERI (Suyama)
MVP-BURN, JENDL-3.2, Continuous Energy

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2420E-07	1.8820E-07	1.7181E-07	4.0000E-07
U-235	4.2224E-05	2.9414E-05	1.8869E-05	1.8907E-05
U-236	2.9931E-06	5.2872E-06	6.7963E-06	6.8890E-06
U-238	2.2050E-02	2.1784E-02	2.1490E-02	2.1490E-02
Pu-238	6.2931E-07	1.8237E-06	4.3852E-06	5.8802E-06
Pu-239	5.7038E-04	3.7564E-04	2.6205E-04	2.6422E-04
Pu-240	1.4482E-04	1.7940E-04	1.7532E-04	1.7604E-04
Pu-241	6.0952E-05	9.8666E-05	1.0838E-04	8.5104E-05
Pu-242	5.6926E-06	2.0544E-05	4.1349E-05	4.1351E-05
Np-237	1.1487E-06	2.3024E-06	3.3328E-06	3.5247E-06
Am-241	1.4206E-06	3.9609E-06	5.4876E-06	2.8391E-05
Am-242m	1.9721E-08	7.1245E-08	1.0300E-07	1.0068E-07
Am-243	6.7604E-07	3.8969E-06	1.0018E-05	1.0014E-05
Cm-242	1.6585E-07	8.4733E-07	1.7132E-06	9.7077E-10
Cm-243	1.7173E-09	1.7547E-08	5.2149E-08	4.6178E-08
Cm-244	1.1125E-07	1.1852E-06	4.6620E-06	3.8500E-06
Cm-245	4.4795E-09	8.5529E-08	4.6395E-07	4.6376E-07
Mo-95	No Data	No Data	No Data	No Data
Tc-99	2.2133E-05	4.2272E-05	6.0331E-05	6.0330E-05
Ru-101	2.1778E-05	4.2738E-05	6.2743E-05	6.2743E-05
Rh-103	2.1753E-05	3.7028E-05	4.6816E-05	4.6816E-05
Ag-109	No Data	No Data	No Data	No Data
Cs-133	2.4622E-05	4.6206E-05	6.4721E-05	6.4721E-05
Nd-143	1.5119E-05	2.8567E-05	3.8912E-05	3.9704E-05
Nd-145	1.1211E-05	2.1607E-05	3.1044E-05	3.1044E-05
Sm-147	No Data	No Data	No Data	No Data
Sm-149	2.0479E-07	1.7635E-07	1.4911E-07	2.0236E-07
Sm-150	4.8983E-06	1.0556E-05	1.6245E-05	1.6245E-05
Sm-151	9.0581E-07	8.7395E-07	8.2915E-07	7.9785E-07
Sm-152	3.0654E-06	5.1229E-06	6.1310E-06	6.1310E-06
Eu-153	2.1454E-06	5.2174E-06	7.9604E-06	7.9604E-06
Gd-155	2.4175E-09	4.7969E-09	7.4505E-09	3.1896E-07
k-infinity	1.09004	0.98782	0.9045	0.88175

Table B.6. Benchmark calculation results for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

JAERI (Suyama)
SWAT, JENDL-3.2, 107 Groups

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2530E-07	1.9097E-07	1.7658E-07	4.0913E-07
U-235	4.2129E-05	2.9251E-05	1.8697E-05	1.8735E-05
U-236	3.0111E-06	5.2997E-06	6.7815E-06	6.8766E-06
U-238	2.2044E-02	2.1773E-02	2.1474E-02	2.1474E-02
Pu-238	6.4457E-07	1.8785E-06	4.4986E-06	5.9938E-06
Pu-239	5.7198E-04	3.7741E-04	2.6341E-04	2.6562E-04
Pu-240	1.4622E-04	1.8177E-04	1.7902E-04	1.7970E-04
Pu-241	6.0082E-05	9.7610E-05	1.0722E-04	8.4301E-05
Pu-242	5.6673E-06	2.0512E-05	4.1423E-05	4.1425E-05
Np-237	1.3223E-06	2.6474E-06	3.7967E-06	3.9956E-06
Am-241	1.4106E-06	3.9552E-06	5.4934E-06	2.8277E-05
Am-242m	1.8176E-08	6.6055E-08	9.6030E-08	9.3699E-08
Am-243	6.5049E-07	3.7968E-06	9.8408E-06	9.8457E-06
Cm-242	1.6289E-07	8.3809E-07	1.7070E-06	9.8278E-10
Cm-243	1.6877E-09	1.7364E-08	5.2143E-08	4.6176E-08
Cm-244	1.0433E-07	1.1143E-06	4.4408E-06	3.6685E-06
Cm-245	4.1681E-09	7.7330E-08	4.1969E-07	4.1952E-07
Mo-95	1.2179E-05	2.9440E-05	4.5466E-05	5.1515E-05
Tc-99	2.2752E-05	4.3726E-05	6.2558E-05	6.2797E-05
Ru-101	2.1961E-05	4.3149E-05	6.3437E-05	6.3439E-05
Rh-103	1.9310E-05	3.5692E-05	4.6508E-05	4.9881E-05
Ag-109	5.5276E-06	9.6408E-06	1.2721E-05	1.2738E-05
Cs-133	2.4248E-05	4.6049E-05	6.4788E-05	6.5345E-05
Nd-143	1.5161E-05	2.8736E-05	3.9178E-05	4.0057E-05
Nd-145	1.1266E-05	2.1741E-05	3.1276E-05	3.1286E-05
Sm-147	7.7596E-07	2.3306E-06	3.7692E-06	9.7095E-06
Sm-149	1.9523E-07	1.6685E-07	1.4132E-07	1.9301E-07
Sm-150	4.8089E-06	1.0237E-05	1.5675E-05	1.5675E-05
Sm-151	9.0438E-07	8.7531E-07	8.3329E-07	8.1417E-07
Sm-152	3.2887E-06	5.9195E-06	7.5315E-06	7.5318E-06
Eu-153	1.9306E-06	4.6848E-06	7.3069E-06	7.3574E-06
Gd-155	2.4003E-09	4.4380E-09	6.7361E-09	2.9651E-07
k-infinity	1.09248	0.99281	0.91364	0.89002

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

DTLR (O'Connor)
MONK8A - 172-group WIMS '1997' JEF2.2 Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1711E-07	1.7161E-07	1.3235E-07	1.3235E-07
U-235	4.2111E-05	2.9230E-05	1.8662E-05	1.8700E-05
U-236	2.9988E-06	5.2884E-06	6.7949E-06	6.8895E-06
U-238	2.2050E-02	2.1784E-02	2.1491E-02	2.1491E-02
Pu-238	3.7975E-07	2.9932E-07	2.2302E-07	2.1438E-07
Pu-239	5.7205E-04	3.7762E-04	2.6342E-04	2.6558E-04
Pu-240	1.4632E-04	1.8183E-04	1.7928E-04	1.7919E-04
Pu-241	5.8757E-05	9.5594E-05	1.0479E-04	8.2385E-05
Pu-242	5.3839E-06	1.9411E-05	3.9131E-05	3.9131E-05
Np-237	1.3066E-07	4.5480E-07	8.4399E-07	8.6100E-07
Am-241	1.3545E-06	3.7387E-06	5.1107E-06	2.7511E-05
Am-242m	1.9737E-08	6.8280E-08	9.5982E-08	9.5982E-08
Am-243	6.2576E-07	3.5798E-06	9.2075E-06	9.2075E-06
Cm-242	No Data	No Data	No Data	No Data
Cm-243	No Data	No Data	No Data	No Data
Cm-244	No Data	No Data	No Data	No Data
Cm-245	No Data	No Data	No Data	No Data
Mo-95	1.2126E-05	2.9274E-05	4.5094E-05	5.1093E-05
Tc-99	2.2164E-05	4.2203E-05	6.0009E-05	6.0009E-05
Ru-101	2.2741E-05	4.4492E-05	6.5117E-05	6.5117E-05
Rh-103	1.8830E-05	3.4912E-05	4.5714E-05	4.9078E-05
Ag-109	4.4955E-06	8.1116E-06	1.1036E-05	1.1036E-05
Cs-133	2.3729E-05	4.4683E-05	6.2347E-05	6.2805E-05
Nd-143	1.5208E-05	2.8619E-05	3.8798E-05	3.9583E-05
Nd-145	1.1328E-05	2.1656E-05	3.0859E-05	3.0859E-05
Sm-147	7.6678E-07	2.2671E-06	3.6066E-06	9.4187E-06
Sm-149	2.0252E-07	1.7762E-07	1.5159E-07	2.0878E-07
Sm-150	4.9090E-06	1.0450E-05	1.5830E-05	1.5830E-05
Sm-151	9.1677E-07	9.4220E-07	9.4122E-07	9.1440E-07
Sm-152	3.0673E-06	5.1823E-06	6.2773E-06	6.2773E-06
Eu-153	2.2115E-06	5.4599E-06	8.5189E-06	8.5758E-06
Gd-155	4.5368E-09	6.2082E-09	7.7799E-09	4.4372E-07
k-infinity	1.0843	0.9847	0.9044	0.8765

Table B.6. Benchmark calculation results for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel

OECD/NEANSC Burnup Credit Benchmark, Phase IV-B (MOX)

Case 6 - Weapons Disposition MOX, Pincell Model

ORNL (DeHart, Sanders)
SAS2D - 238-group ENDF/VI based Nuclear Data Library

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.1960E-07	1.8440E-07	1.7080E-07	4.1960E-07
U-235	4.1730E-05	2.9220E-05	1.8870E-05	1.8910E-05
U-236	3.2070E-06	5.5340E-06	7.0580E-06	7.1480E-06
U-238	2.2040E-02	2.1760E-02	2.1470E-02	2.1470E-02
Pu-238	6.8740E-07	2.1200E-06	4.8960E-06	6.4020E-06
Pu-239	5.8390E-04	3.9360E-04	2.7690E-04	2.7920E-04
Pu-240	1.2110E-04	1.6430E-04	1.7050E-04	1.7140E-04
Pu-241	7.8540E-05	1.0040E-04	1.0460E-04	8.2140E-05
Pu-242	7.2920E-06	2.3750E-05	4.3870E-05	4.3880E-05
Np-237	No Data	No Data	No Data	No Data
Am-241	1.7130E-06	4.4050E-06	5.5970E-06	2.7900E-05
Am-242m	3.3950E-08	1.1260E-07	1.4530E-07	1.4180E-07
Am-243	1.0070E-06	5.2190E-06	1.2190E-05	1.2190E-05
Cm-242	2.0010E-07	9.4650E-07	1.7220E-06	1.1030E-09
Cm-243	2.6880E-09	2.4890E-08	6.5360E-08	5.7880E-08
Cm-244	1.7060E-07	1.6390E-06	5.9420E-06	4.9160E-06
Cm-245	5.7480E-09	9.1670E-08	4.1350E-07	4.1330E-07
Mo-95	1.2250E-05	2.9460E-05	4.5340E-05	5.1290E-05
Tc-99	2.1990E-05	4.2120E-05	5.9940E-05	6.0170E-05
Ru-101	2.1990E-05	4.3010E-05	6.2900E-05	6.2910E-05
Rh-103	1.8990E-05	3.5240E-05	4.5930E-05	4.9230E-05
Ag-109	5.5650E-06	9.7020E-06	1.2640E-05	1.2660E-05
Cs-133	2.4230E-05	4.6050E-05	6.4700E-05	6.5220E-05
Nd-143	1.5230E-05	2.8820E-05	3.9210E-05	4.0040E-05
Nd-145	1.1260E-05	2.1590E-05	3.0790E-05	3.0800E-05
Sm-147	7.5980E-07	2.2550E-06	3.6070E-06	9.3280E-06
Sm-149	2.2800E-07	2.0190E-07	1.6920E-07	2.3230E-07
Sm-150	5.3530E-06	1.1700E-05	1.8050E-05	1.8050E-05
Sm-151	1.0310E-06	1.1290E-06	1.1150E-06	1.0850E-06
Sm-152	2.9460E-06	5.1270E-06	6.3660E-06	6.3670E-06
Eu-153	2.2420E-06	5.3710E-06	8.3090E-06	8.3650E-06
Gd-155	1.8270E-09	3.9780E-09	6.4270E-09	2.3290E-07
k-infinity	1.0963	1.0014	0.9254	0.9048

Table B.6. Benchmark calculation results for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel

Mean

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.2275E-07	1.8639E-07	1.6917E-07	3.8061E-07
U-235	4.1997E-05	2.9152E-05	1.8648E-05	1.8678E-05
U-236	3.0826E-06	5.3996E-06	6.8962E-06	6.9690E-06
U-238	2.2044E-02	2.1773E-02	2.1478E-02	2.1478E-02
Pu-238	6.3183E-07	1.7754E-06	4.1429E-06	5.4762E-06
Pu-239	5.7218E-04	3.7839E-04	2.6460E-04	2.6679E-04
Pu-240	1.4446E-04	1.8030E-04	1.7763E-04	1.7827E-04
Pu-241	6.1938E-05	9.7577E-05	1.0631E-04	8.3579E-05
Pu-242	5.8275E-06	2.0766E-05	4.1293E-05	4.1295E-05
Np-237	1.1725E-06	2.3415E-06	3.3511E-06	3.4812E-06
Am-241	1.4171E-06	3.8861E-06	5.2755E-06	2.7868E-05
Am-242m	2.1952E-08	7.6698E-08	1.0733E-07	1.0528E-07
Am-243	6.9894E-07	3.9981E-06	1.0185E-05	1.0187E-05
Cm-242	1.7402E-07	8.7230E-07	1.7235E-06	1.0398E-09
Cm-243	1.9440E-09	1.9196E-08	5.5237E-08	4.9042E-08
Cm-244	1.1331E-07	1.1916E-06	4.6825E-06	3.8685E-06
Cm-245	4.2258E-09	7.5432E-08	3.9378E-07	3.9365E-07
Mo-95	1.3058E-05	3.0225E-05	4.6055E-05	5.1204E-05
Tc-99	2.2297E-05	4.2570E-05	6.0593E-05	6.0738E-05
Ru-101	2.2421E-05	4.3873E-05	6.4237E-05	6.4238E-05
Rh-103	1.9225E-05	3.4990E-05	4.5471E-05	4.8077E-05
Ag-109	4.8065E-06	8.5321E-06	1.1421E-05	1.1429E-05
Cs-133	2.4005E-05	4.5209E-05	6.3182E-05	6.3574E-05
Nd-143	1.5348E-05	2.8895E-05	3.9263E-05	3.9994E-05
Nd-145	1.1302E-05	2.1630E-05	3.0852E-05	3.0857E-05
Sm-147	7.7091E-07	2.2748E-06	3.6323E-06	9.3420E-06
Sm-149	2.1212E-07	1.8566E-07	1.5754E-07	2.1529E-07
Sm-150	5.0204E-06	1.0774E-05	1.6425E-05	1.6425E-05
Sm-151	9.3572E-07	9.5883E-07	9.4573E-07	9.1722E-07
Sm-152	3.0935E-06	5.2719E-06	6.4743E-06	6.4745E-06
Eu-153	2.1796E-06	5.3264E-06	8.2228E-06	8.2658E-06
Gd-155	4.2658E-09	6.9282E-09	9.7789E-09	4.7081E-07

Two Times Relative Standard Deviation (%)

Nuclide	End of Cycle 1	End of Cycle 2	End of Cycle 3	5 Years Cooling
U-234	2.69	6.69	16.78	49.04
U-235	0.78	1.32	2.56	2.62
U-236	4.85	3.55	2.99	2.50
U-238	0.05	0.09	0.10	0.10
Pu-238	31.70	63.51	71.50	72.36
Pu-239	2.47	4.90	6.84	6.80
Pu-240	12.30	7.02	4.69	4.60
Pu-241	20.89	4.41	3.61	3.80
Pu-242	20.24	12.80	7.40	7.41
Np-237	78.98	71.35	66.01	66.30
Am-241	16.43	11.14	7.87	3.39
Am-242m	50.25	46.52	41.42	40.48
Am-243	33.66	24.32	17.19	17.18
Cm-242	16.04	11.47	7.79	39.35
Cm-243	33.58	26.72	18.34	18.32
Cm-244	42.49	32.13	23.35	23.49
Cm-245	36.19	28.48	23.16	23.14
Mo-95	34.76	14.24	8.72	1.31
Tc-99	3.32	3.59	3.87	4.00
Ru-101	4.70	4.49	4.36	4.36
Rh-103	10.93	9.27	9.42	13.39
Ag-109	28.63	26.09	24.77	24.85
Cs-133	2.90	3.35	3.99	4.14
Nd-143	4.97	3.54	3.11	1.79
Nd-145	1.93	2.29	3.18	3.19
Sm-147	2.09	2.25	3.49	5.79
Sm-149	11.09	11.94	11.28	11.13
Sm-150	6.57	8.36	9.67	9.67
Sm-151	9.62	17.76	21.07	21.44
Sm-152	8.94	14.51	19.23	19.23
Eu-153	10.65	10.42	9.84	9.91
Gd-155	85.98	73.59	67.17	89.50

Figure B.1. TRSD (%) for Case 1

Supercell model, first recycle MOX fuel

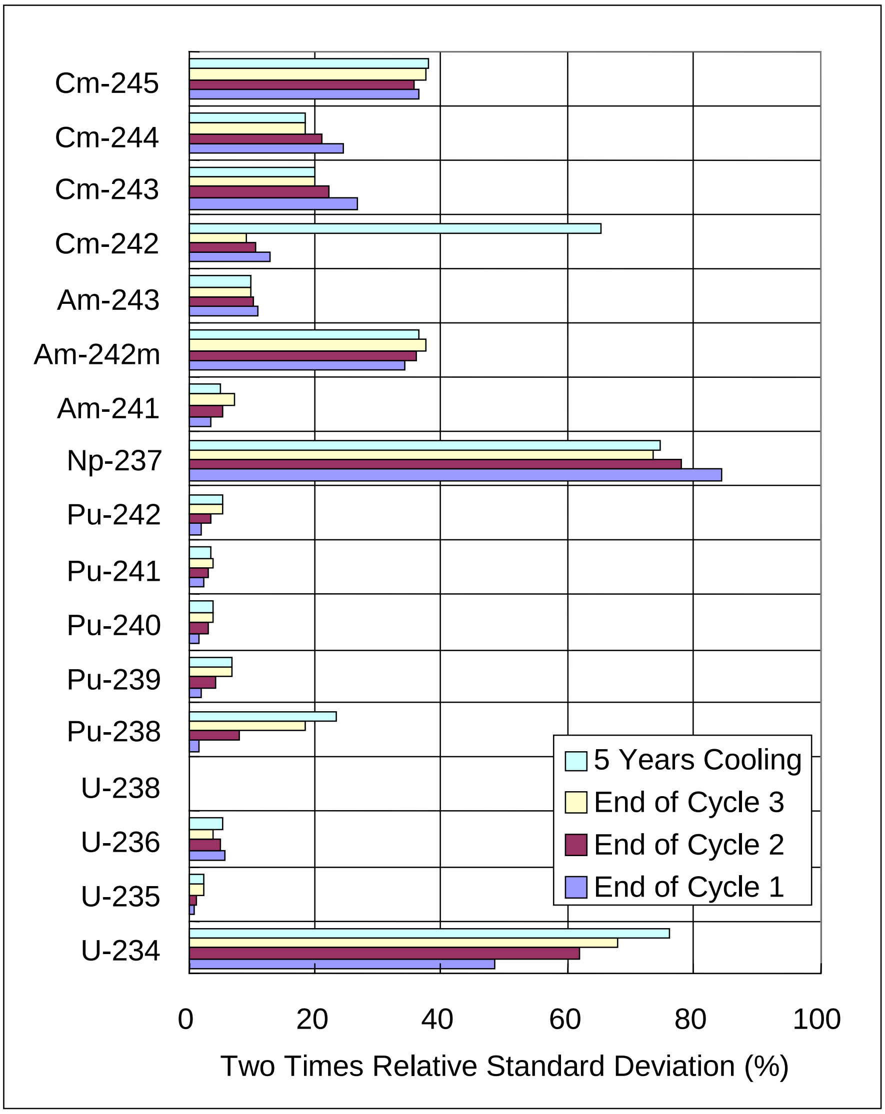


Figure B.1. TRSD (%) for Case 1 (*cont.*)

Supercell model, first recycle MOX fuel

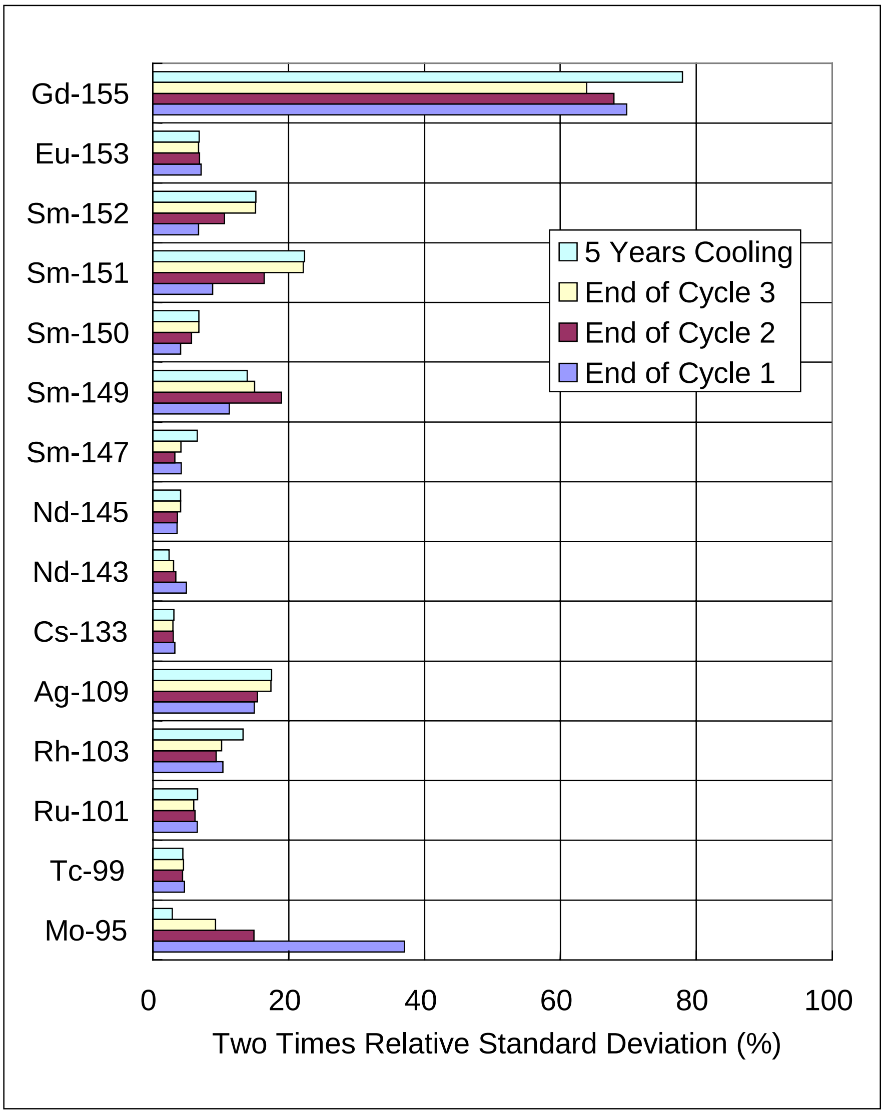


Figure B.2. TRSD (%) for Case 2

Supercell model, weapons disposition MOX fuel

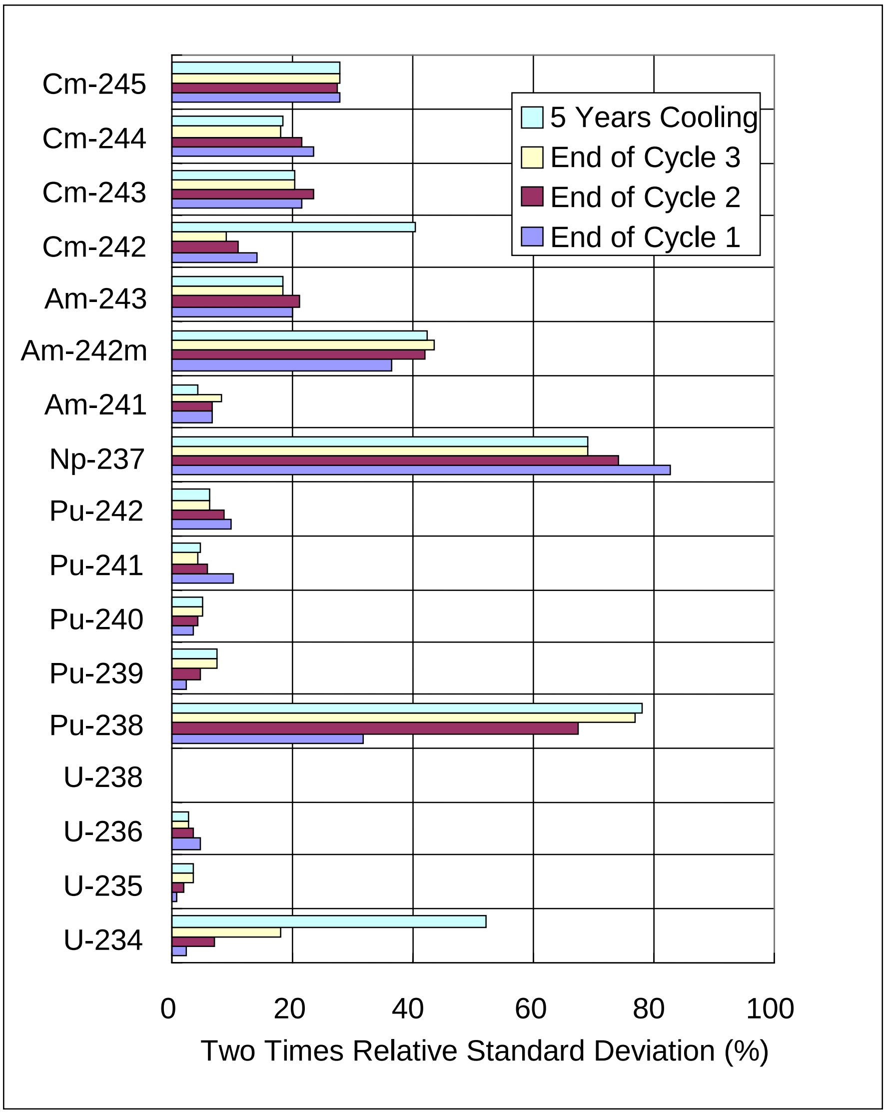


Figure B.2. TRSD (%) for Case 2 (*cont.*)

Supercell model, weapons disposition MOX fuel

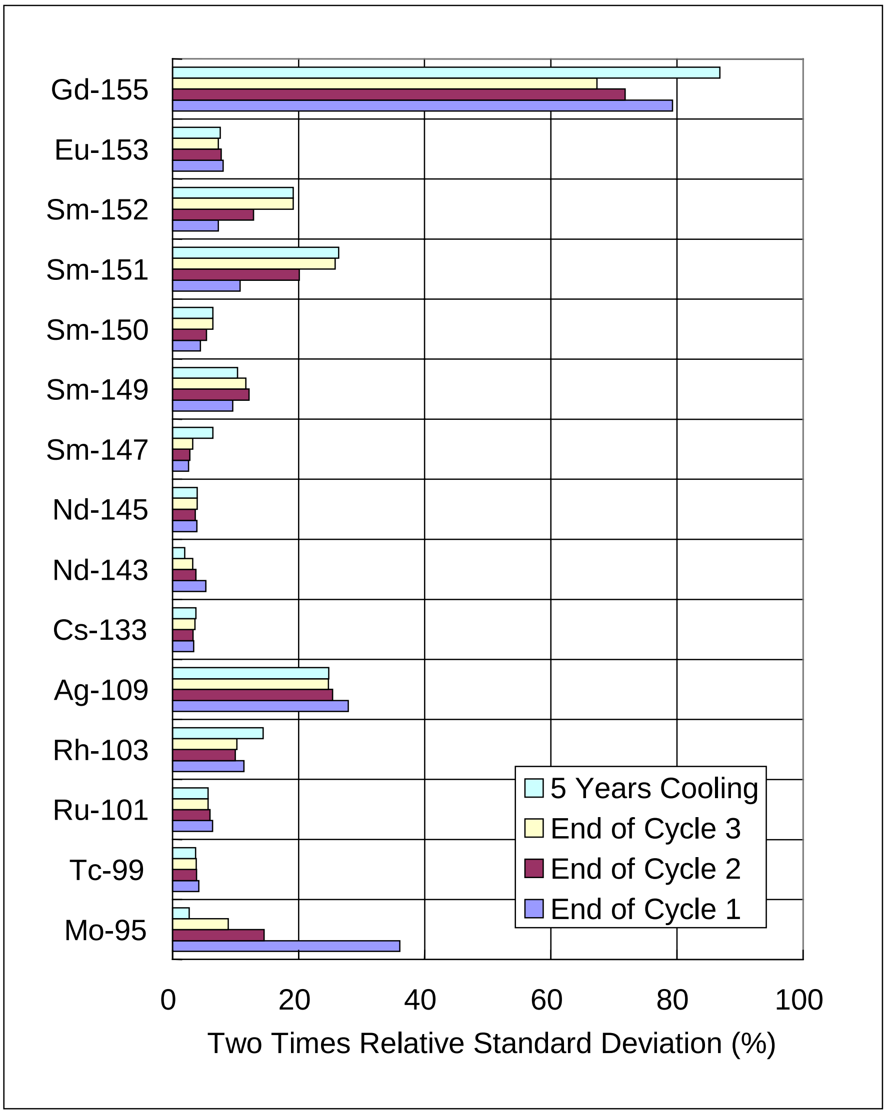


Figure B.3. TRSD (%) for Case 3

Assembly model, first recycle MOX fuel

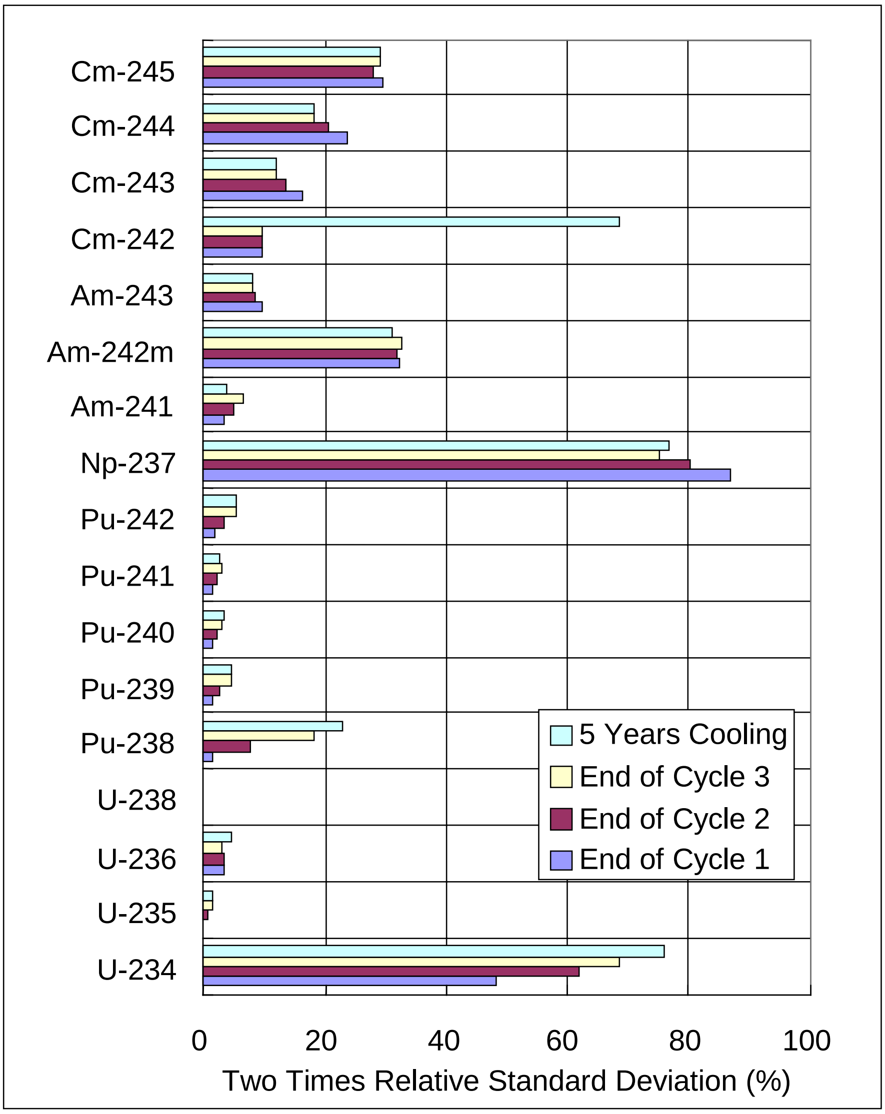


Figure B.3. TRSD (%) for Case 3 (*cont.*)

Assembly model, first recycle MOX fuel

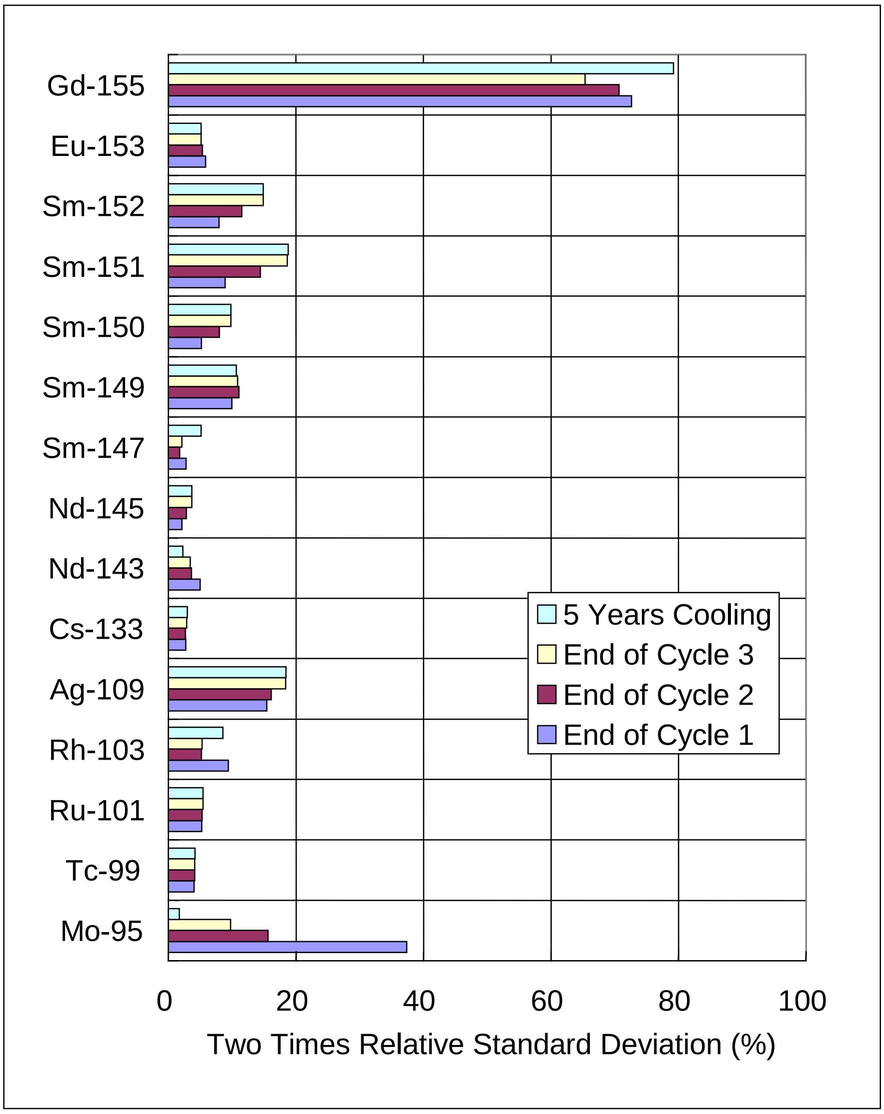


Figure B.4. TRSD (%) for Case 4

Assembly model, weapons disposition MOX fuel

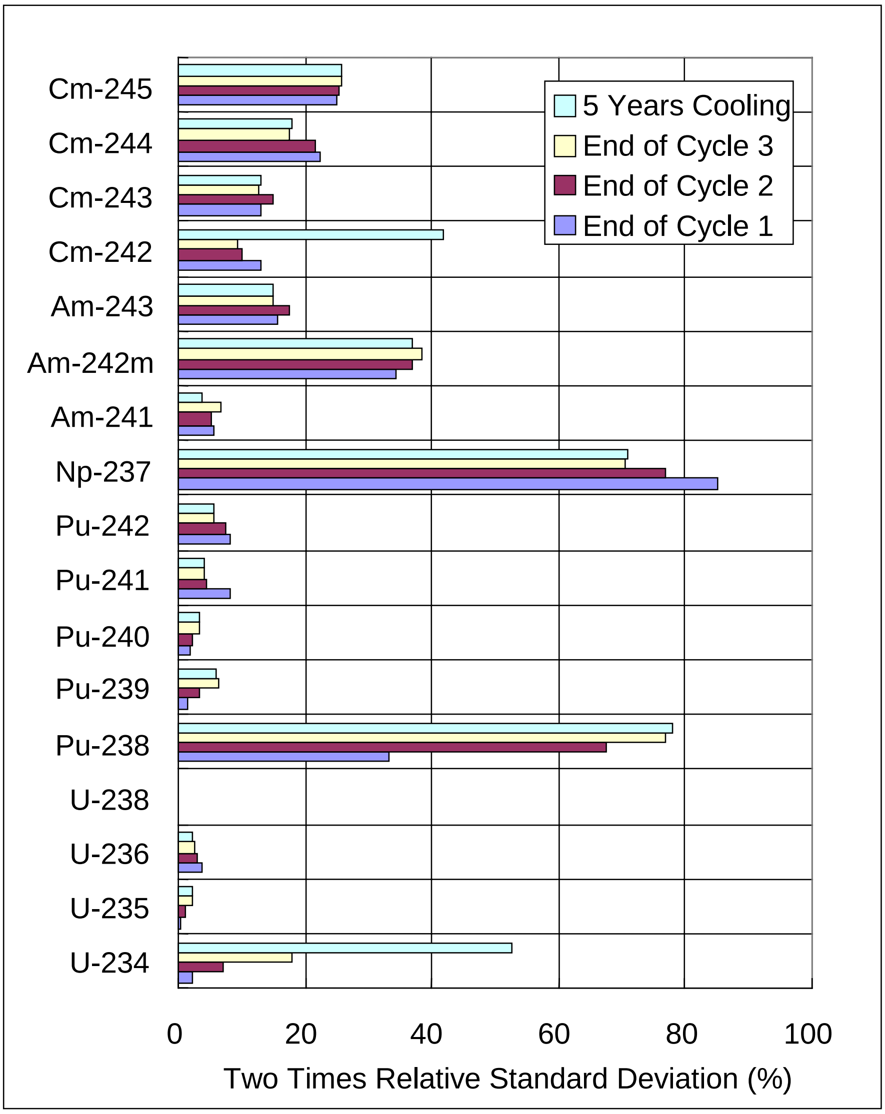


Figure B.4. TRSD (%) for Case 4 (*cont.*)

Assembly model, weapons disposition MOX fuel

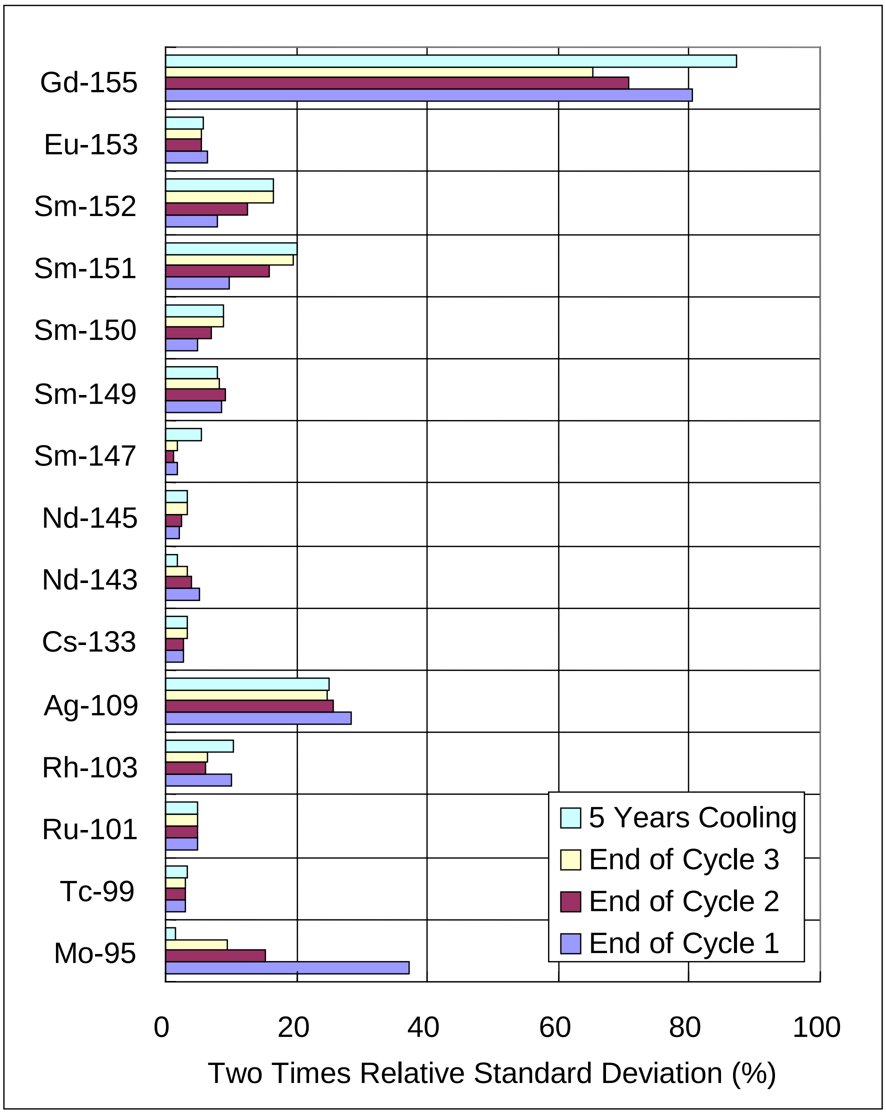


Figure B.5. TRSD (%) for Case 5

Pin cell model, first recycle MOX fuel

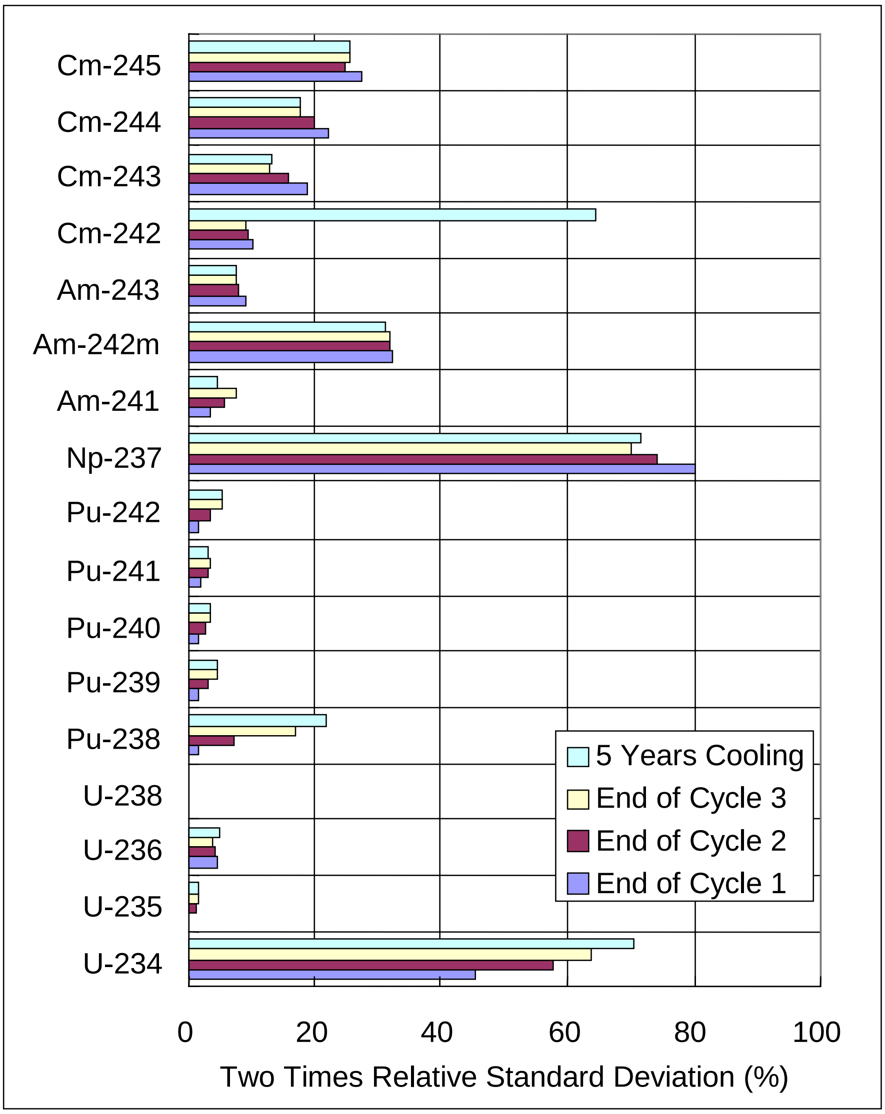


Figure B.5. TRSD (%) for Case 5 (*cont.*)

Pin cell model, first recycle MOX fuel

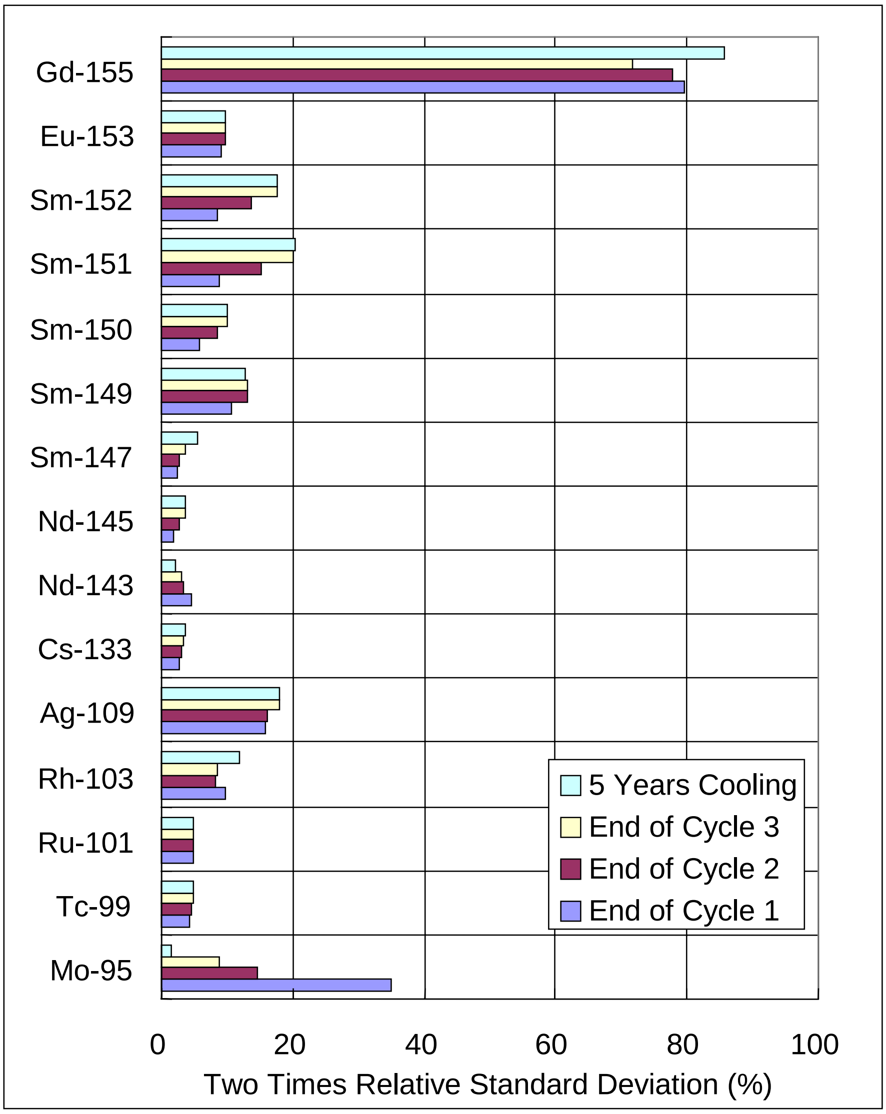


Figure B.6. TRSD (%) for Case 6

Pin cell model, weapons disposition MOX fuel

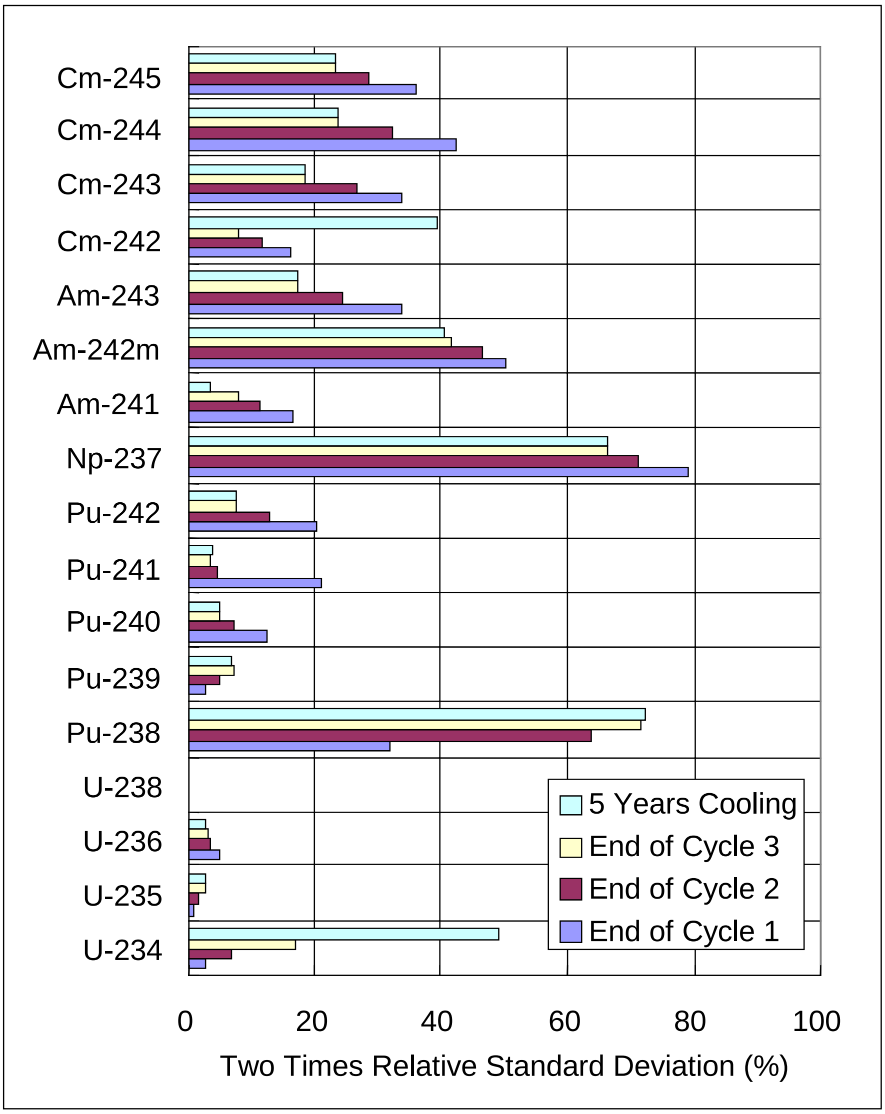
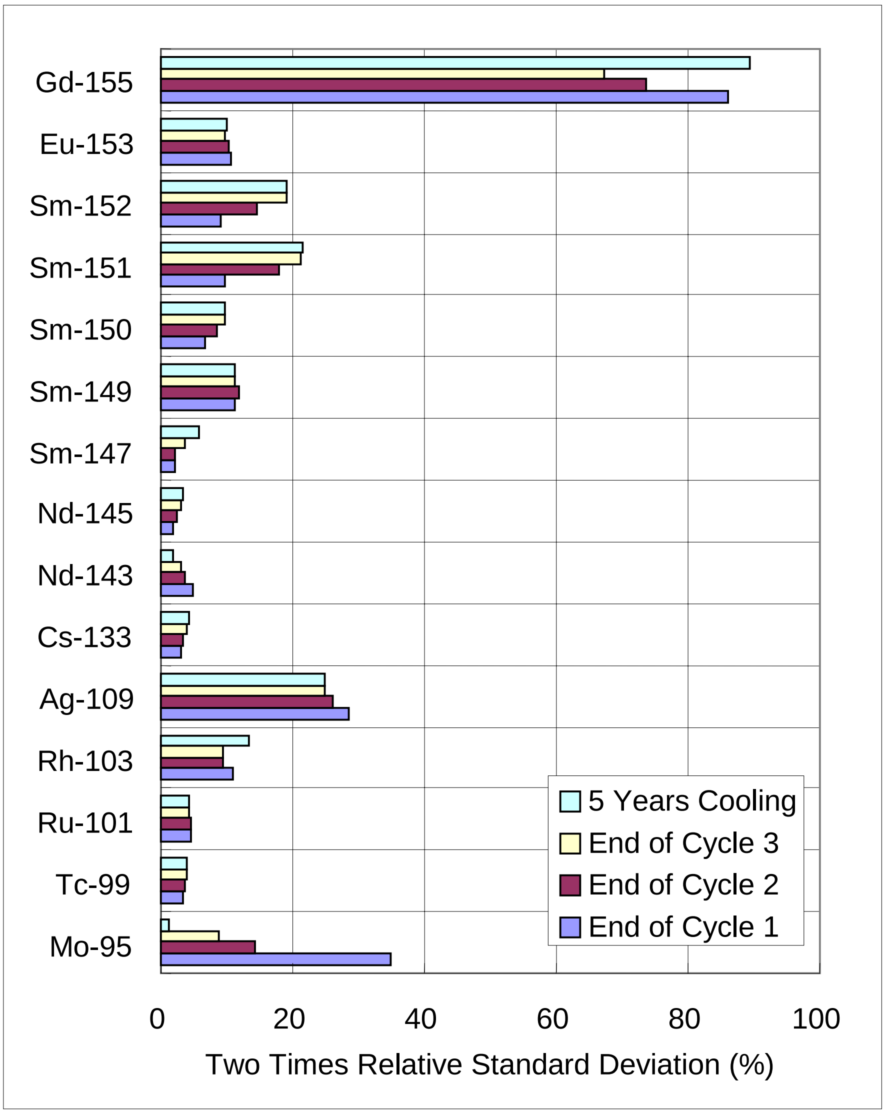


Figure B.6. TRSD (%) for Case 6 (*cont.*)

Pin cell model, weapons disposition MOX fuel



Appendix C

SUMMARY OF CALCULATION RESULTS FOR K_∞ AND REACTIVITY CHANGE

Table C.1. K_∞ and reactivity change for Case 1

Supercell model, first recycle MOX fuel

Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.09906	1.00024	0.92200	0.90332	0.41	0.32	0.01	-0.49
CEA	1.10154	1.00401	0.92554	0.91255	0.63	0.70	0.39	0.53
GRS	1.09111	0.98840	0.91013	0.89200	-0.32	-0.87	-1.28	-1.74
PSI	1.10163	1.00671	0.93077	0.91775	0.64	0.97	0.96	1.10
BNFL	1.07571	0.98225	0.91344	0.89595	-1.73	-1.49	-0.92	-1.30
JAERI	1.09525	0.99587	0.92144	0.91134	0.06	-0.12	-0.05	0.93
DTLR	1.09880	0.99910	0.91980	0.90820	0.38	0.20	-0.23	0.05
ORNL	1.09382	0.99992	0.93210	0.92098	-0.07	0.29	1.11	1.46
Average	1.09462	0.99706	0.92190	0.90776				
Stand. dev.	0.00849	0.00810	0.00766	0.01013				
Stand. dev. (%)	0.78	0.81	0.83	1.12				
Ave + SD	1.10311	1.00517	0.92956	0.91789				
Ave – SD	1.08612	0.98896	0.91424	0.89763				
Minimum	1.07571	0.98225	0.91013	0.89200				
Maximum	1.10163	1.00671	0.93210	0.92098				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-9.0	-8.5	-2.2	-19.7	0.6	3.7	32.3	4.8
CEA	-8.8	-8.4	-1.5	-18.8	-1.4	3.3	-9.3	-0.1
GRS	-9.5	-8.7	-2.2	-20.5	6.5	6.4	31.7	8.7
PSI	-8.6	-8.1	-1.5	-18.2	-4.3	-0.9	-10.1	-3.3
BNFL	-8.8	-7.7	-2.1	-18.7	-1.0	-6.2	26.1	-0.9
JAERI	-9.1	-8.1	-1.2	-18.4	1.9	-0.8	-29.1	-2.1
DTLR	-9.1	-8.6	-1.4	-19.1	1.6	5.5	-18.1	1.5
ORNL	-8.6	-7.3	-1.3	-17.2	-4.0	-11.0	-23.6	-8.8
Average	-8.9	-8.2	-1.7	-18.8				
Stand. dev.	0.3	0.5	0.4	1.0				
Stand. dev. (%)	-3.5	-6.1	-25.8	-5.3				
Ave + SD	-8.6	-7.7	-1.3	-17.8				
Ave – SD	-9.3	-8.7	-2.1	-19.8				
Minimum	-9.5	-8.7	-2.2	-20.5				
Maximum	-8.6	-7.3	-1.2	17.2				

Figure C.1. K_∞ and reactivity change for Case 1

Supercell model, first recycle MOX fuel

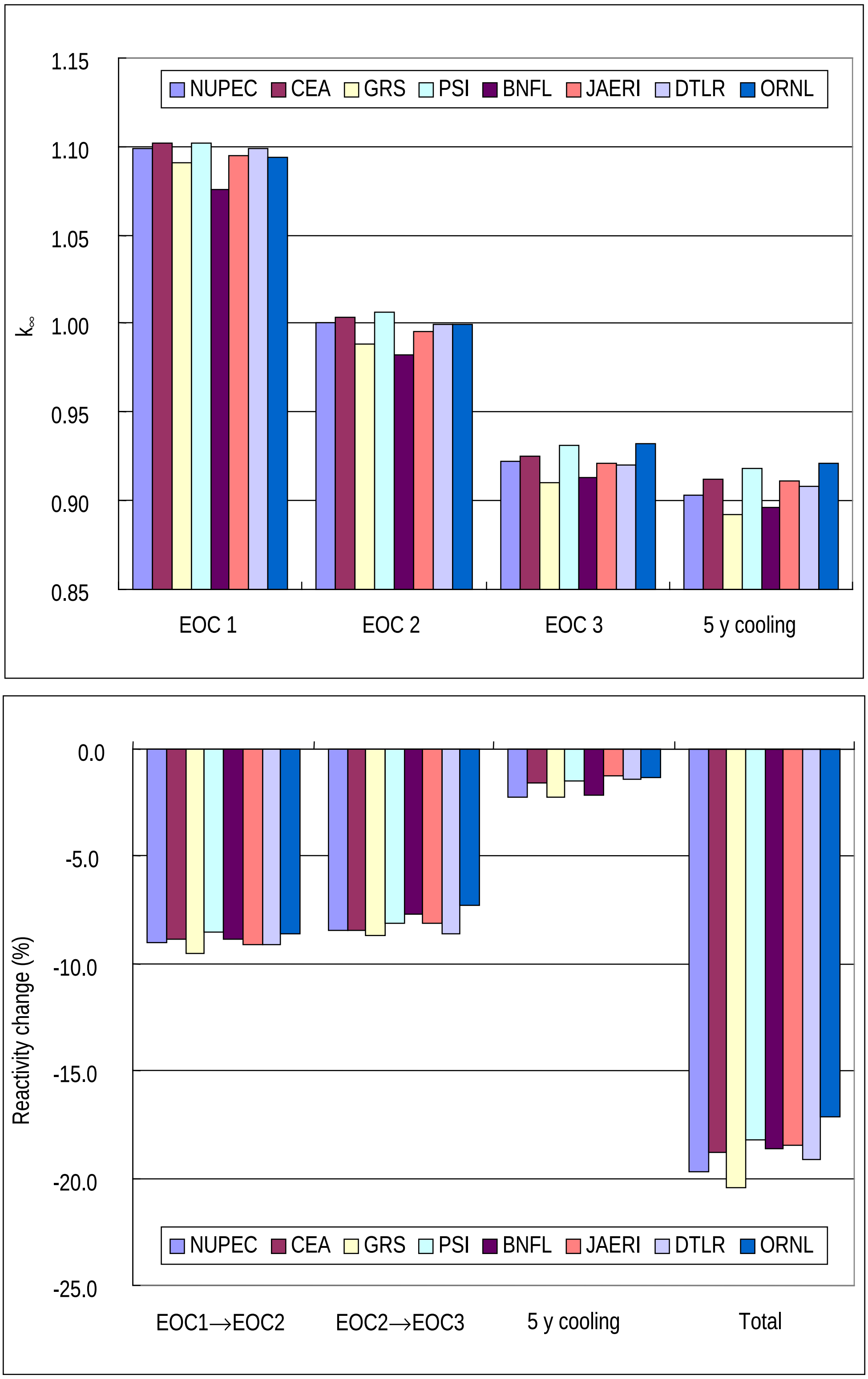


Table C.2. K_∞ and reactivity change for Case 2

Supercell model, weapons disposition MOX fuel

Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.10834	0.99068	0.89595	0.87758	0.31	0.26	-0.02	-0.78
CEA	1.10649	0.99022	0.89605	0.88515	0.15	0.21	-0.01	0.08
GRS	1.09387	0.97408	0.8814	0.86485	-1.00	-1.42	-1.65	-2.22
PSI	1.10934	0.99662	0.90549	0.89540	0.40	0.86	1.04	1.24
BNFL	1.09188	0.97718	0.88947	0.87658	-1.18	-1.11	-0.75	-0.89
JAERI	1.11003	0.99169	0.8989	0.89068	0.47	0.36	0.30	0.70
DTLR	1.10770	0.98660	0.89190	0.88090	0.26	-0.16	-0.48	-0.40
ORNL	1.11129	0.99815	0.91021	0.90466	0.58	1.01	1.57	2.28
Average	1.10487	0.988	0.896	0.884				
Stand. dev.	0.00756	0.009	0.009	0.012				
Stand. dev. (%)	0.68	0.87	1.01	1.40				
Ave + SD	1.11243	0.99673	0.90522	0.89686				
Ave – SD	1.09731	0.97957	0.88713	0.87209				
Minimum	1.09188	0.97408	0.88140	0.86485				
Maximum	1.11129	0.99815	0.91021	0.90466				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-10.7	-10.7	-2.3	-23.7	0.2	2.7	57.3	5.1
CEA	-10.6	-10.6	-1.4	-22.6	-0.8	2.1	-7.5	0.1
GRS	-11.2	-10.8	-2.2	-24.2	5.1	3.9	46.2	7.3
PSI	-10.2	-10.1	-1.2	-21.5	-4.7	-2.8	-16.2	-4.6
BNFL	-10.8	-10.1	-1.7	-22.5	0.5	-2.9	11.4	-0.3
JAERI	-10.8	-10.4	-1.0	-22.2	0.5	0.2	-30.9	-1.7
DTLR	-11.1	-10.8	-1.4	-23.2	3.6	3.6	-5.7	3.0
ORNL	-10.2	-9.7	-0.7	-20.6	-4.6	-6.8	-54.6	-8.9
Average	-10.7	-10.4	-1.5	-22.6				
Stand. dev.	0.4	0.4	0.6	1.2				
Stand. dev. (%)	-3.5	-3.8	-37.5	-5.2				
Ave + SD	-10.3	-10.0	-0.9	-21.4				
Ave – SD	-11.1	-10.8	-2.0	-23.7				
Minimum	-11.2	-10.8	-2.3	-24.2				
Maximum	-10.2	-9.7	-0.7	-20.6				

Figure C.2. K_∞ and reactivity change for Case 2

Supercell model, weapons disposition MOX fuel

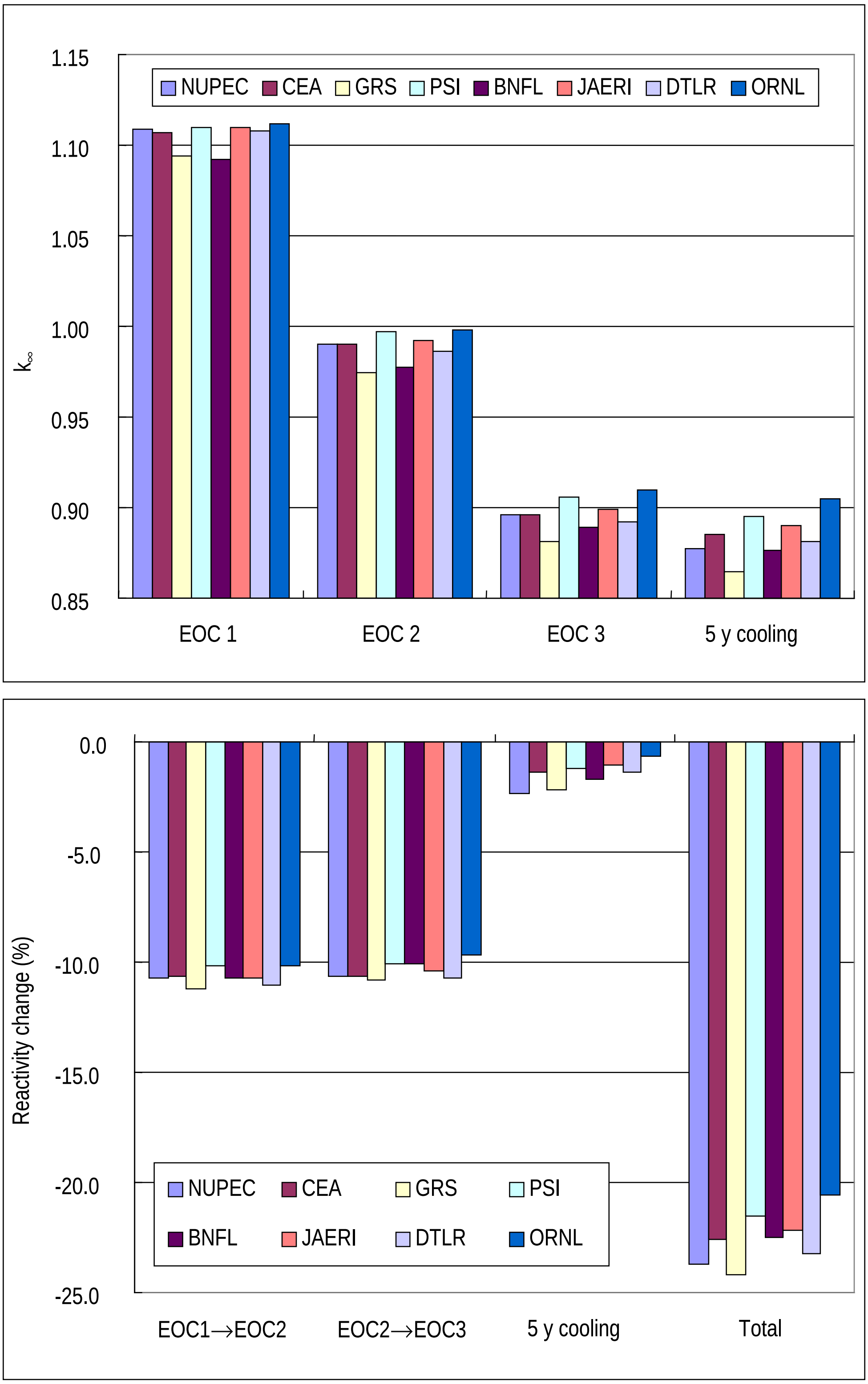


Table C.3. K_∞ and reactivity change for Case 3

Assembly model, first recycle MOX fuel

Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.05978	1.00753	0.961	0.91857	0.18	0.64	0.69	0.80
CEA	1.05624	0.99968	0.94869	0.90715	-0.15	-0.14	-0.60	-0.45
GRS	1.05910	0.99909	0.94752	0.90325	0.12	-0.20	-0.72	-0.88
PSI	1.06088	1.00618	0.95837	0.91826	0.29	0.51	0.41	0.77
BNFL	1.04976	0.99654	0.94974	0.90409	-0.77	-0.45	-0.49	-0.79
JAERI	1.05541	0.99749	0.95292	0.91676	-0.23	-0.36	-0.16	0.60
DTLR	1.05900	1.00460	0.95100	0.91080	0.11	0.35	-0.36	-0.05
ORNL	1.06269	1.01166	0.96610	No data	0.46	1.06	1.22	No data
Average	1.05786	1.00108	0.95442	0.91127				
Stand. dev.	0.00402	0.00543	0.00667	0.00665				
Stand. dev. (%)	0.38	0.54	0.70	0.73				
Ave + SD	1.06188	1.00652	0.96109	0.91792				
Ave – SD	1.05383	0.99565	0.94774	0.90462				
Minimum	1.04976	0.99654	0.94752	0.90325				
Maximum	1.06269	1.01166	0.96610	0.91857				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-4.9	-4.8	-4.8	-14.5	-5.7	-5.1	0.6	-4.2
CEA	-5.4	-5.4	-4.8	-15.6	3.3	6.2	1.0	2.7
GRS	-5.7	-5.4	-5.2	-16.3	9.3	7.6	8.2	7.5
PSI	-5.1	-5.0	-4.6	-14.6	-1.2	-2.0	-4.7	-3.4
BNFL	-5.1	-4.9	-5.3	-15.3	-1.9	-2.3	11.2	1.3
JAERI	-5.5	-4.7	-4.1	-14.3	6.1	-7.4	-13.4	-5.4
DTLR	-5.1	-5.6	-4.6	-15.4	-1.4	10.8	-2.9	1.4
ORNL	-4.7	-4.7	No data	No data	-8.5	-7.9	No data	No data
Average	-5.2	-5.1	-4.8	-15.1				
Stand. dev.	0.3	0.4	0.4	0.7				
Stand. dev. (%)	-5.9	-7.2	-8.2	-4.6				
Ave + SD	-4.9	-4.7	-4.4	-14.5				
Ave – SD	-5.5	-5.4	-5.2	-15.8				
Minimum	-5.7	-5.6	-5.3	-16.3				
Maximum	-4.7	-4.7	-4.1	-14.3				

Figure C.3. K_∞ and reactivity change for Case 3

Assembly model, first recycle MOX fuel

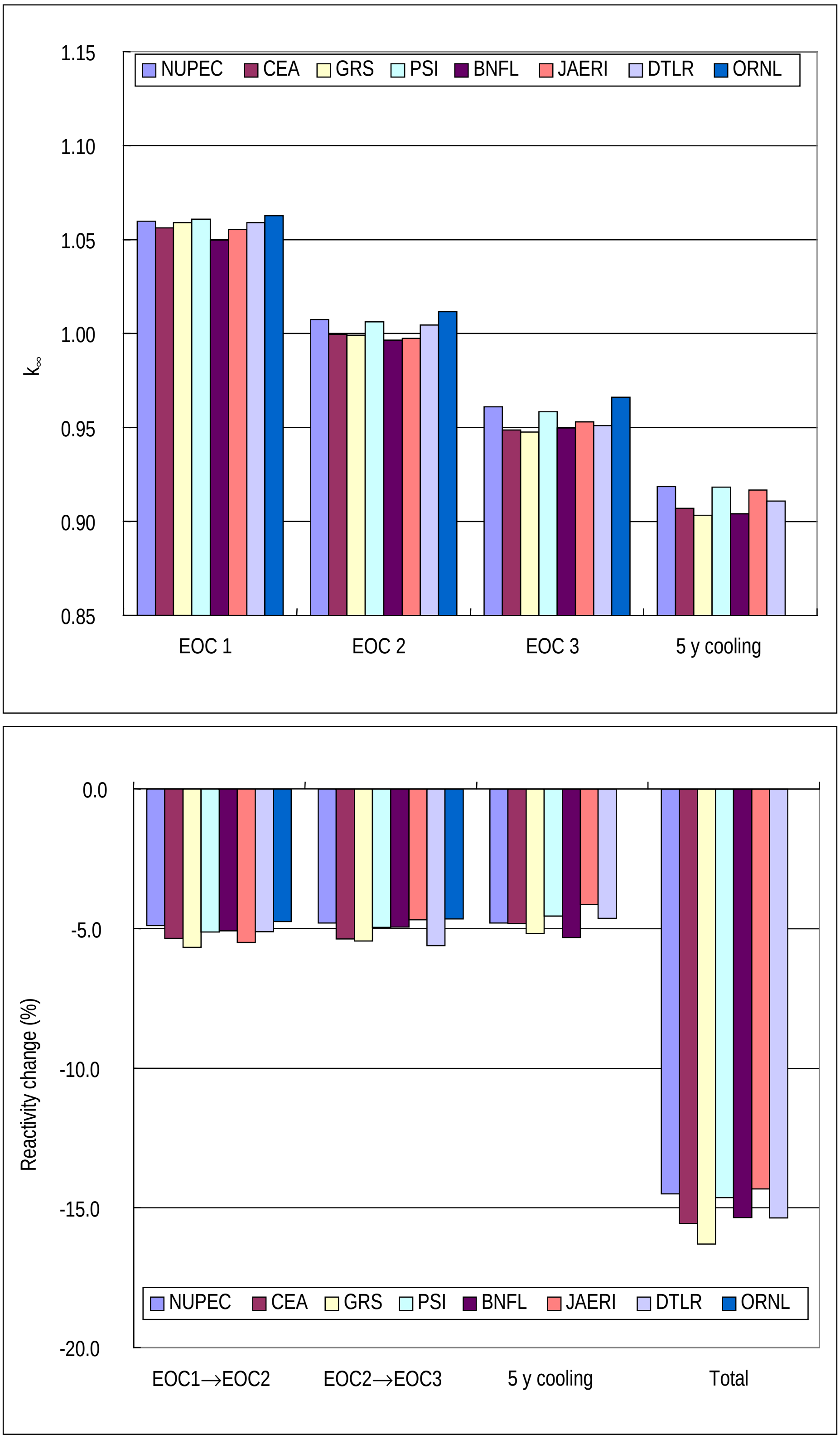


Table C.4. K_∞ and reactivity change for Case 4

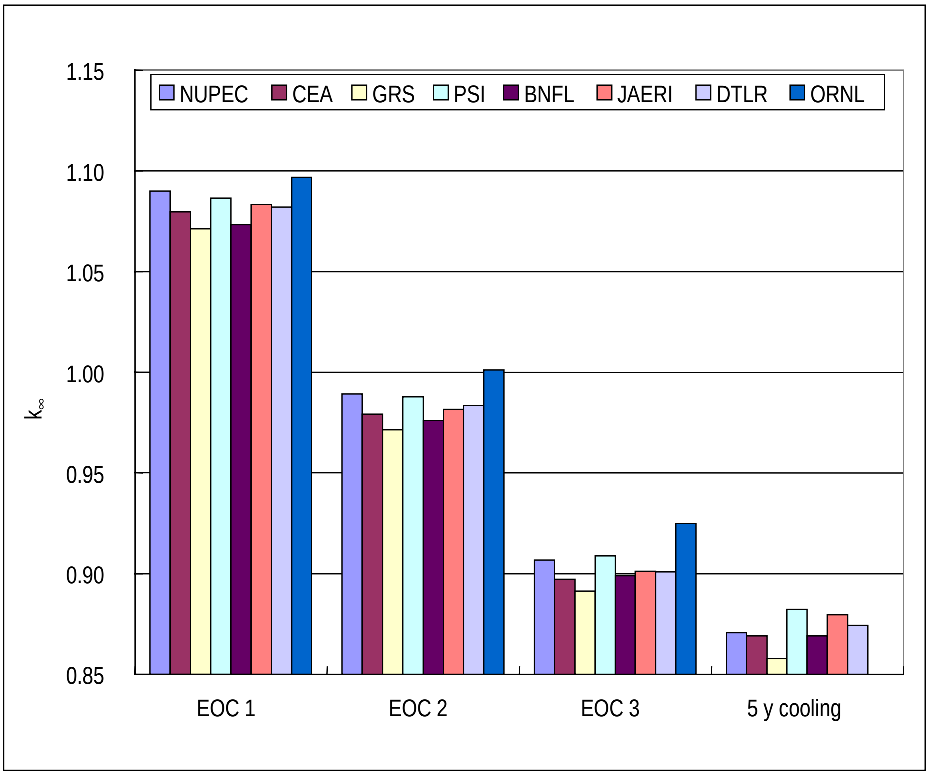
Assembly model, weapons disposition MOX fuel

Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.08996	0.98919	0.9067	0.87071	0.66	0.55	0.32	-0.13
CEA	1.07981	0.97923	0.89724	0.86897	-0.28	-0.46	-0.72	-0.33
GRS	1.07112	0.97149	0.89143	0.85771	-1.08	-1.25	-1.37	-1.62
PSI	1.08652	0.9878	0.9089	0.88219	0.34	0.41	0.57	1.19
BNFL	1.07323	0.97602	0.89903	0.86913	-0.89	-0.79	-0.53	-0.31
JAERI	1.08330	0.98167	0.90121	0.87964	0.04	-0.21	-0.28	0.90
DTLR	1.08210	0.98350	0.90090	0.87440	-0.07	-0.03	-0.32	0.30
ORNL	1.096727	1.001136	0.924771	No data	1.28	1.77	2.32	No data
Average	1.08285	0.98375	0.90377	0.87182				
Stand. dev.	0.00842	0.00913	0.01006	0.00807				
Stand. dev. (%)	0.78	0.93	1.11	0.93				
Ave + SD	1.09127	0.99288	0.91383	0.87989				
Ave – SD	1.07442	0.97463	0.89371	0.86375				
Minimum	1.07112	0.97149	0.89143	0.85771				
Maximum	1.09673	1.00114	0.92477	0.88219				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-9.3	-9.2	-4.6	-23.1	0.4	2.2	23.5	4.1
CEA	-9.5	-9.3	-3.6	-22.5	2.2	3.7	-1.8	1.3
GRS	-9.6	-9.2	-4.4	-23.2	2.9	2.7	19.5	4.7
PSI	-9.2	-8.8	-3.3	-21.3	-1.1	-2.4	-9.7	-3.9
BNFL	-9.3	-8.8	-3.8	-21.9	-0.3	-2.5	3.7	-1.4
JAERI	-9.6	-9.1	-2.7	-21.4	2.7	1.0	-26.3	-3.7
DTLR	-9.3	-9.3	-3.4	-22.0	-0.4	3.6	-8.9	-1.1
ORNL	-8.7	-8.2	No data	No data	-6.4	-8.4	No data	No data
Average	-9.3	-9.0	-3.7	-22.2				
Stand. dev.	0.3	0.4	0.6	0.3				
Stand. dev. (%)	-3.0	-4.2	-17.4	-3.5				
Ave + SD	-9.0	-8.6	-3.0	-21.4				
Ave – SD	-9.6	-9.4	-4.3	-23.0				
Minimum	-9.6	-9.3	-4.6	-23.2				
Maximum	-8.7	-8.2	-2.7	-21.3				

Figure C.4. K_∞ and reactivity change for Case 4

Assembly model, weapons disposition MOX fuel



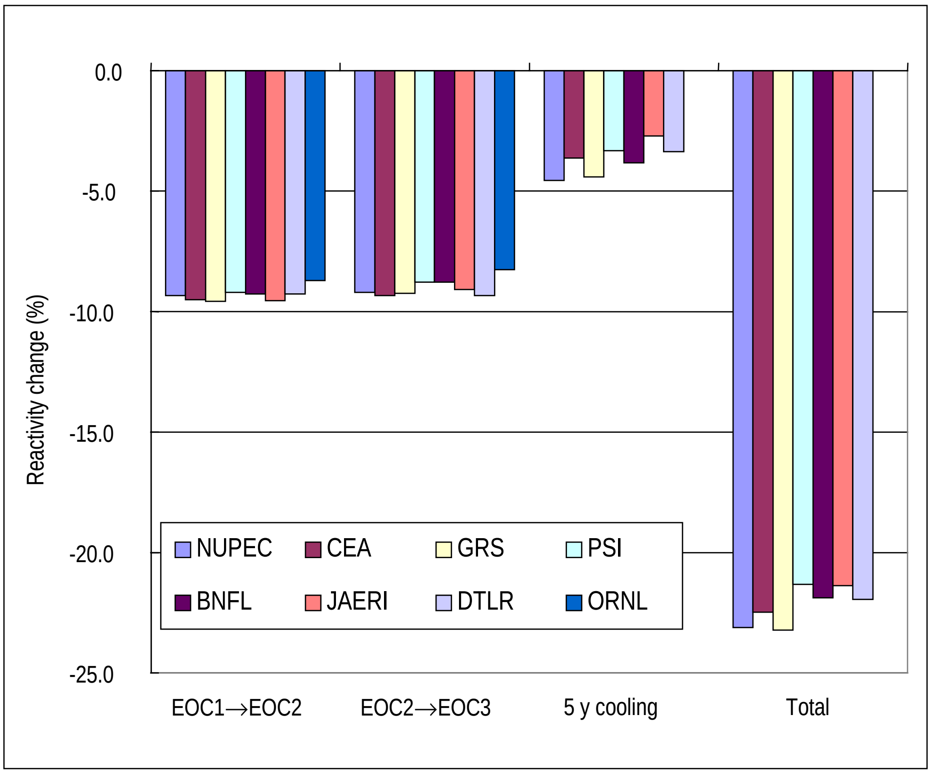


Table C.5. K_∞ and reactivity change for Case 5

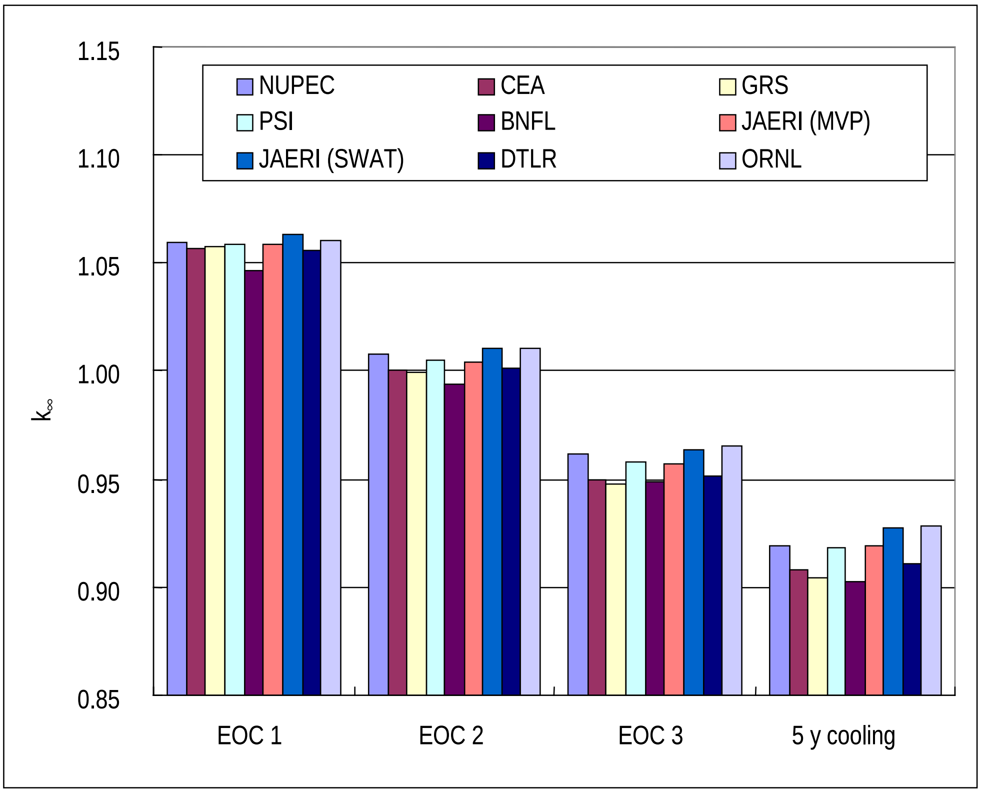
Pin cell model, first recycle MOX fuel

Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.05958	1.00783	0.96162	0.91903	0.21	0.41	0.59	0.41
CEA	1.05638	1.00028	0.94969	0.90789	-0.09	-0.34	-0.66	-0.80
GRS	1.05753	0.99969	0.94775	0.90424	0.02	-0.40	-0.86	-1.20
PSI	1.05824	1.00469	0.95812	0.91803	0.08	0.10	0.22	0.30
BNFL	1.04636	0.99422	0.94853	0.90233	-1.04	-0.94	-0.78	-1.41
JAERI (MVP)	1.05829	1.00398	0.95731	0.9194	0.09	0.03	0.14	0.45
JAERI (SWAT)	1.06295	1.01043	0.96399	0.92710	0.53	0.67	0.83	1.29
DTLR	1.05610	1.00160	0.95170	0.91120	-0.12	-0.21	-0.45	-0.44
ORNL	1.06080	1.01035	0.96541	0.92808	0.33	0.67	0.98	1.40
Average	1.05736	1.00367	0.95601	0.91526				
Stand. dev.	0.00465	0.00536	0.00682	0.00938				
Stand. dev. (%)	0.44	0.53	0.71	1.02				
Ave + SD	1.06201	1.00903	0.96284	0.92463				
Ave – SD	1.05270	0.99832	0.94919	0.90588				
Minimum	1.04636	0.99422	0.94775	0.90233				
Maximum	1.06295	1.01043	0.96541	0.92808				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-4.8	-4.8	-4.8	-14.4	-4.2	-4.0	3.3	-1.8
CEA	-5.3	-5.3	-4.8	-15.5	4.9	7.2	4.0	5.4
GRS	-5.5	-5.5	-5.1	-16.0	8.1	10.3	8.9	9.1
PSI	-5.0	-4.8	-4.6	-14.4	-0.5	-2.6	-2.3	-1.8
BNFL	-5.0	-4.8	-5.4	-15.3	-0.9	-2.5	15.8	3.8
JAERI (MVP)	-5.1	-4.9	-4.3	-14.3	1.0	-2.3	-7.6	-2.8
JAERI (SWAT)	-4.9	-4.8	-4.1	-13.8	-3.4	-4.1	-11.5	-6.2
DTLR	-5.2	-5.2	-4.7	-15.1	1.8	5.3	0.1	2.5
ORNL	-4.7	-4.6	-4.2	-13.5	-7.0	-7.3	-10.7	-8.2
Average	-5.1	-5.0	-4.7	-14.7				
Stand. dev.	0.2	0.3	0.4	0.8				
Stand. dev. (%)	-4.7	-6.0	-9.1	-5.6				
Ave + SD	-4.8	-4.7	-4.2	-13.9				
Ave – SD	-5.3	-5.3	-5.1	-15.5				
Minimum	-5.5	-5.5	-5.4	-16.0				
Maximum	-4.7	-4.6	-4.1	-13.5				

Table C.5. K_∞ and reactivity change for Case 5

Pin cell model, first recycle MOX fuel



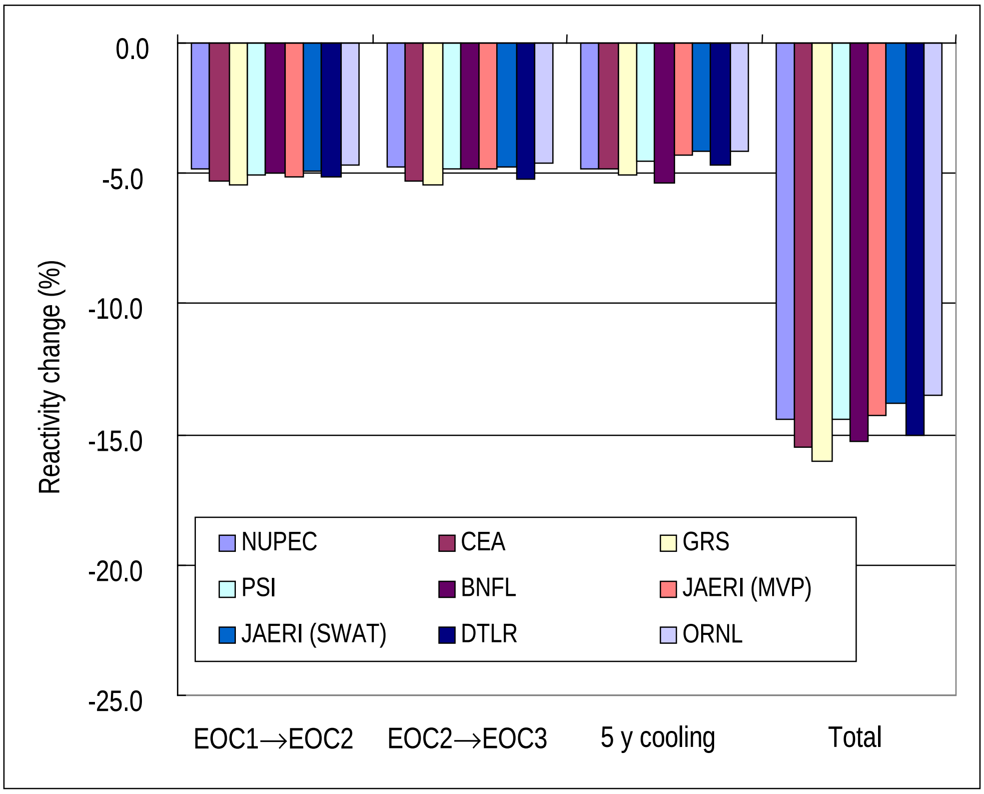


Table C.6. K_∞ and reactivity change for Case 6

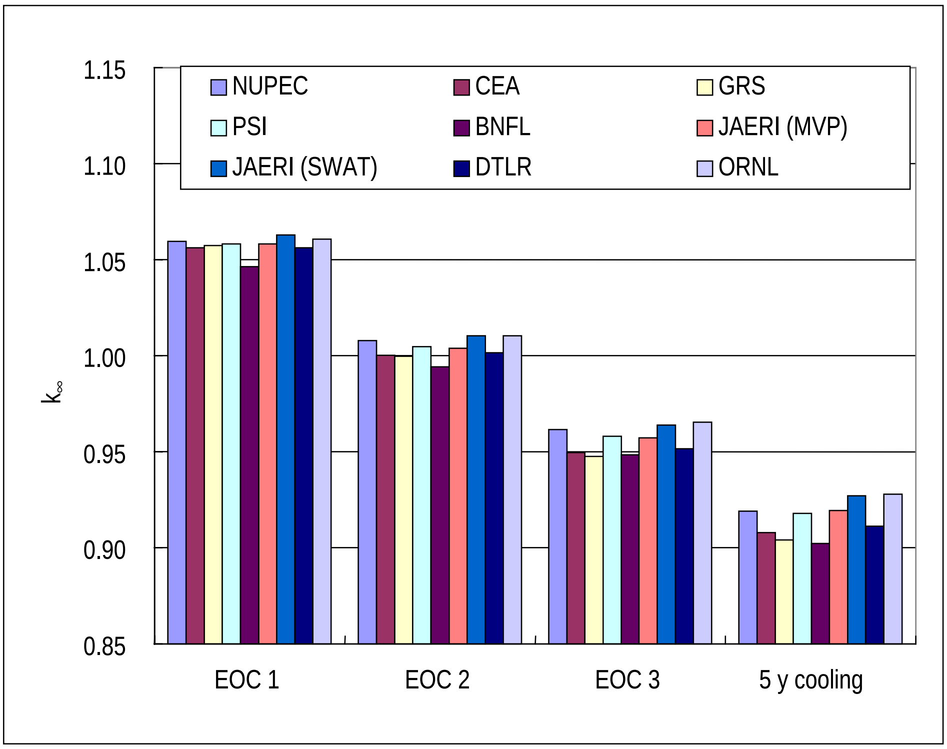
Pin cell model, weapons disposition MOX fuel

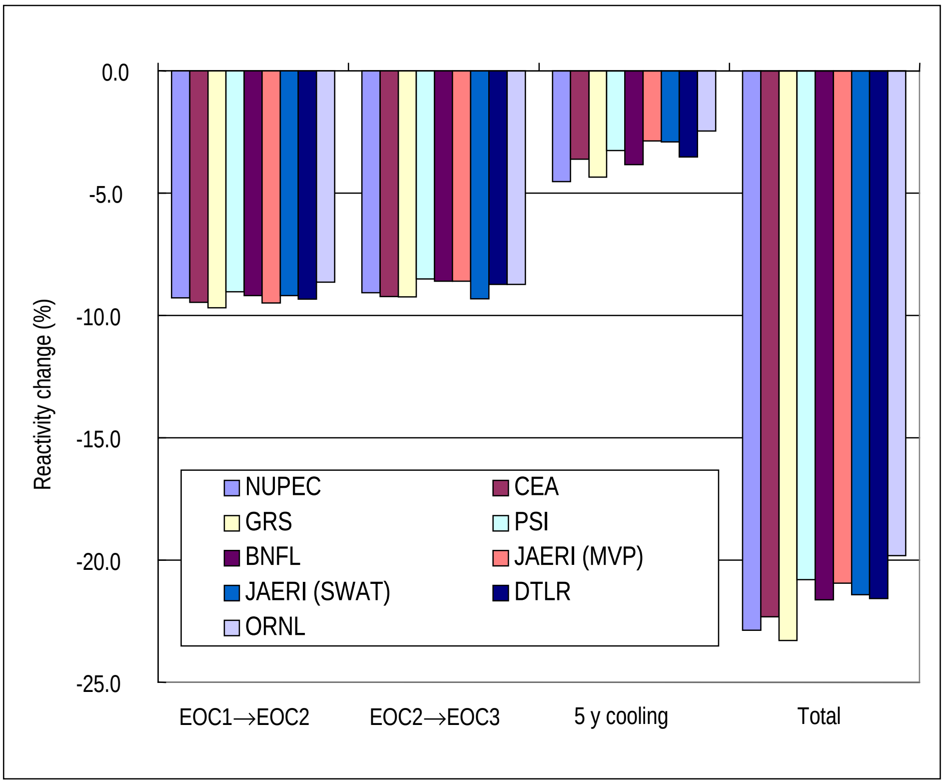
Participant	k_∞				Relative difference in k_∞ (%)			
	EOC 1	EOC 2	EOC 3	5 y cooling	EOC 1	EOC 2	EOC 3	5 y cooling
NUPEC	1.09068	0.99041	0.90879	0.87288	0.55	0.47	0.26	-0.68
CEA	1.08089	0.98056	0.89916	0.87082	-0.35	-0.53	-0.80	-0.91
GRS	1.07057	0.96996	0.89012	0.85692	-1.31	-1.60	-1.80	-2.49
PSI	1.08547	0.98849	0.91182	0.88549	0.07	0.28	0.59	0.76
BNFL	1.07194	0.97580	0.90020	0.87016	-1.18	-1.01	-0.69	-0.99
JAERI (MVP)	1.09004	0.98782	0.9045	0.88175	0.49	0.21	-0.22	0.33
JAERI (SWAT)	1.09248	0.99281	0.91364	0.89002	0.71	0.71	0.79	1.27
DTLR	1.08430	0.98470	0.90440	0.87650	-0.04	-0.11	-0.23	-0.26
ORNL	1.09625	1.00144	0.92544	0.90484	1.06	1.59	2.09	2.96
Average	1.08474	0.98578	0.90645	0.87882				
Stand. dev.	0.00892	0.00939	0.01008	0.01376				
Stand. dev. (%)	0.82	0.95	1.11	1.57				
Ave + SD	1.09365	0.99517	0.91653	0.89258				
Ave – SD	1.07582	0.97638	0.89637	0.86506				
Minimum	1.07057	0.96996	0.89012	0.85692				
Maximum	1.09625	1.00144	0.92544	0.90484				

Participant	Reactivity change (%)				Rel. difference in reactivity change (%)			
	EOC 1 → EOC2	EOC 2 → EOC 3	5 y cooling	Total	EOC 1 EOC2	EOC 2 EOC 3	5 y cooling	Total
NUPEC	-9.3	-9.1	-4.5	-22.9	0.3	2.0	30.0	5.8
CEA	-9.5	-9.2	-3.6	-22.3	2.3	3.8	4.0	3.2
GRS	-9.7	-9.2	-4.4	-23.3	4.7	4.0	25.0	7.7
PSI	-9.0	-8.5	-3.3	-20.8	-2.4	-4.4	-6.3	-3.8
BNFL	-9.2	-8.6	-3.8	-21.6	-0.7	-3.2	10.2	0.0
JAERI (MVP)	-9.5	-8.6	-2.9	-21.0	2.6	-3.2	-18.1	-3.1
JAERI (SWAT)	-9.2	-9.3	-2.9	-21.4	-0.7	4.8	-16.6	-1.0
DTLR	-9.3	-8.7	-3.5	-21.6	0.8	-1.9	1.1	-0.3
ORNL	-8.6	-8.7	-2.5	-19.8	-6.7	-1.9	-29.3	-8.4
Average	-9.3	-8.9	-3.5	-21.6				
Stand. dev.	0.3	0.3	0.7	1.1				
Stand. dev. (%)	-3.3	-3.6	-19.8	-5.0				
Ave + SD	-9.0	-8.6	-2.8	-20.6				
Ave – SD	-9.6	-9.2	-4.2	-22.7				
Minimum	-9.7	-9.3	-4.5	-23.3				
Maximum	-8.6	-8.5	-2.5	-19.8				

Table C.6. K$_\infty$ and reactivity change for Case 6

Pin cell model, weapons disposition MOX fuel





Appendix D

SUMMARY OF CALCULATION RESULTS FOR AVERAGE BURN-UP

Table D.1. Average burn-up for Case 1

Supercell model, first recycle MOX fuel

Participant	Burn-up (MWd/teHM)				Relative difference in burn-up (%)			
	High	Medium	Low	Assembly average	High	Medium	Low	Assembly average
NUPEC	49.259	45.519	42.736	47.999	-0.04	0.15	-0.15	0.00
CEA	49.087	45.867	43.415	48.000	-0.39	0.92	1.44	0.00
GRS	49.124	45.76	43.304	47.993	-0.32	0.68	1.18	-0.01
PSI	49.243	45.546	42.809	47.998	-0.07	0.21	0.03	0.00
BNFL	49.864	44.119	41.219	47.991	1.19	-2.93	-3.69	-0.02
JAERI	49.169	45.702	43.071	47.999	-0.22	0.55	0.64	0.00
DTLR	49.211	45.639	43.033	48.010	-0.14	0.42	0.55	0.02
Average	49.280	45.450	42.798	47.999				
Stand. dev.	0.265	0.599	0.738	0.006				
Stand dev. (%)	0.538	1.319	1.723	0.013				
Ave. + SD	49.545	46.049	43.536	48.005				
Ave. – SD	49.015	44.851	42.061	47.993				
Minimum	49.087	44.119	41.219	47.991				
Maximum	49.864	45.867	43.415	48.010				

Figure D.1. Average burn-up for Case 1

Supercell model, first recycle MOX fuel

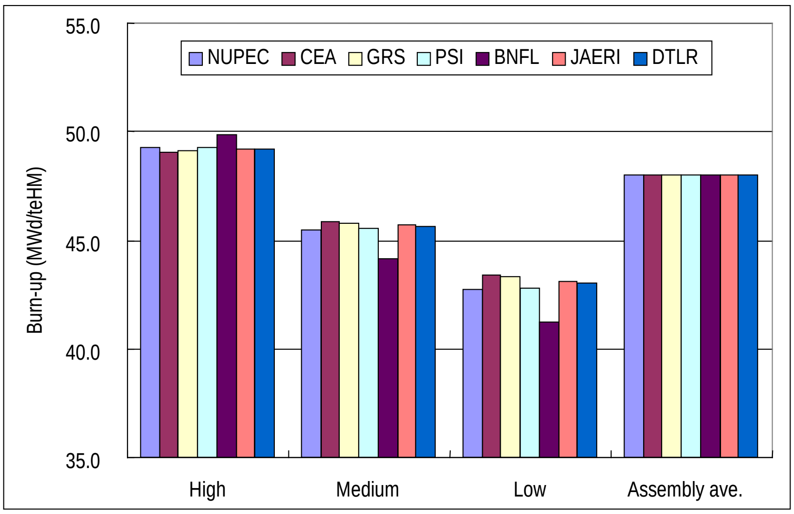


Table D.2. Average burn-up for Case 2

Supercell model, weapons disposition MOX fuel

Participant	Burn-up (MWd/teHM)				Relative difference in burn-up (%)			
	High	Medium	Low	Assembly average	High	Medium	Low	Assembly average
NUPEC	50.264	43.376	39.470	47.999	0.07	-0.14	-0.52	0.00
CEA	50.061	43.775	40.343	48.000	-0.34	0.78	1.68	0.00
GRS	50.204	43.489	39.748	47.999	-0.05	0.12	0.18	0.00
PSI	50.249	43.408	39.493	47.998	0.04	-0.06	-0.46	0.00
BNFL	50.423	43.000	39.240	48.003	0.38	-1.00	-1.10	0.00
JAERI	50.210	43.493	39.636	47.999	-0.04	0.13	-0.10	0.00
DTLR	50.203	43.503	39.802	48.004	-0.05	0.16	0.32	0.01
Average	50.231	43.435	39.676	48.000				
Stand. dev.	0.107	0.231	0.350	0.002				
Stand dev. (%)	0.214	0.532	0.881	0.005				
Ave. + SD	50.338	43.666	40.026	48.003				
Ave. – SD	50.123	43.204	39.326	47.998				
Minimum	50.061	43.000	39.240	47.998				
Maximum	50.423	43.775	40.343	48.004				

Figure D.2. Average burn-up for Case 2

Supercell model, weapons disposition MOX fuel

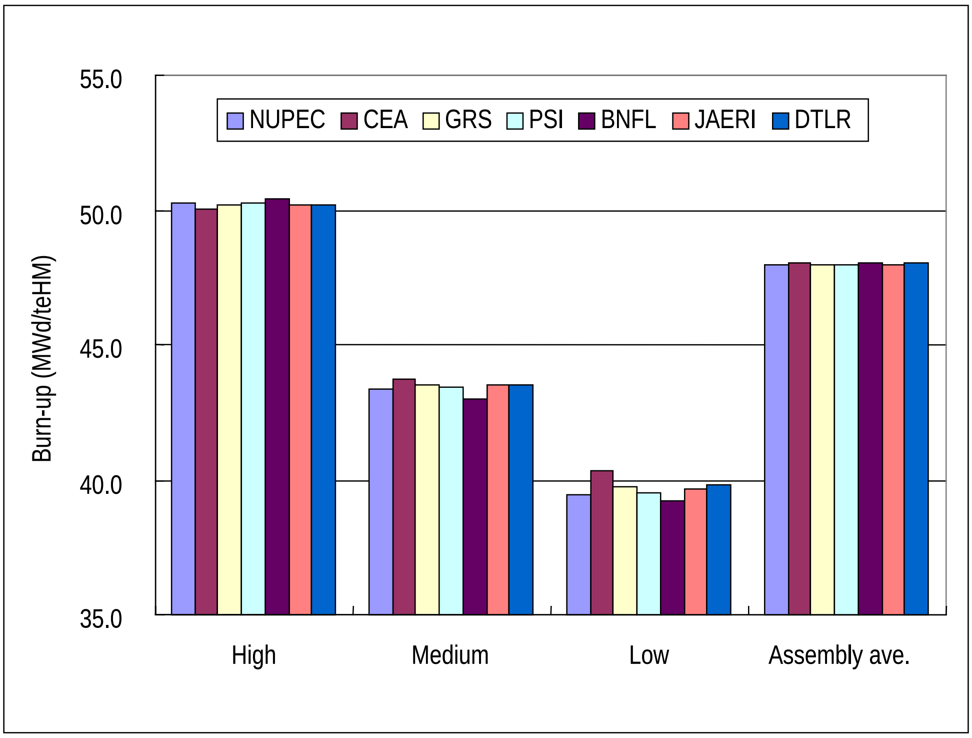


Table D.3. Average burn-up for Case 3

Assembly model, first recycle MOX fuel

Participant	Burn-up (MWd/teHM)				Relative difference in burn-up (%)			
	High	Medium	Low	Assembly average	High	Medium	Low	Assembly average
NUPEC	50.966	41.784	37.668	47.996	-0.04	0.04	0.37	0.00
CEA	50.910	41.960	37.612	48.000	-0.15	0.46	0.22	0.00
GRS	51.024	41.680	37.377	47.997	0.08	-0.21	-0.40	0.00
PSI	50.978	41.776	37.546	47.997	-0.01	0.02	0.05	0.00
BNFL	50.988	41.778	37.443	48.000	0.01	0.30	-0.23	0.00
JAERI	51.004	41.700	37.577	47.997	0.04	-0.16	0.13	0.00
DTLR	51.019	41.689	37.473	48.000	0.07	-0.19	-0.15	0.00
Average	50.984	41.767	37.528	47.998				
Stand. dev.	0.039	0.096	0.102	0.002				
Stand dev. (%)	0.076	0.231	0.272	0.004				
Ave. + SD	51.023	41.863	37.630	48.000				
Ave. – SD	50.945	41.670	37.426	47.997				
Minimum	50.910	41.680	37.377	47.996				
Maximum	51.024	41.960	37.668	48.000				

Figure D.3. Average burn-up for Case 3

Assembly model, first recycle MOX fuel

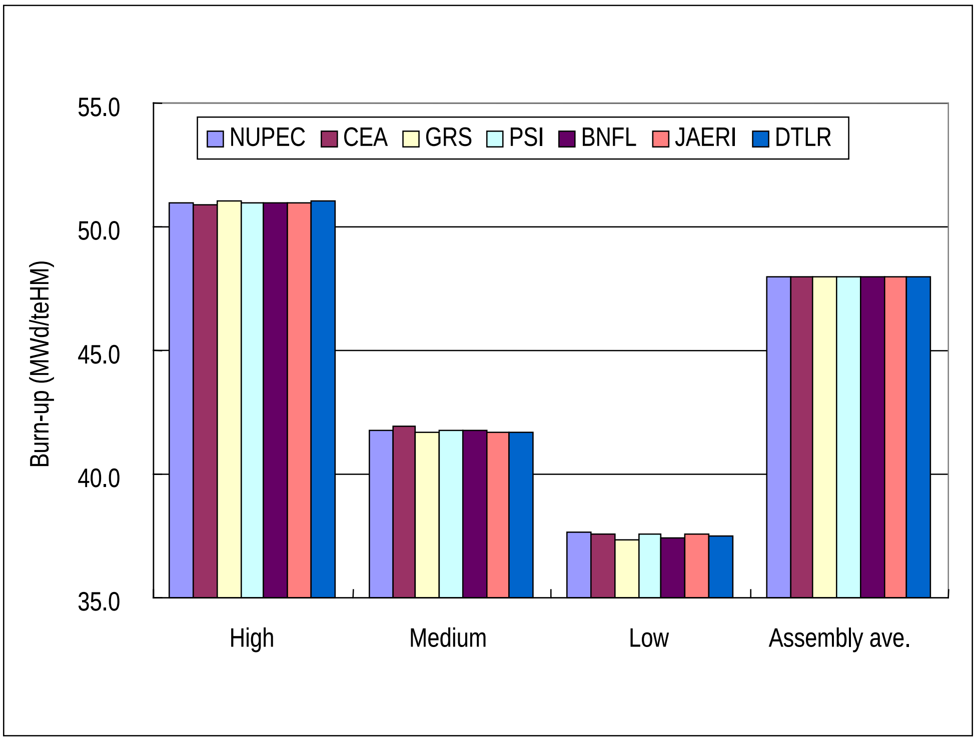


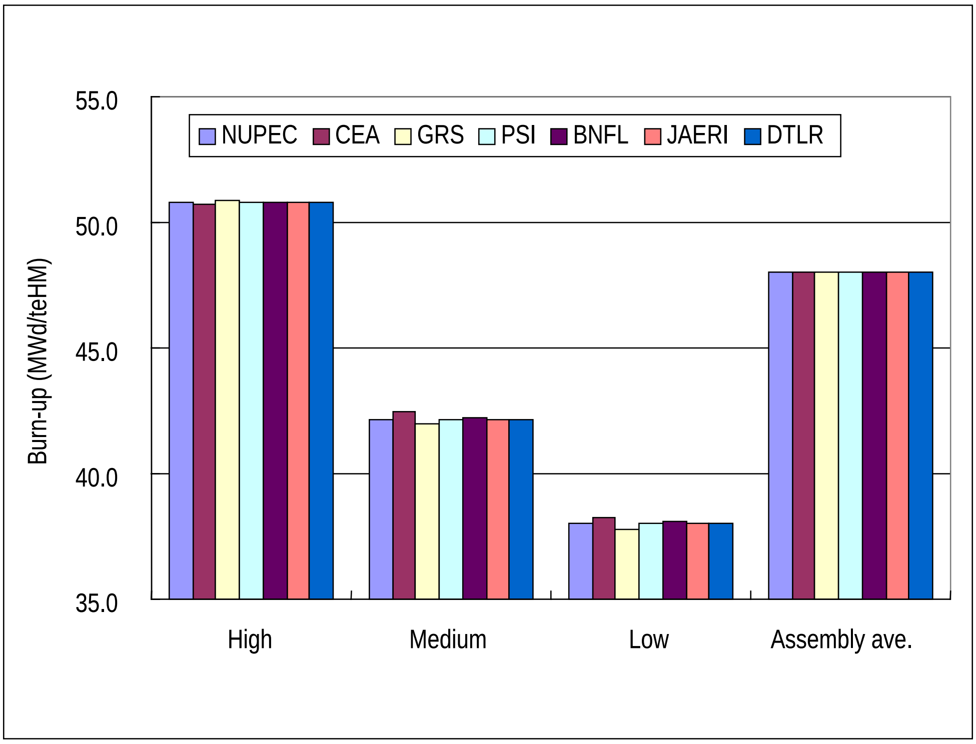
Table D.4. Average burn-up for Case 4

Assembly model, weapons disposition MOX fuel

Participant	Burn-up (MWd/teHM)				Relative difference in burn-up (%)			
	High	Medium	Low	Assembly average	High	Medium	Low	Assembly average
NUPEC	50.826	42.112	37.988	47.998	0.04	-0.14	-0.08	0.00
CEA	50.693	42.430	38.272	48.000	-0.22	0.61	0.67	0.00
GRS	50.880	42.005	37.786	47.999	0.15	-0.40	-0.61	0.00
PSI	50.810	42.156	37.984	47.998	0.01	-0.04	-0.09	0.00
BNFL	50.786	42.215	38.059	48.000	-0.03	0.10	0.11	0.00
JAERI	50.821	42.126	37.996	47.999	0.03	-0.11	-0.06	0.00
DTLR	50.809	42.158	38.036	48.000	0.01	-0.03	0.05	0.00
Average	50.804	42.172	38.017	47.999				
Stand. dev.	0.057	0.131	0.143	0.001				
Stand dev. (%)	0.111	0.310	0.376	0.002				
Ave. + SD	50.860	42.302	38.160	48.000				
Ave. – SD	50.747	42.041	37.874	47.998				
Minimum	50.693	42.005	37.786	47.998				
Maximum	50.880	42.430	38.272	48.000				

Figure D.4. Average burn-up for Case 4

Assembly model, weapons disposition MOX fuel



Appendix E

ADDITIONAL ANALYSIS RESULTS

E.1. Reactivity effects of ^{239}Pu by Greg O'Connor (DTLR)

Analysis of the Phase IV-A results [1] indicates that the ^{239}Pu nuclide is important in terms of its reactivity worth within MOX fuel. Therefore, for the initial analysis of the Phase IV-B results, it was considered appropriate to initially concentrate on this nuclide.

For the Phase IV-B OECD benchmark, the participants performed calculations using two initial MOX fuel compositions; first recycle MOX and MOX derived from the disposition of weapons. These two initial MOX compositions were irradiated in three different geometry arrangements intended to simulate the core of a reactor; MOX supercell, MOX assembly and MOX pin cell, schematically presented in Figures 1, 2 and 3 of Ref. [2], respectively.

From the results provided by the participants, the percentage difference between their final ^{239}Pu nuclide compositions and the k_∞ calculated from each of the participants final inventory composition are presented in Tables E.1 and E.2, respectively. It should be noted that the final results are evaluated at the end of Cycle 3. For intercomparison, the percentage deviation from the mean for both the first recycle MOX and weapons disposition MOX compositions are summarised in Tables E.1 and E.2, respectively.

From the first recycle MOX composition results presented in Table E.1, it can be seen that the contributions from BNFL give the largest predictions for the ^{239}Pu nuclide composition for each of the three reactor core geometry representations, while the GRS contributions give the smallest prediction for the ^{239}Pu nuclide composition for the assembly and pin cell models. The DTLR contribution gives the smallest ^{239}Pu nuclide composition prediction for the supercell geometry model.

From the weapons disposition MOX results presented in Table E.2, it can be seen that the contributions from BNFL again give the largest predictions for the ^{239}Pu nuclide composition for each of the three reactor core geometry representations. The NUPEC contributions give the smallest predictions for the ^{239}Pu nuclide composition for each of the three geometry representations.

It can be seen that comparing the highest and lowest ^{239}Pu isotopic predictions for both MOX fuel compositions from Tables E.1 and E.2 gives a discrepancy of about 8-10% for each of the three geometry models.

The results presented by Dr. Sakurai and Dr. Mitake [3] before the Burn-up Credit Working Group in Paris (2000), also show that there is approximately a 10% spread in the ^{239}Pu composition between the different participants.

Although there are large discrepancies in the calculated ^{239}Pu composition between the various participants, this does not necessarily mean that there will be large differences in the neutron multiplication factors for the MOX fuel, as there could be compensating effects from the other nuclides.

In order to test this theory, each of the participant's final MOX fuel compositions for each of the six cases were placed into pin cell models. The geometry chosen was similar to the pin cell model for the Phase IV-B Benchmark, presented in Figure 3 of Appendix A, except that the 600 ppm boronated water was replaced with the full density water from the Phase IV-A specification [4].

The calculations were run using the MONK code [5] until a standard deviation of 0.0005 was attained. The neutron multiplication factors produced from these calculations were converted into the percentage that they deviated from the mean. The values produced are presented in Tables E.3 and E.4 for the first recycle MOX case and the weapons disposition MOX case, respectively.

From the first recycle MOX results presented in Table E.3, it can be seen that the MOX fuel compositions calculated by JAERI give the largest neutron multiplication factors for each of the three reactor core geometry representations. The MOX fuel compositions calculated by GRS, give the smallest neutron multiplication factors for each of the three geometry representations.

From the weapons disposition MOX results presented in Table E.4, it can be seen that the MOX fuel compositions calculated by JAERI again give the largest neutron multiplication factors for each of the three reactor core geometry representations. The MOX fuel compositions calculated by NUPEC give the smallest neutron multiplication factors for each of the three geometry representations.

It can be seen that comparing the highest and lowest neutron multiplication factors (JAERI and GRS respectively) for the first recycle MOX case, Table E.3, gives a discrepancy of about 3% for each of the three geometry models. The discrepancy between the highest and lowest neutron multiplication factors (JAERI and NUPEC respectively) for the weapons disposition case, Table E.4, increases to approximately 4%.

The summary of k_∞ values, their standard deviations and spread are given in Table E.5.

REFERENCES

[1] R.L. Bowden, P.R. Thorne, G.J. O'Connor, "Burn-up Credit Criticality Benchmark, Results of Phase IV-A", Final Version, OECD/NEA document, to be published.

[2] P.R. Thorne, G.J. O'Connor, R.L. Bowden, "Problem Specification for the OECD/NEANSC Burn-up Credit Benchmark Phase IV-B: Mixed Oxide (MOX) Fuels", OECD/NEA document, November 1999.

[3] S. Sakurai, S. Mitake, "MOX Fuel Inventory Analysis with CASMO", Institute of Nuclear Safety, NUPEC, Japan, September 2000.

[4] R.L. Bowden, P.R. Thorne, "Problem Specification for the OECD/NEA NSC Burn-up Credit Benchmark Phase IV-A: Mixed Oxide (MOX) Fuels", Version 1, OECD/NEA document, March 1998.

[5] "MONK®, A Monte Carlo Program for Nuclear Criticality Safety and Reactor Physics Analyses", ANSWERS/MONK(98)6 Issue 2, User Guide for Version 8, AEA Technology, January 1999.

Table E.1. Percentage deviation from mean for ^{239}Pu composition predicted by each of the participants using first recycle MOX

^{239}Pu composition	First recycle MOX – Supercell model	First recycle MOX – Assembly model	First recycle MOX – Pin cell model
Maximum	BNFL (5.3%)	BNFL (3.5%)	BNFL (4.1%)
	PSI (2.4%)	JAERI[1] (1.8%)	PSI (2.8%)
	JAERI[1] (2.1%)	PSI (1.8%)	JAERI[2] (0.6%)
	CEA (-0.7%)	CEA (0.7%)	CEA (0.4%)
	NUPEC (-1.4%)	NUPEC (-1.4%)	JAERI[1] (0.1%)
	GRS (-2.9%)	DTLR (-2.4%)	NUPEC (-1.7%)
	DTLR (-4.8%)	GRS (-4.0%)	DTLR (-2.1%)
Minimum			GRS (-4.2%)

[1] JAERI contribution using MVP-BURN, JENDL-3.2, continuous energy.
[2] JAERI contribution using SWAT, JENDL-3.2, 107 groups.
Note: Codes and data used for all contributions are presented in Table 2.1.

Table E.2. Percentage deviation from mean for ^{239}Pu composition predicted by each of the participants using weapons disposition MOX

^{239}Pu composition	Weapons disposition MOX – Supercell model	Weapons disposition MOX – Assembly model	Weapons disposition MOX – Pin cell model
Maximum	BNFL (4.9%)	BNFL (3.9%)	BNFL (4.5%)
	PSI (3.2%)	JAERI[1] (2.5%)	PSI (4.0%)
	GRS (3.1%)	PSI (2.2%)	JAERI[2] (0.1%)
	JAERI[1] (-0.6%)	DTLR (-0.8%)	DTLR (0.1%)
	CEA (-2.0%)	CEA (-1.2%)	JAERI[1] (-0.4%)
	DTLR (-4.3%)	GRS (-1.8%)	GRS (-1.4%)
	NUPEC (-4.3%)	NUPEC (-4.8%)	CEA (-1.7%)
Minimum			NUPEC (-5.1%)

[1] JAERI contribution using MVP-BURN, JENDL-3.2, continuous energy.
[2] JAERI contribution using SWAT, JENDL-3.2, 107 groups.
Note: Codes and data used for all contributions are presented in Table 2.1.

Table E.3. Percentage deviation from mean for the neutron multiplication factor (k_{eff}) calculated from each of the participants final inventory compositions using first recycle MOX

Neutron multiplication factor (k_{eff})	First recycle MOX – Supercell model	First recycle MOX – Assembly model	First recycle MOX – Pin cell model
Maximum	JAERI[1] (1.9%)	JAERI[1] (1.8%)	JAERI[1] (1.6%)
	BNFL (0.7%)	BNFL (0.4%)	BNFL (0.6%)
	PSI (0.1%)	PSI (-0.1%)	JAERI[2] (0.5%)
	NUPEC (-0.2%)	CEA (-0.3%)	PSI (0.1%)
	CEA (-0.7%)	NUPEC (-0.3%)	NUPEC (-0.4%)
	DTLR (-0.8%)	DTLR (-0.4%)	DTLR (-0.5%)
	GRS (-1.0%)	GRS (-1.2%)	CEA (-0.5%)
Minimum			GRS (-1.4%)

[1] JAERI contribution using MVP-BURN, JENDL-3.2, continuous energy.
[2] JAERI contribution using SWAT, JENDL-3.2, 107 groups.
Note: Codes and data used for all contributions are presented in Table 2.1.

Table E.4. Percentage deviation from mean for the neutron multiplication factor (k_{eff}) calculated from each of the participants final inventory compositions using weapons disposition MOX

Neutron multiplication factor (k_{eff})	Weapons disposition MOX		
	Supercell model	**Assembly model**	**Pin cell model**
Maximum	JAERI[1] (1.9%)	JAERI[1] (2.3%)	JAERI[1] (1.9%)
	BNFL (0.7%)	BNFL (0.6%)	BNFL (0.8%)
	GRS (0.5%)	PSI (0.2%)	JAERI[2] (0.5%)
	PSI (0.5%)	DTLR (0.0%)	PSI (0.5%)
	CEA (-0.9%)	GRS (-0.6%)	DTLR (0.1%)
	DTLR (-1.0%)	CEA (-0.8%)	GRS (-0.7%)
	NUPEC (-1.8%)	NUPEC (-1.9%)	CEA (-1.0%)
Minimum			NUPEC (-2.1%)

[1] JAERI contribution using MVP-BURN, JENDL-3.2, continuous energy.
[2] JAERI contribution using SWAT, JENDL-3.2, 107 groups.
Note: Codes and data used for all contributions are presented in Table 2.1.

Table E.5. K_∞ calculated from each of the participants final inventory compositions by the MONK code

Participant	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
DTLR	1.0254	0.9843	1.0426	1.0061	1.0440	1.0105
JAERI (MVP)	1.0539	1.0132	1.0658	1.0294	1.0662	1.0290
JAERI (SWAT)					1.0546	1.0150
BNFL	1.0413	1.0018	1.0510	1.0121	1.0551	1.0176
PSI	1.0353	0.9993	1.0457	1.0077	1.0500	1.0149
GRS	1.0236	0.9999	1.0345	1.0002	1.0349	1.0024
CEA	1.0265	0.9855	1.0345	0.9982	1.0438	0.9991
NUPEC	1.0325	0.9781	1.0430	0.9872	1.0448	0.9888
Average	1.0341	0.9946	1.0466	1.0058	1.0492	1.0097
Standard deviation	0.0107	0.0123	0.0098	0.0131	0.0095	0.0125
Percentage spread	2.9	3.5	3.0	4.2	3.0	4.0

E.2. Burn-up zone division and burn-up step length sensitivity study by Peter Grimm (PSI)

There are two possible improvements which appear to be applicable to BOXER [1] calculations, *viz*. the radial subdivision of the pin and the number of burn-up steps. Consequently, two more calculations for Case 6 were performed:

- In one case, the fuel pellet was subdivided radially into five zones of equal cross-sectional areas and zone-wise self-shielding of the resonances was applied (in the standard model or base case, the fuel pellet was represented by a single zone).

- In the second case, the maximum length of the burn-up steps was reduced from 4 GWd/t to 2 GWd/t. The shorter steps at the beginning of each cycle of irradiation were retained.

As the BOXER code and the associated cross-section library have been modified since the original calculation was carried out two years ago, we also reran the base case using the current version. The new calculation reproduces the original results practically perfectly, with only a few small deviations in the last digit of the output. The results of the new calculations and the comparison with the base case are shown in Tables E.6, E.7 and E.8 where the nuclide names should be self-evident, for example the number "195242" stands for ^{242m}Am.

The results are little sensitive to the two options tested. This is consistent with our previous experience with BOXER. In the case of the radial subdivision, the changes of the nuclide densities are less than 1%, except for ^{244}Cm and ^{245}Cm. Maybe more interesting is the trend for ^{240}Pu and ^{241}Pu; the density of the former is systematically higher and that of the latter lower in the case of five radial zones. In other words, the ratio ^{241}Pu/^{240}Pu is reduced up to 1.7% by the subdivision. The effect on k_∞ remains within about 100 pcm ($\Delta k/k$) throughout the fuel life.

The impact of the shorter burn-up steps on the nuclide densities is also small for most of the nuclides, particularly for the major actinides. The largest changes are found for ^{155}Gd, ^{149}Sm, ^{103}Rh and ^{151}Sm. This observation leads me to suspect that the differences are linked to the numerical methods in BOXER. In the depletion calculation, asymptotic densities of short-lived nuclides are computed analytically.

^{155}Gd, ^{149}Sm and ^{103}Rh or their precursors (^{103}Ru and ^{149}Pm) are treated using this method. The calculation of the ^{155}Gd density is switched from the asymptotic method to the normal Taylor series expansion when the burn-up step is reduced from 4 to 2 GWd/t. This is probably the cause for the relatively big difference found in the density of this nuclide, especially at low burn-up. However, this difference is not really relevant for burn-up credit, because ^{155}Gd in fuel cooled for some time originates mostly from the decay of ^{155}Eu after the discharge. The effect of the burn-up steps on k_∞ is even smaller than that of the radial subdivision and reaches a maximum of 71 pcm at end of life (48 GWd/t).

Thus, this study has shown that the BOXER results should be correct in the sense that they are not affected by insufficient approximations. There are of course other parameters in the calculations, the sensitivity to which could be investigated almost indefinitely, but based on our experience we do not expect any significant effect. We do not have a clear idea as to what could be the cause of the 10% spread in the ^{239}Pu density observed.

REFERENCE

[1] J.M. Paratte, P. Grimm, J.M. Hollard, “ELCOS, The PSI Code System for LWR Core Analysis, Part II: User’s Manual for the Fuel Assembly Code BOXER,” PSI Report 96-08, February 1996.

Table E.6. Calculated k_∞ and nuclide density for base case

Base case (1 region, burn-up step 4 GWd/t)				
Burn-up (MWd/t)	**16000**	**32000**	**48000**	**48000 5 y cooling**
92234	2.2260E-07	1.8754E-07	1.7399E-07	4.1485E-07
92235	4.2013E-05	2.9191E-05	1.8752E-05	1.8752E-05
92236	3.1463E-06	5.5072E-06	7.0291E-06	7.0291E-06
92238	2.2038E-02	2.1765E-02	2.1467E-02	2.1467E-02
94238	7.2527E-07	2.0838E-06	4.8067E-06	6.1788E-06
94239	5.7981E-04	3.8829E-04	2.7378E-04	2.7594E-04
94240	1.4792E-04	1.8476E-04	1.8322E-04	1.8395E-04
94241	5.7546E-05	9.5358E-05	1.0642E-04	8.3603E-05
94242	5.3826E-06	1.9557E-05	3.9631E-05	3.9633E-05
93237	1.6938E-06	3.2645E-06	4.5453E-06	4.7485E-06
95241	1.3316E-06	3.7493E-06	5.2376E-06	2.7921E-05
195242	2.5882E-08	9.2764E-08	1.3466E-07	1.3139E-07
95243	6.2852E-07	3.6669E-06	9.5721E-06	9.5766E-06
96242	1.5362E-07	7.8303E-07	1.5904E-06	1.0140E-09
96243	1.6848E-09	1.6585E-08	4.8291E-08	4.2872E-08
96244	9.8738E-08	1.0411E-06	4.1598E-06	3.4354E-06
96245	3.8026E-09	6.9096E-08	3.7125E-07	3.7110E-07
42095	1.8204E-05	3.5100E-05	5.0594E-05	5.0594E-05
43099	2.1909E-05	4.1694E-05	5.9150E-05	5.9360E-05
44101	2.2890E-05	4.4765E-05	6.5504E-05	6.5504E-05
45103	1.8776E-05	3.4904E-05	4.5884E-05	4.9175E-05
47109	4.5541E-06	8.2345E-06	1.1276E-05	1.1276E-05
55133	2.3817E-05	4.4918E-05	6.2865E-05	6.3312E-05
60143	1.5241E-05	2.8729E-05	3.9107E-05	3.9869E-05
60145	1.1412E-05	2.1830E-05	3.1169E-05	3.1169E-05
62147	7.7166E-07	2.2874E-06	3.6614E-06	9.5113E-06
62149	2.2509E-07	1.9656E-07	1.6747E-07	2.2382E-07
62150	5.1385E-06	1.1188E-05	1.7357E-05	1.7357E-05
62151	8.9053E-07	8.6180E-07	8.2491E-07	7.9473E-07
62152	2.9745E-06	4.8501E-06	5.7378E-06	5.7378E-06
63153	2.2645E-06	5.4188E-06	8.1493E-06	8.2008E-06
64155	5.2990E-09	8.0615E-09	1.1333E-08	4.4447E-07
k_∞	1.08547	0.98849	0.91182	0.88549

Table E.7. Sensitivity of number of burn-up regions in fuel

5 radial regions in fuel (burn-up step 4 GWd/t)				
Burn-up (MWd/t)	**16000**	**32000**	**48000**	**48000 5 y cooling**
92234	2.2248E-07	1.8741E-07	1.7384E-07	4.1385E-07
92235	4.2023E-05	2.9246E-05	1.8847E-05	1.8847E-05
92236	3.1464E-06	5.5013E-06	7.0188E-06	7.0188E-06
92238	2.2038E-02	2.1763E-02	2.1465E-02	2.1465E-02
94238	7.2607E-07	2.0849E-06	4.7960E-06	6.1559E-06
94239	5.8089E-04	3.9008E-04	2.7528E-04	2.7744E-04
94240	1.4793E-04	1.8528E-04	1.8484E-04	1.8557E-04
94241	5.7209E-05	9.4503E-05	1.0558E-04	8.2939E-05
94242	5.4429E-06	1.9619E-05	3.9518E-05	3.9520E-05
93237	1.6957E-06	3.2689E-06	4.5531E-06	4.7552E-06
95241	1.3232E-06	3.7086E-06	5.1843E-06	2.7688E-05
195242	2.5855E-08	9.2010E-08	1.3358E-07	1.3034E-07
95243	6.3507E-07	3.6869E-06	9.5735E-06	9.5777E-06
96242	1.5463E-07	7.8115E-07	1.5776E-06	1.0058E-09
96243	1.7029E-09	1.6628E-08	4.8073E-08	4.2679E-08
96244	9.9843E-08	1.0525E-06	4.1878E-06	3.4585E-06
96245	3.8576E-09	7.0155E-08	3.7570E-07	3.7555E-07
42095	1.8201E-05	3.5093E-05	5.0589E-05	5.0589E-05
43099	2.1903E-05	4.1677E-05	5.9118E-05	5.9328E-05
44101	2.2889E-05	4.4761E-05	6.5499E-05	6.5499E-05
45103	1.8772E-05	3.4888E-05	4.5853E-05	4.9143E-05
47109	4.5525E-06	8.2257E-06	1.1253E-05	1.1253E-05
55133	2.3810E-05	4.4896E-05	6.2824E-05	6.3271E-05
60143	1.5237E-05	2.8725E-05	3.9120E-05	3.9882E-05
60145	1.1411E-05	2.1824E-05	3.1159E-05	3.1159E-05
62147	7.7092E-07	2.2838E-06	3.6541E-06	9.4922E-06
62149	2.2513E-07	1.9715E-07	1.6826E-07	2.2462E-07
62150	5.1420E-06	1.1196E-05	1.7367E-05	1.7367E-05
62151	8.8944E-07	8.6311E-07	8.2666E-07	7.9642E-07
62152	2.9712E-06	4.8391E-06	5.7210E-06	5.7210E-06
63153	2.2686E-06	5.4251E-06	8.1551E-06	8.2068E-06
64155	5.3080E-09	8.1141E-09	1.1441E-08	4.4604E-07
k_∞	1.08474	0.98841	0.91174	0.88574

% deviation from base case				
Burn-up (MWd/t)	**16000**	**32000**	**48000**	**48000 5 y cooling**
92234	-0.05	-0.07	-0.08	-0.24
92235	0.02	0.19	0.51	0.51
92236	0.00	-0.11	-0.15	-0.15
92238	0.00	-0.01	-0.01	-0.01
94238	0.11	0.05	-0.22	-0.37
94239	0.19	0.46	0.55	0.54
94240	0.00	0.28	0.88	0.88
94241	-0.58	-0.90	-0.79	-0.79
94242	1.12	0.32	-0.29	-0.29
93237	0.11	0.14	0.17	0.14
95241	-0.63	-1.09	-1.02	-0.84
195242	-0.11	-0.81	-0.80	-0.80
95243	1.04	0.54	0.01	0.01
96242	0.66	-0.24	-0.81	-0.80
96243	1.07	0.26	-0.45	-0.45
96244	1.12	1.09	0.67	0.67
96245	1.45	1.53	1.20	1.20
42095	-0.02	-0.02	-0.01	-0.01
43099	-0.03	-0.04	-0.05	-0.05
44101	0.00	-0.01	-0.01	-0.01
45103	-0.02	-0.04	-0.07	-0.06
47109	-0.03	-0.11	-0.20	-0.20
55133	-0.03	-0.05	-0.06	-0.06
60143	-0.03	-0.02	0.03	0.03
60145	-0.01	-0.03	-0.03	-0.03
62147	-0.10	-0.16	-0.20	-0.20
62149	0.02	0.30	0.47	0.36
62150	0.07	0.07	0.06	0.06
62151	-0.12	0.15	0.21	0.21
62152	-0.11	-0.23	-0.29	-0.29
63153	0.18	0.12	0.07	0.07
64155	0.17	0.65	0.95	0.35

Table E.8. Sensitivity of burn-up step length

Burn-up step 2 GWd/t (1 radial region)				
Burn-up (MWd/t)	**16000**	**32000**	**48000**	**48000 5 y cooling**
92234	2.2276E-07	1.8774E-07	1.7416E-07	4.1485E-07
92235	4.2013E-05	2.9177E-05	1.8725E-05	1.8725E-05
92236	3.1454E-06	5.5087E-06	7.0331E-06	7.0331E-06
92238	2.2039E-02	2.1766E-02	2.1468E-02	2.1468E-02
94238	7.2416E-07	2.0802E-06	4.7986E-06	6.1749E-06
94239	5.7932E-04	3.8760E-04	2.7299E-04	2.7517E-04
94240	1.4773E-04	1.8453E-04	1.8296E-04	1.8368E-04
94241	5.7572E-05	9.5106E-05	1.0591E-04	8.3196E-05
94242	5.4217E-06	1.9678E-05	3.9848E-05	3.9851E-05
93237	1.6873E-06	3.2543E-06	4.5333E-06	4.7366E-06
95241	1.3341E-06	3.7489E-06	5.2262E-06	2.7799E-05
195242	2.5856E-08	9.2360E-08	1.3370E-07	1.3046E-07
95243	6.2605E-07	3.6511E-06	9.5375E-06	9.5420E-06
96242	1.5451E-07	7.8643E-07	1.5942E-06	1.0133E-09
96243	1.6870E-09	1.6587E-08	4.8256E-08	4.2842E-08
96244	9.7822E-08	1.0356E-06	4.1421E-06	3.4207E-06
96245	3.7780E-09	6.8670E-08	3.6816E-07	3.6801E-07
42095	1.8203E-05	3.5099E-05	5.0594E-05	5.0594E-05
43099	2.1911E-05	4.1705E-05	5.9171E-05	5.9385E-05
44101	2.2890E-05	4.4766E-05	6.5509E-05	6.5509E-05
45103	1.8966E-05	3.5296E-05	4.6413E-05	4.9797E-05
47109	4.5607E-06	8.2483E-06	1.1295E-05	1.1295E-05
55133	2.3817E-05	4.4929E-05	6.2888E-05	6.3342E-05
60143	1.5228E-05	2.8708E-05	3.9070E-05	3.9843E-05
60145	1.1413E-05	2.1832E-05	3.1173E-05	3.1173E-05
62147	7.7201E-07	2.2905E-06	3.6674E-06	9.5270E-06
62149	2.2045E-07	1.9279E-07	1.6458E-07	2.2183E-07
62150	5.1423E-06	1.1192E-05	1.7361E-05	1.7361E-05
62151	8.8432E-07	8.5399E-07	8.1722E-07	7.8733E-07
62152	2.9849E-06	4.8656E-06	5.7546E-06	5.7546E-06
63153	2.2618E-06	5.4176E-06	8.1521E-06	8.2044E-06
64155	4.7599E-09	7.3380E-09	1.0949E-08	4.4055E-07
k_∞	1.08566	0.98832	0.91117	0.88486

% deviation from base case				
Burn-up (MWd/t)	**16000**	**32000**	**48000**	**48000 5 y cooling**
92234	0.07	0.11	0.10	0.00
92235	0.00	-0.05	-0.14	-0.14
92236	-0.03	0.03	0.06	0.06
92238	0.00	0.00	0.00	0.00
94238	-0.15	-0.17	-0.17	-0.06
94239	-0.08	-0.18	-0.29	-0.28
94240	-0.13	-0.12	-0.14	-0.15
94241	0.05	-0.26	-0.48	-0.49
94242	0.73	0.62	0.55	0.55
93237	-0.38	-0.31	-0.26	-0.25
95241	0.19	-0.01	-0.22	-0.44
195242	-0.10	-0.44	-0.71	-0.71
95243	-0.39	-0.43	-0.36	-0.36
96242	0.58	0.43	0.24	-0.07
96243	0.13	0.01	-0.07	-0.07
96244	-0.93	-0.53	-0.43	-0.43
96245	-0.65	-0.62	-0.83	-0.83
42095	-0.01	0.00	0.00	0.00
43099	0.01	0.03	0.04	0.04
44101	0.00	0.00	0.01	0.01
45103	1.01	1.12	1.15	1.26
47109	0.14	0.17	0.17	0.17
55133	0.00	0.02	0.04	0.05
60143	-0.09	-0.07	-0.09	-0.07
60145	0.01	0.01	0.01	0.01
62147	0.05	0.14	0.16	0.17
62149	-2.06	-1.92	-1.73	-0.89
62150	0.07	0.04	0.02	0.02
62151	-0.70	-0.91	-0.93	-0.93
62152	0.35	0.32	0.29	0.29
63153	-0.12	-0.02	0.03	0.04
64155	-10.17	-8.97	-3.39	-0.88

Appendix F

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 1

Supercell model, first recycle MOX fuel

Figure F.1. Relative difference of actinide nuclide densities at the end of Cycle 1

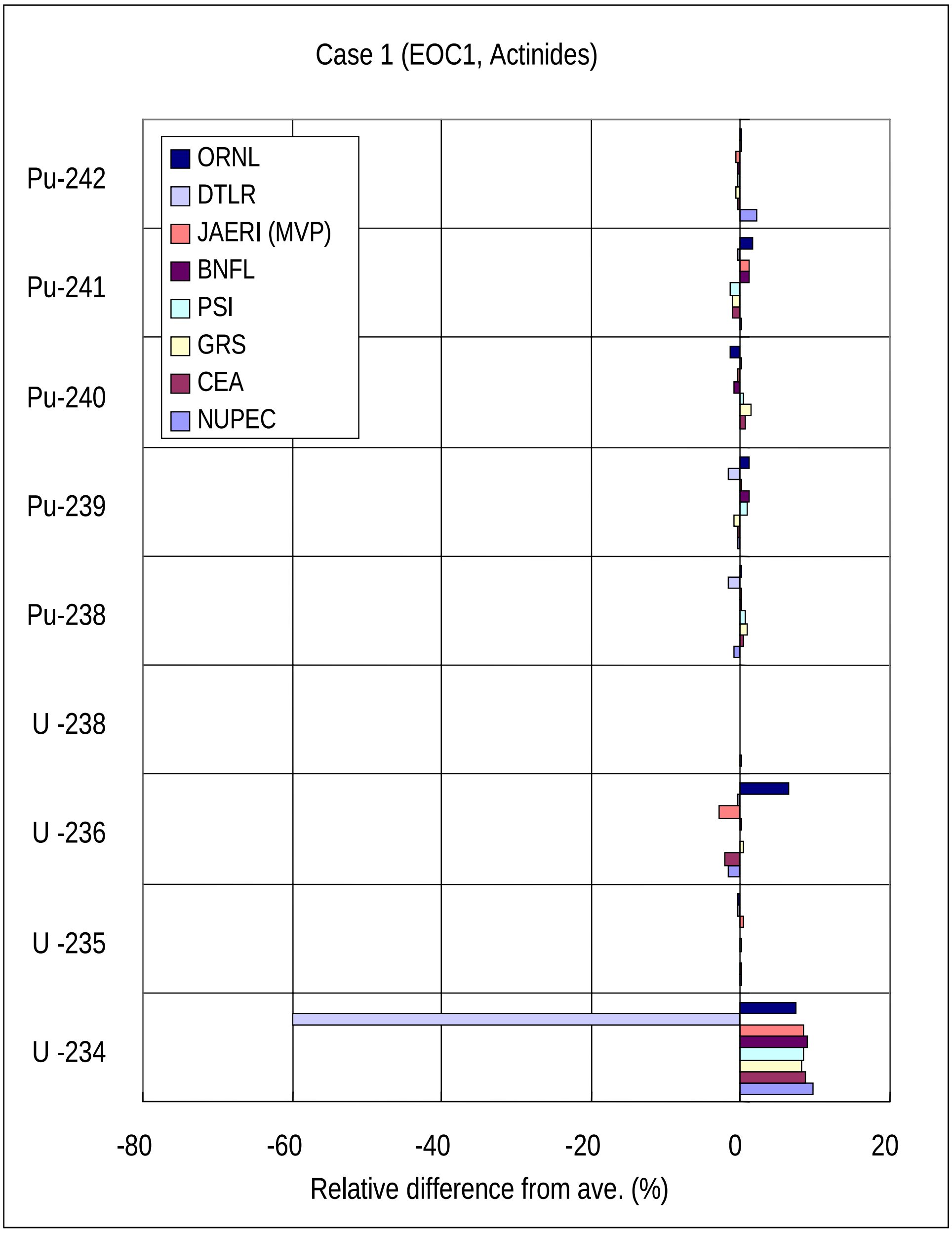


Figure F.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

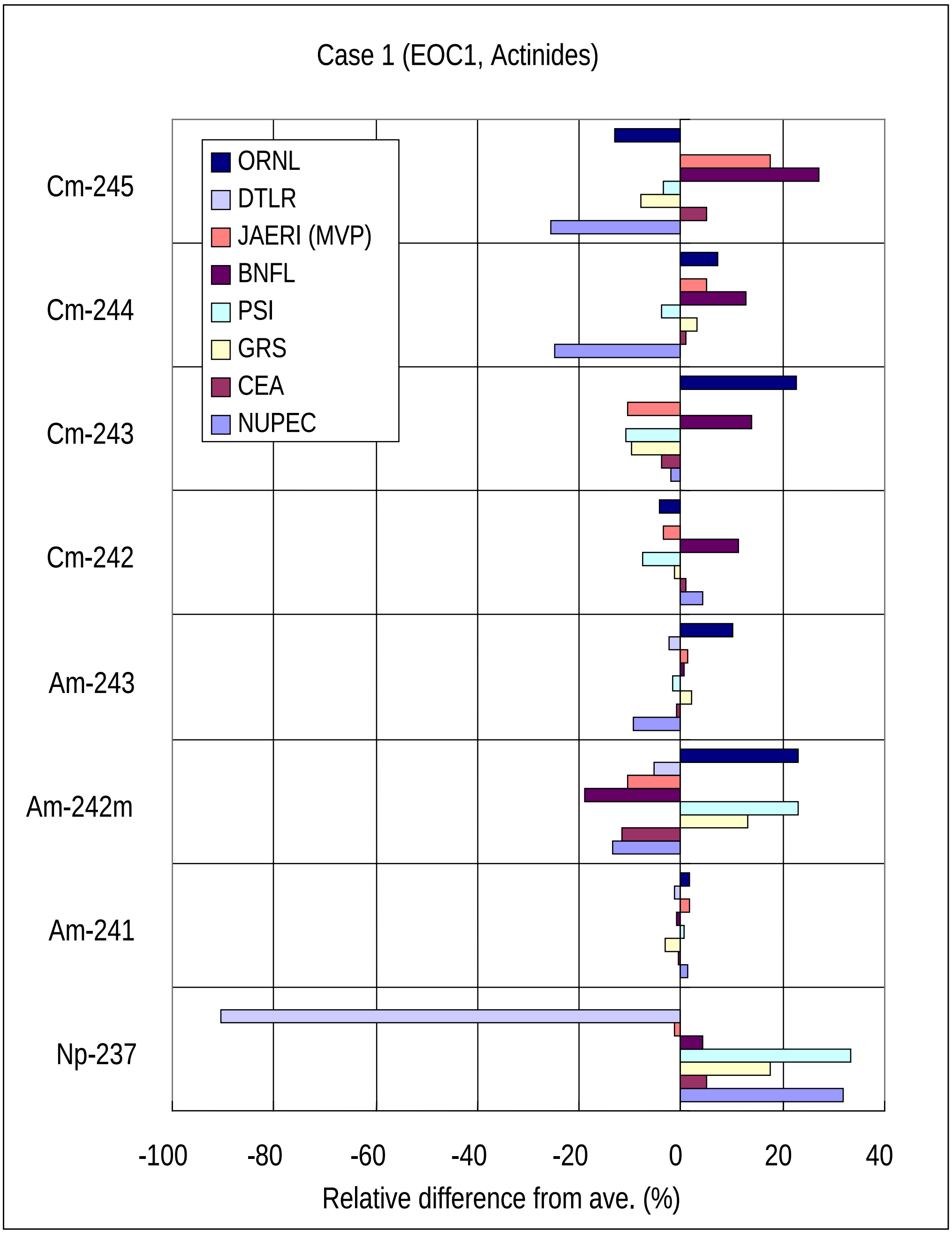


Figure F.2. Relative difference of fission product nuclide densities at the end of Cycle 1

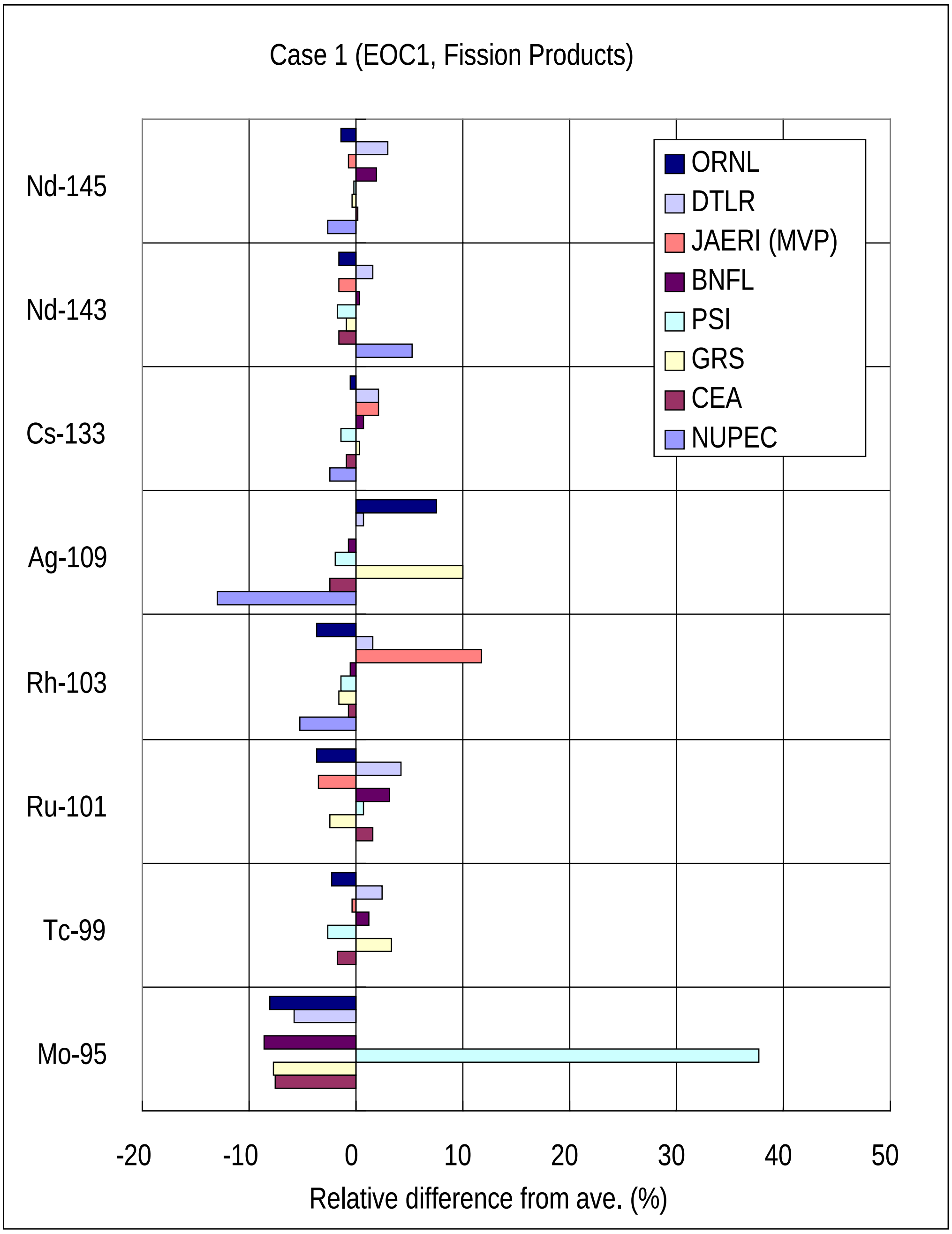


Figure F.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

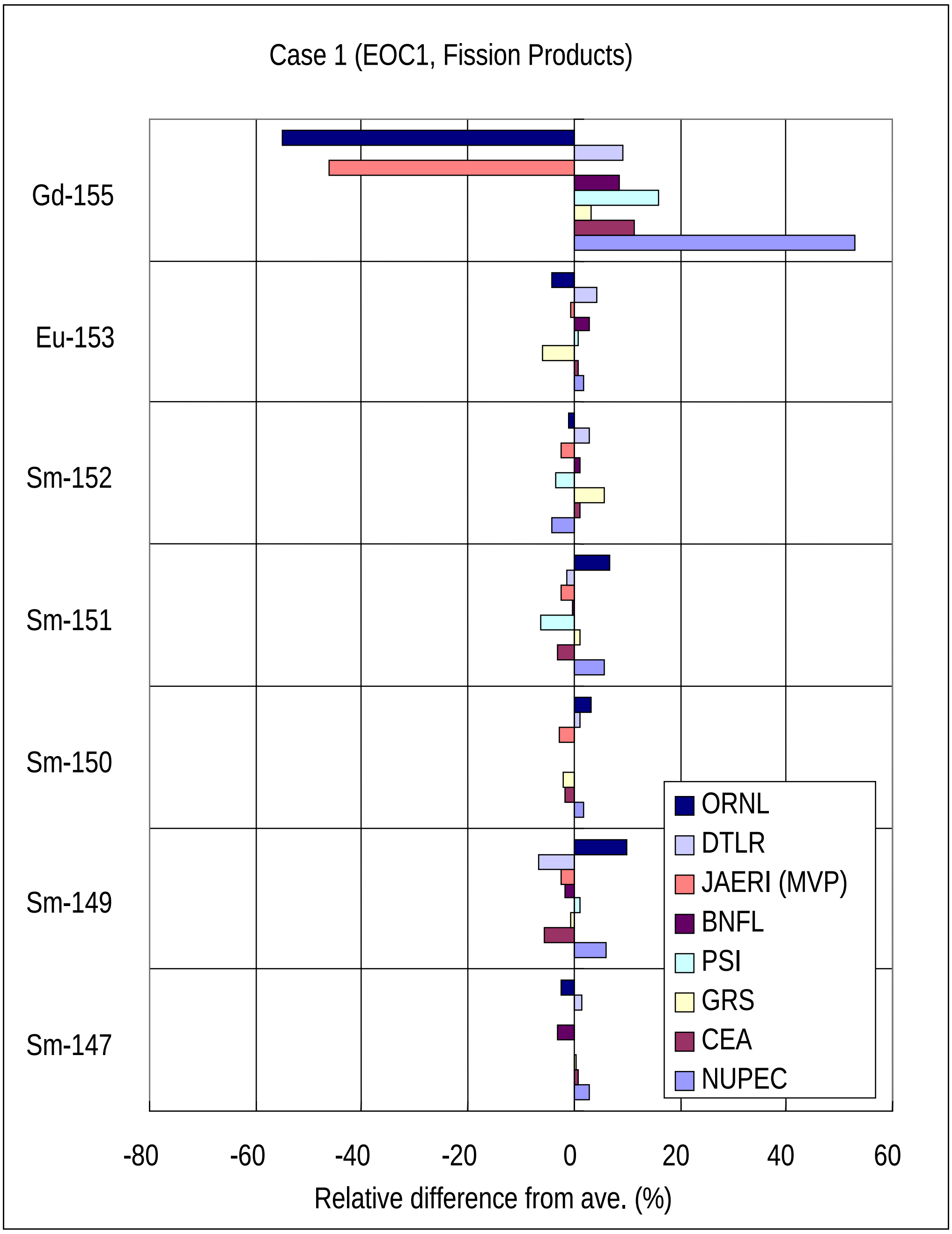


Figure F.3. Relative difference of actinide nuclide densities at the end of Cycle 3

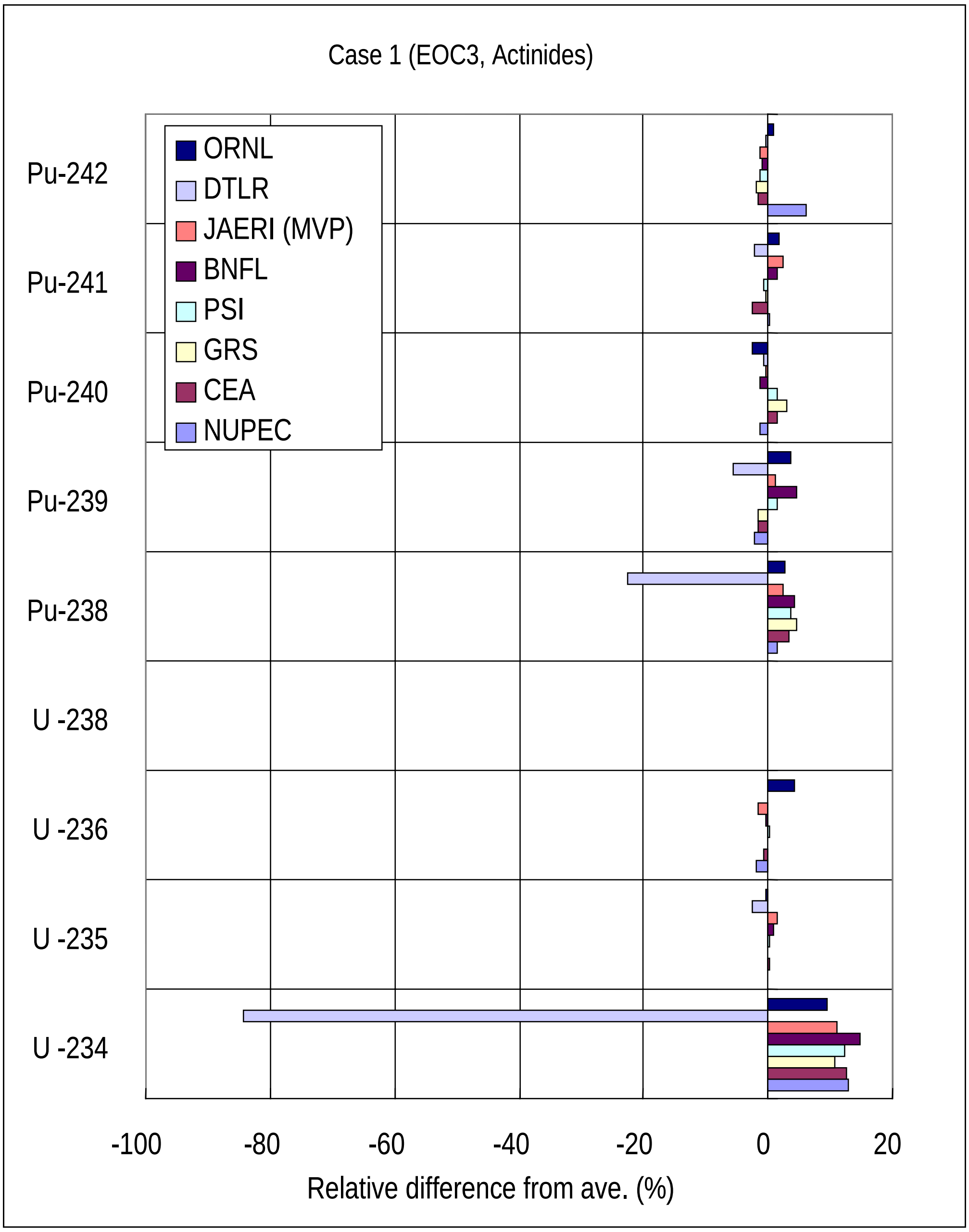


Figure F.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

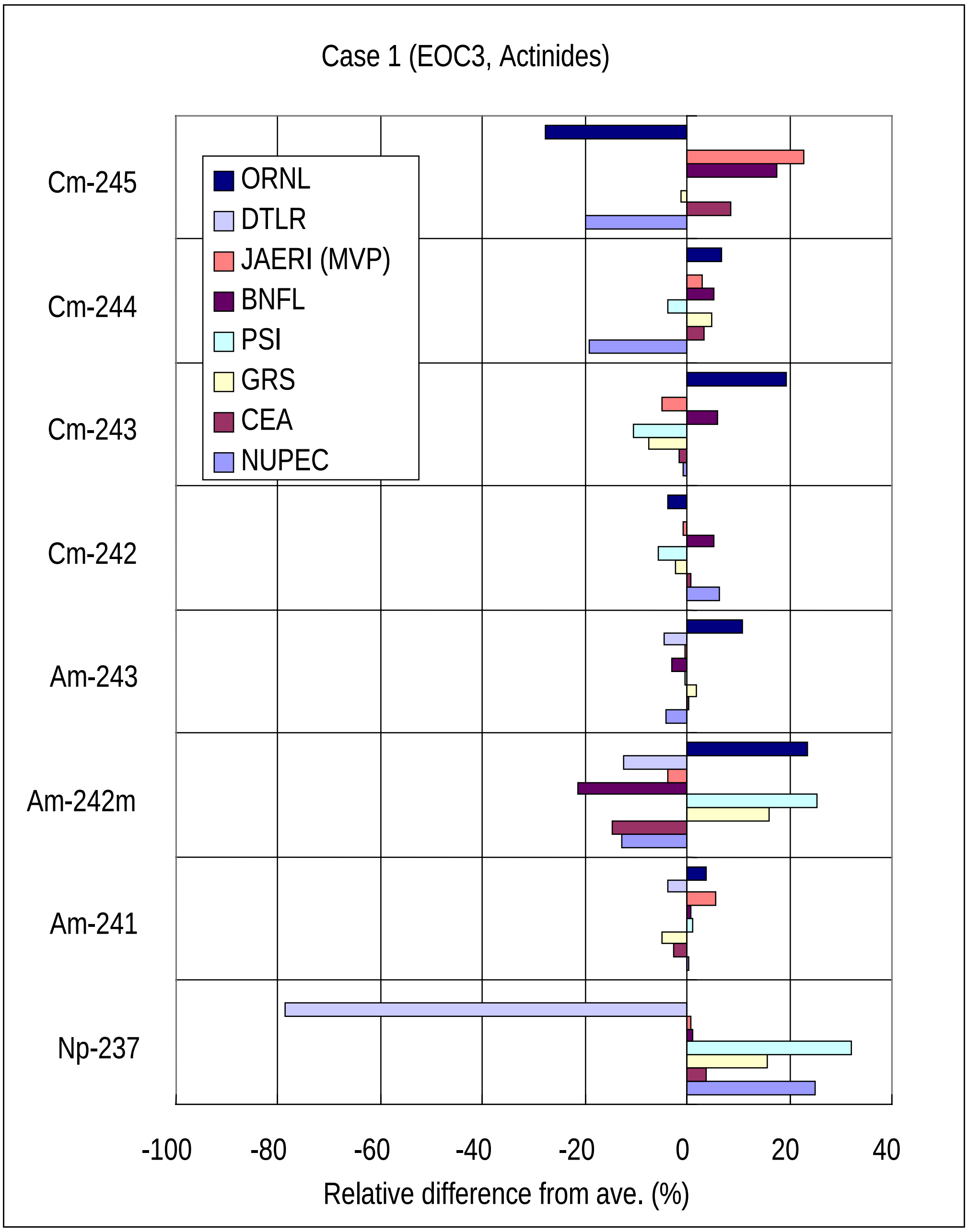


Figure F.4. Relative difference of fission product nuclide densities at the end of Cycle 3

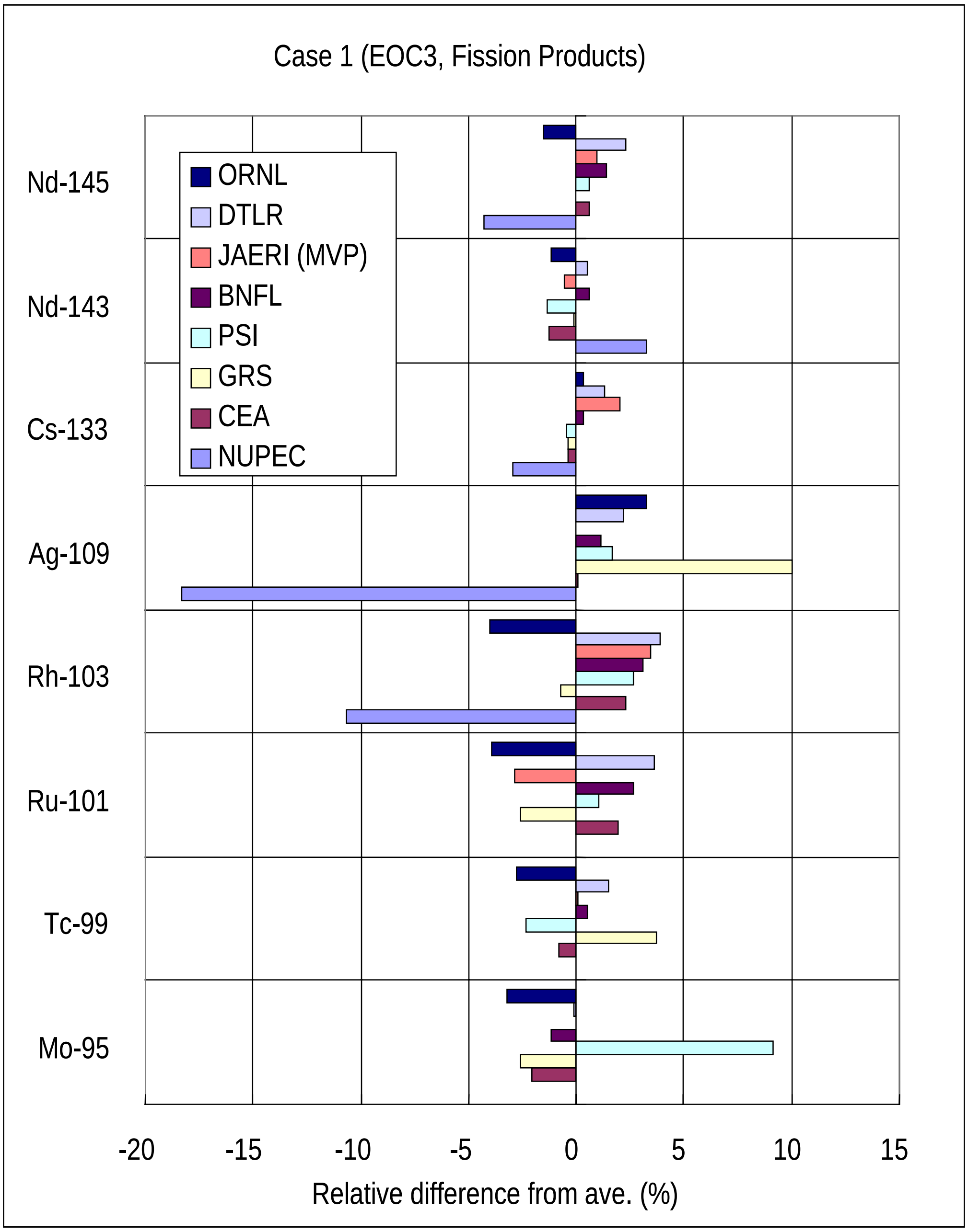


Figure F.4. Relative difference of fission product nuclide densities at the end of Cycle 3 (*cont.*)

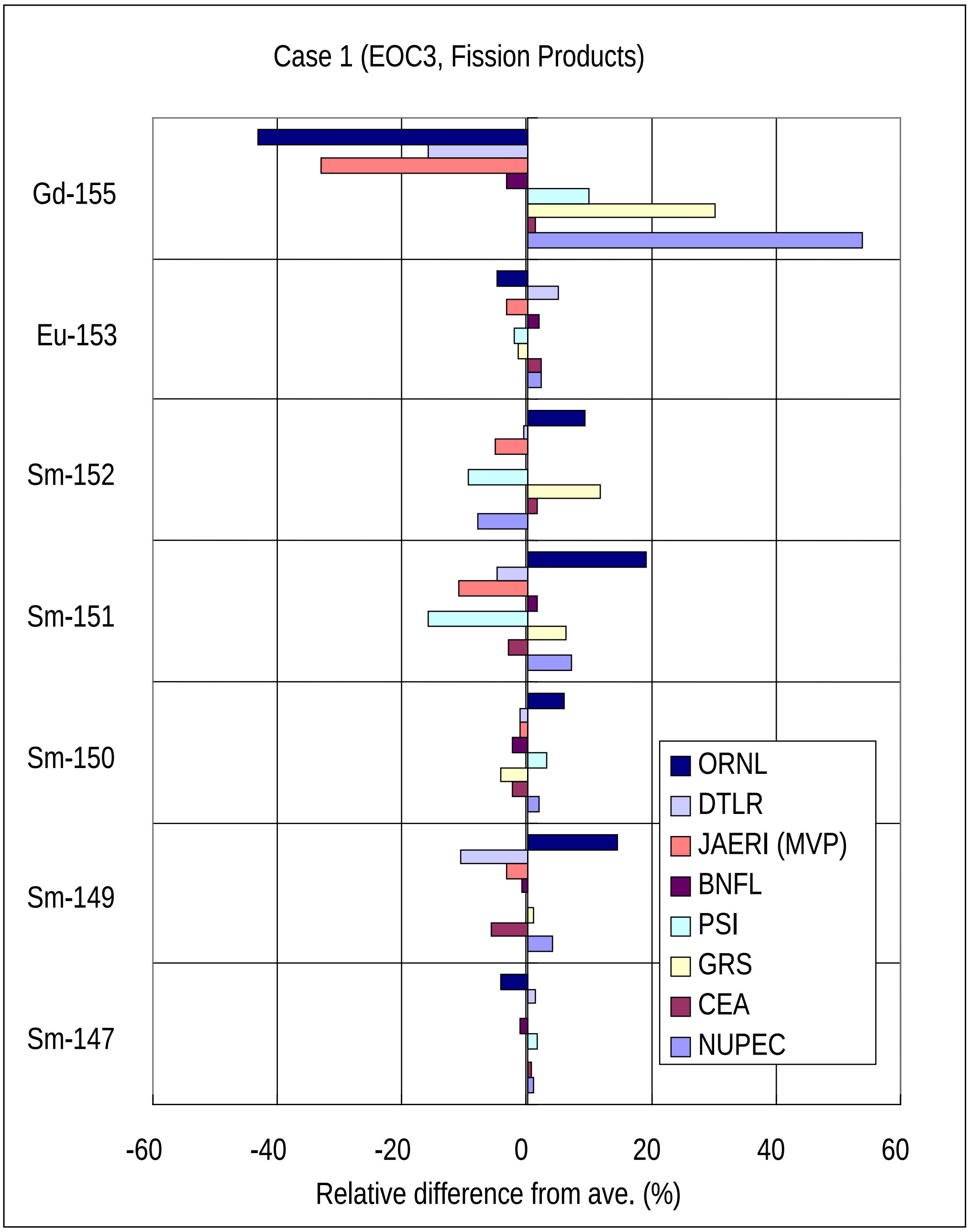


Figure F.5. Relative difference of actinide nuclide densities after 5 years cooling

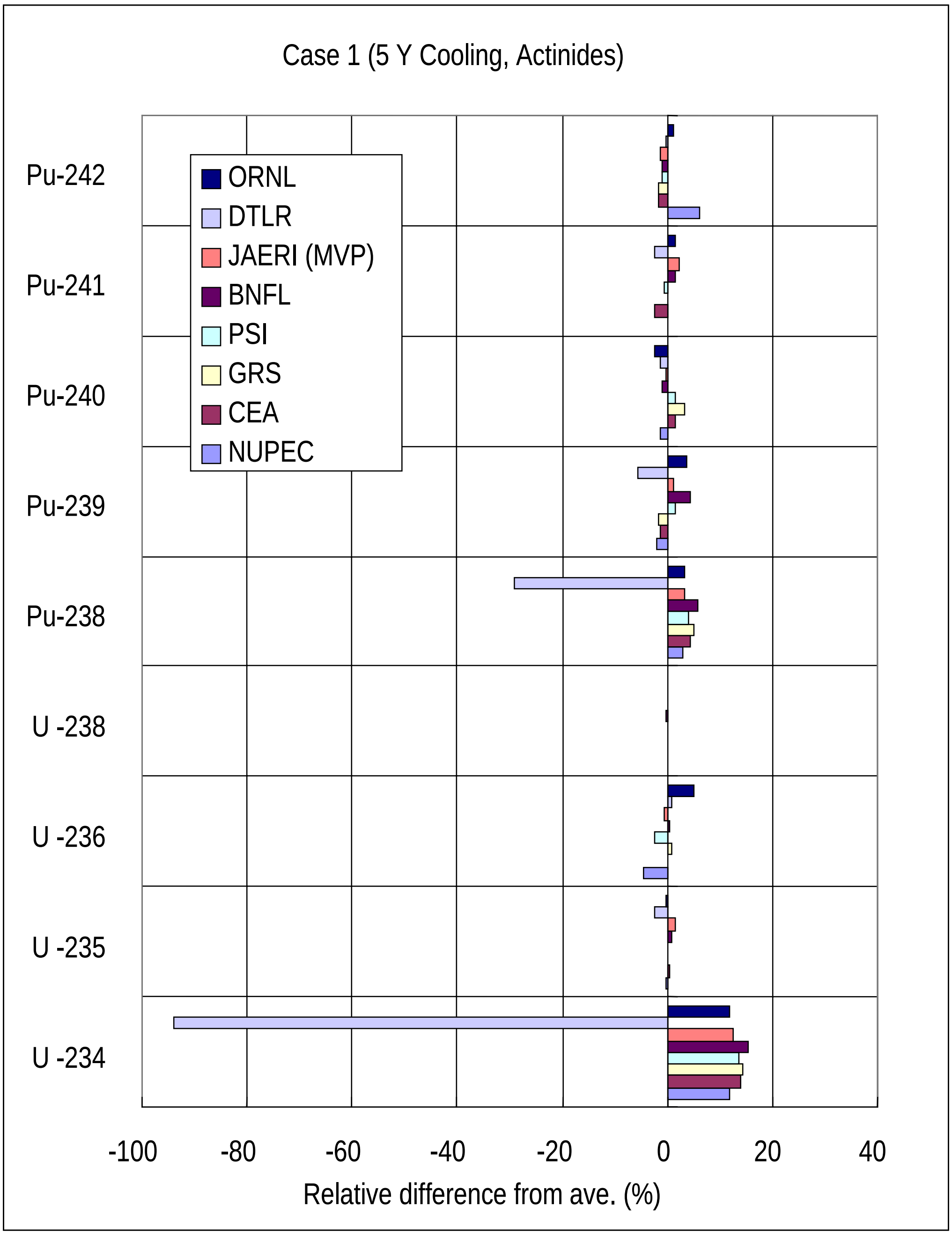


Figure F.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

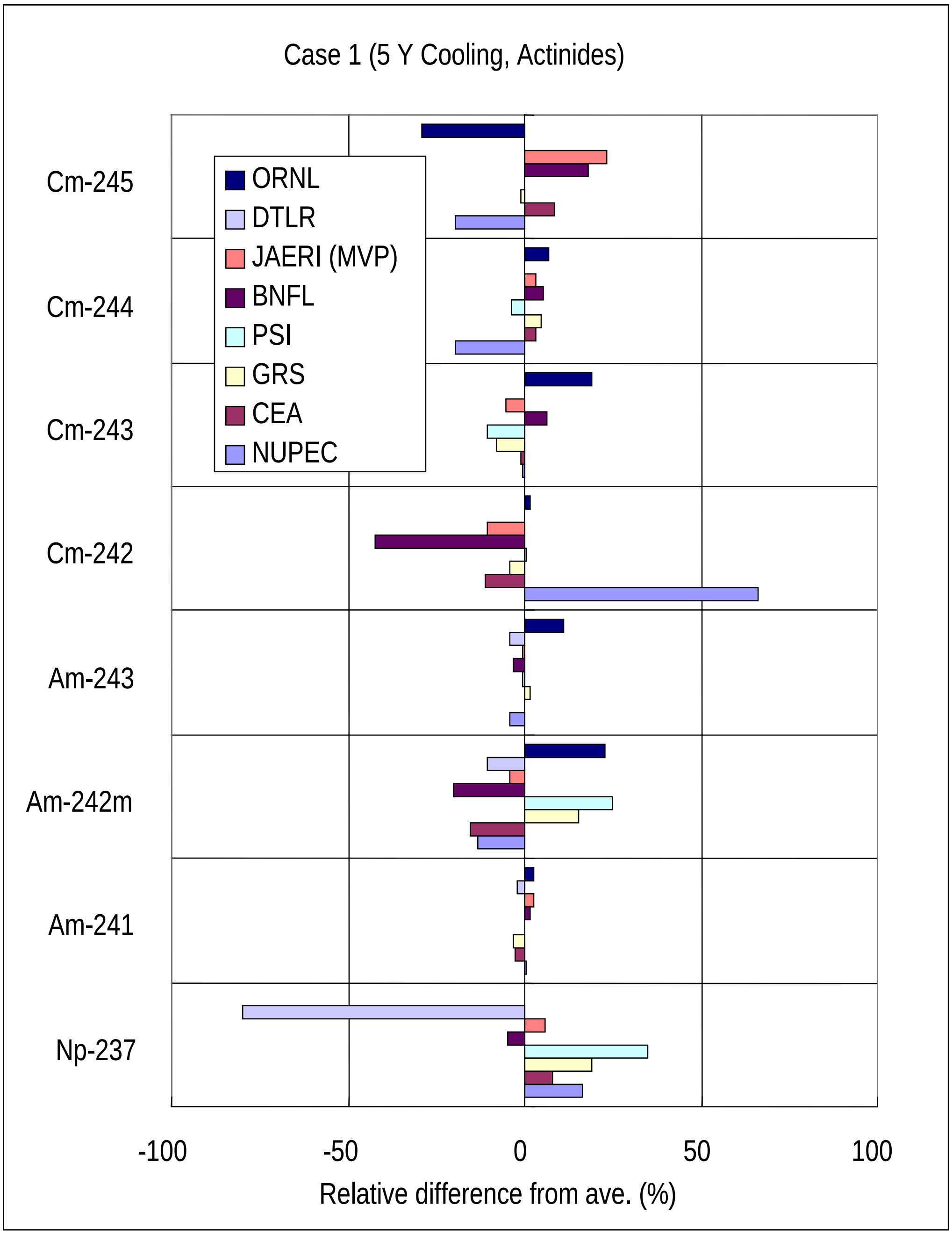


Figure F.6. Relative difference of fission product nuclide densities after 5 years cooling

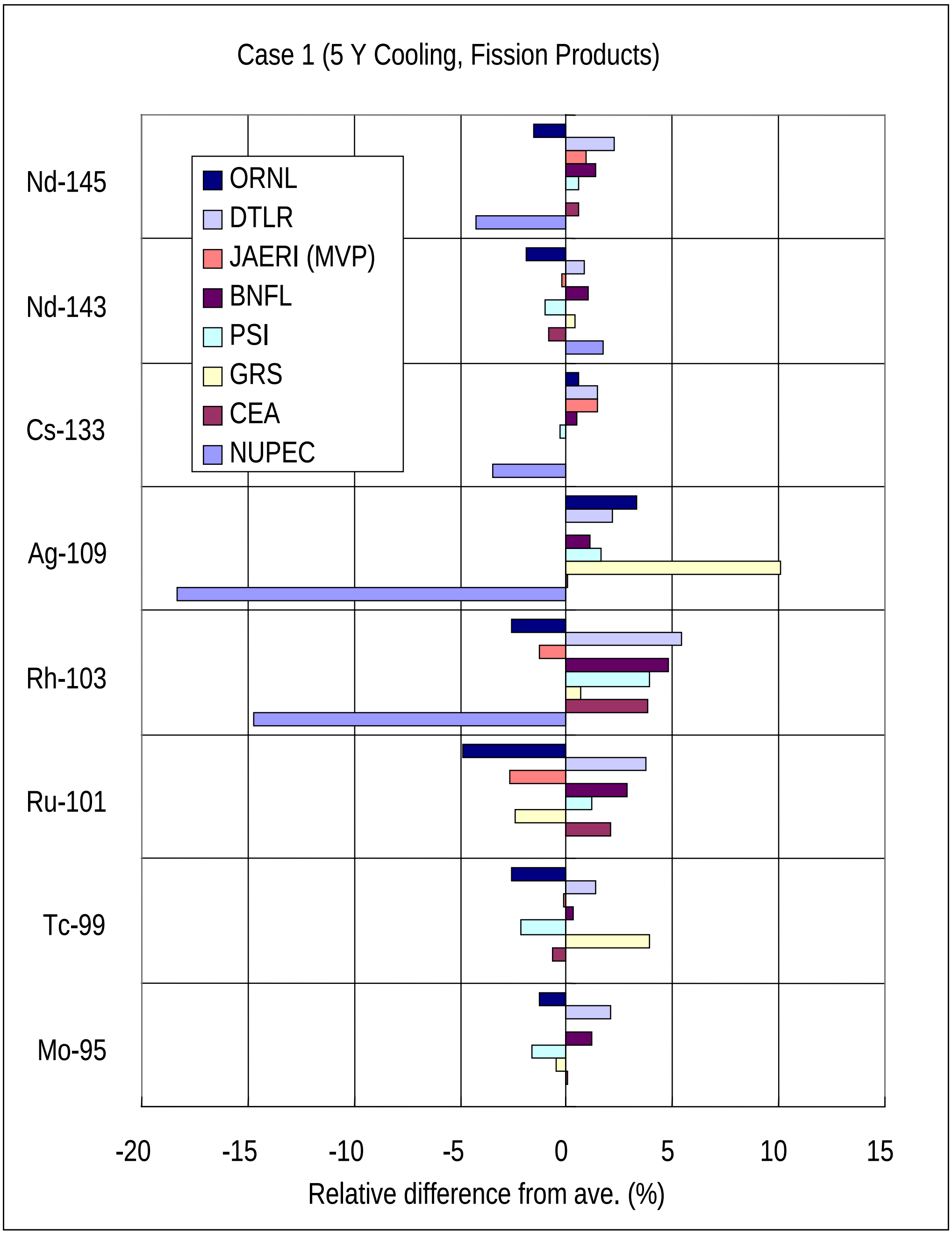
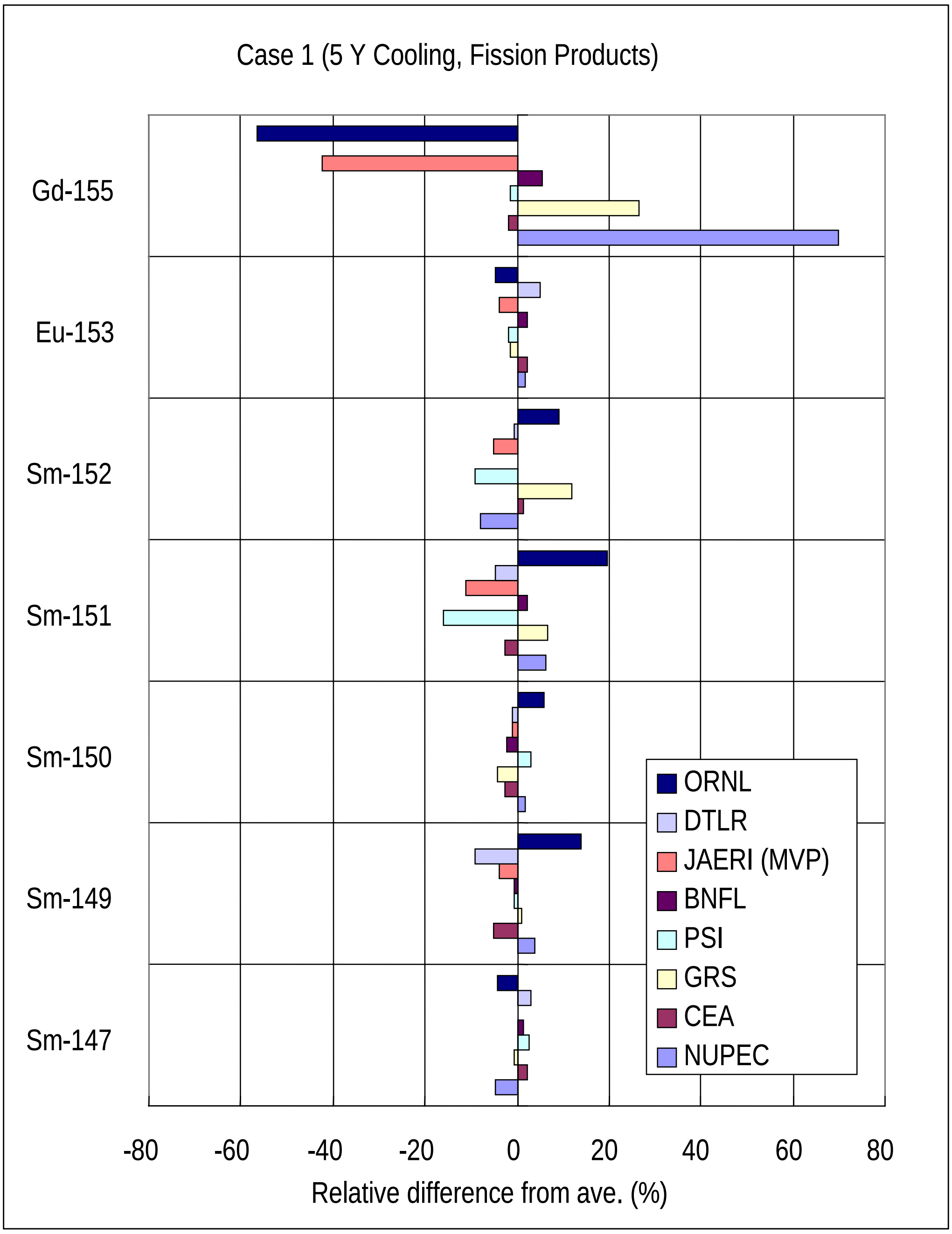


Figure F.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



Appendix G

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 2

Supercell model, weapons disposition MOX fuel

Figure G.1. Relative difference of actinide nuclide densities at the end of Cycle 1

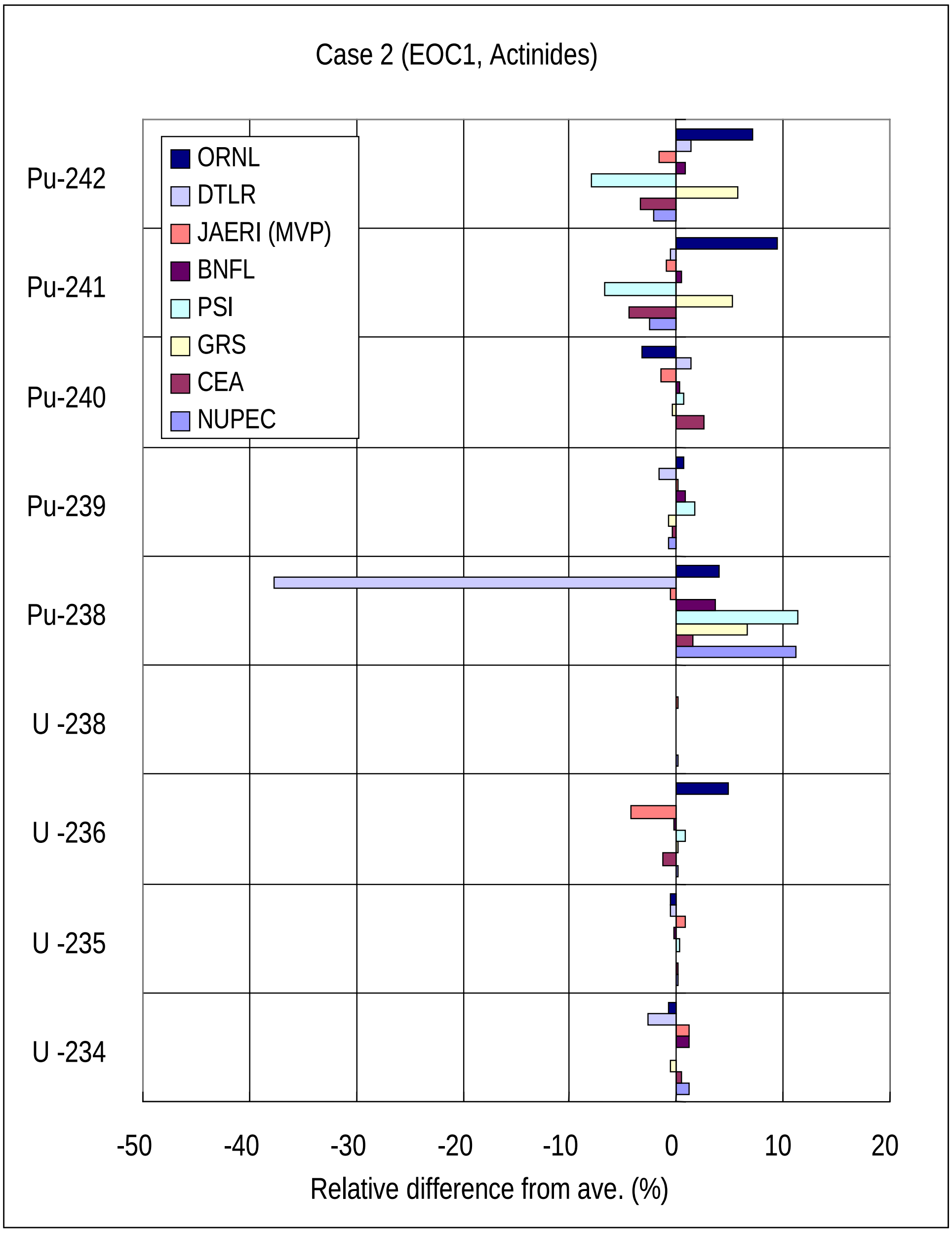


Figure G.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

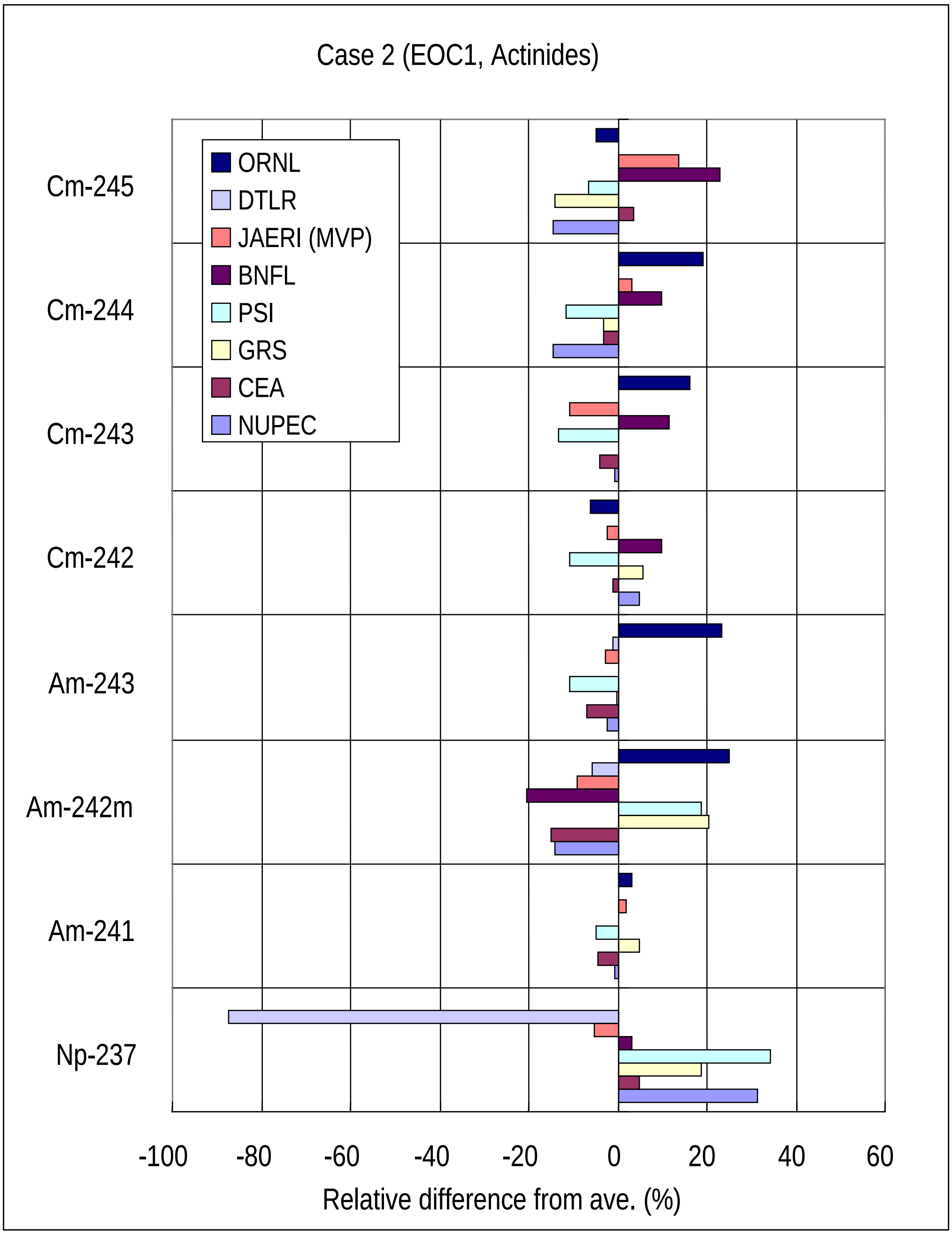


Figure G.2. Relative difference of fission product nuclide densities at the end of Cycle 1

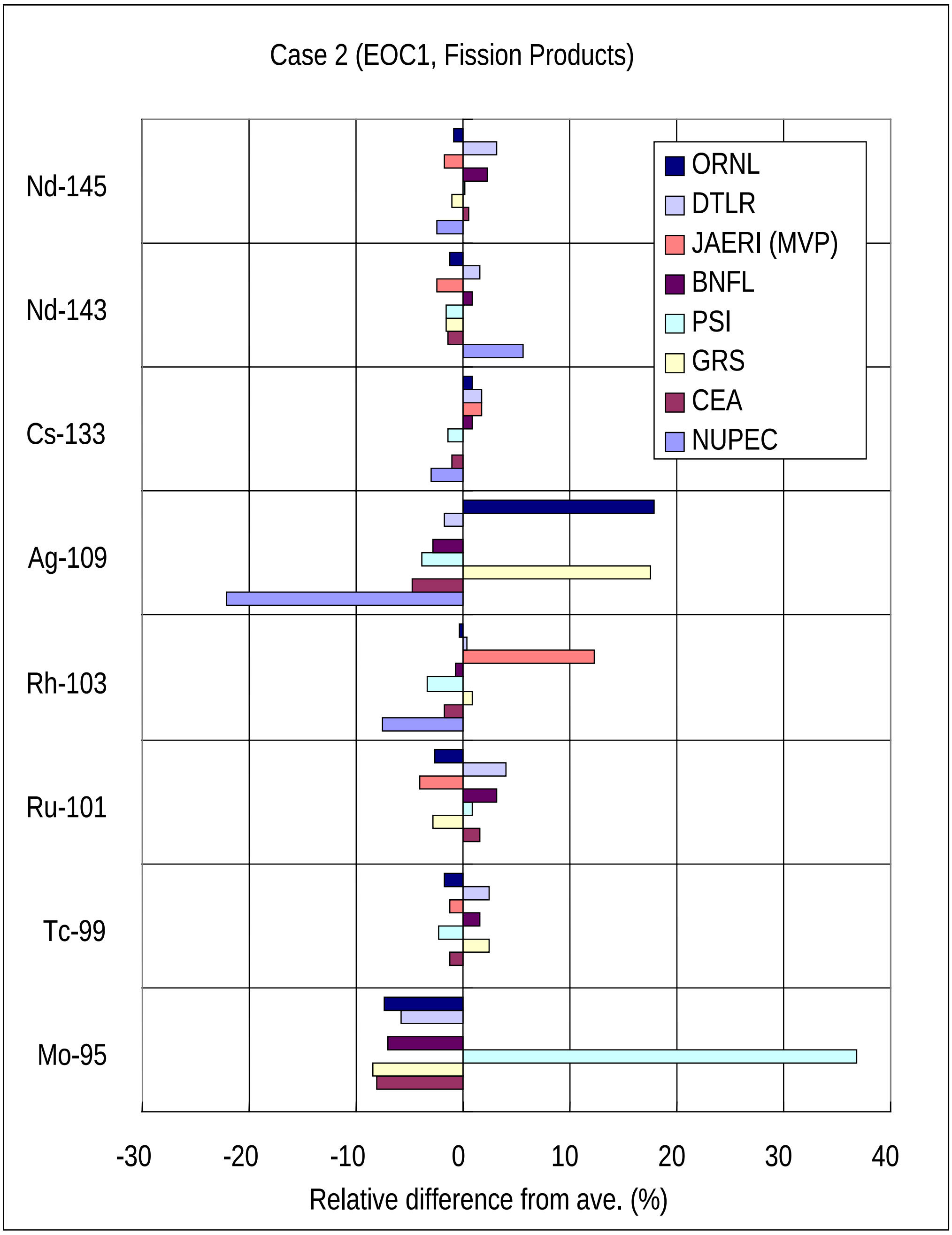


Figure G.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

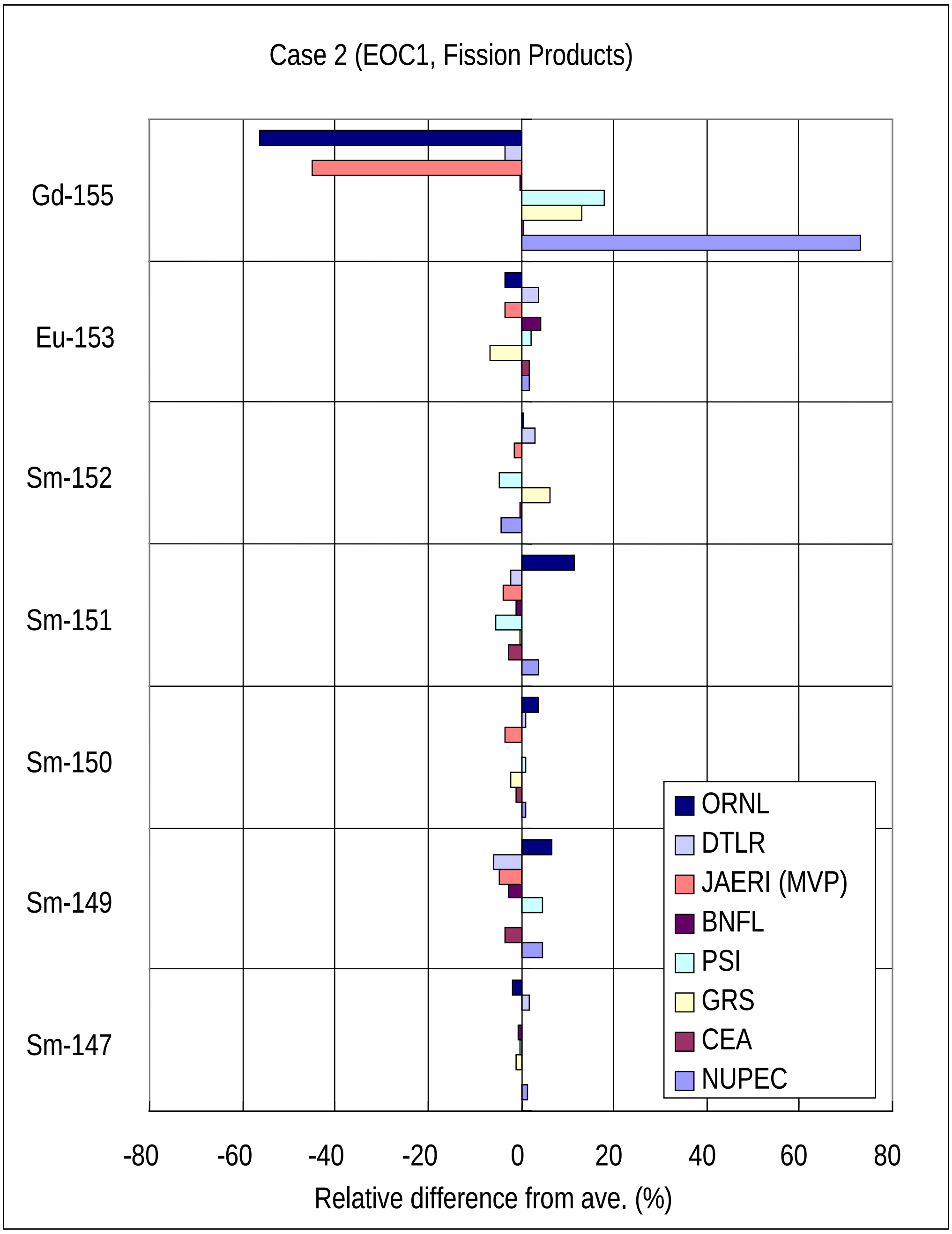


Figure G.3. Relative difference of actinide nuclide densities at the end of Cycle 3

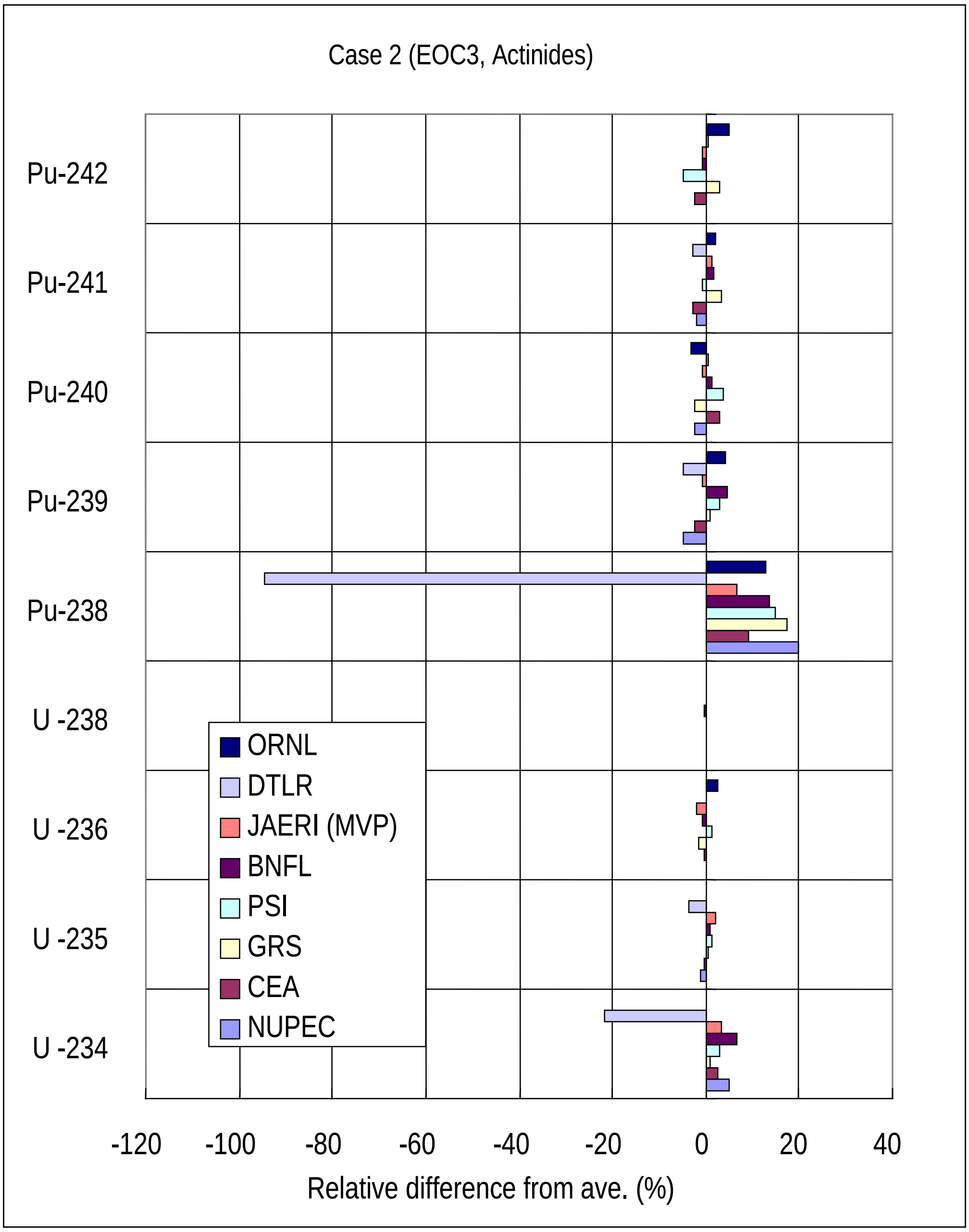


Figure G.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

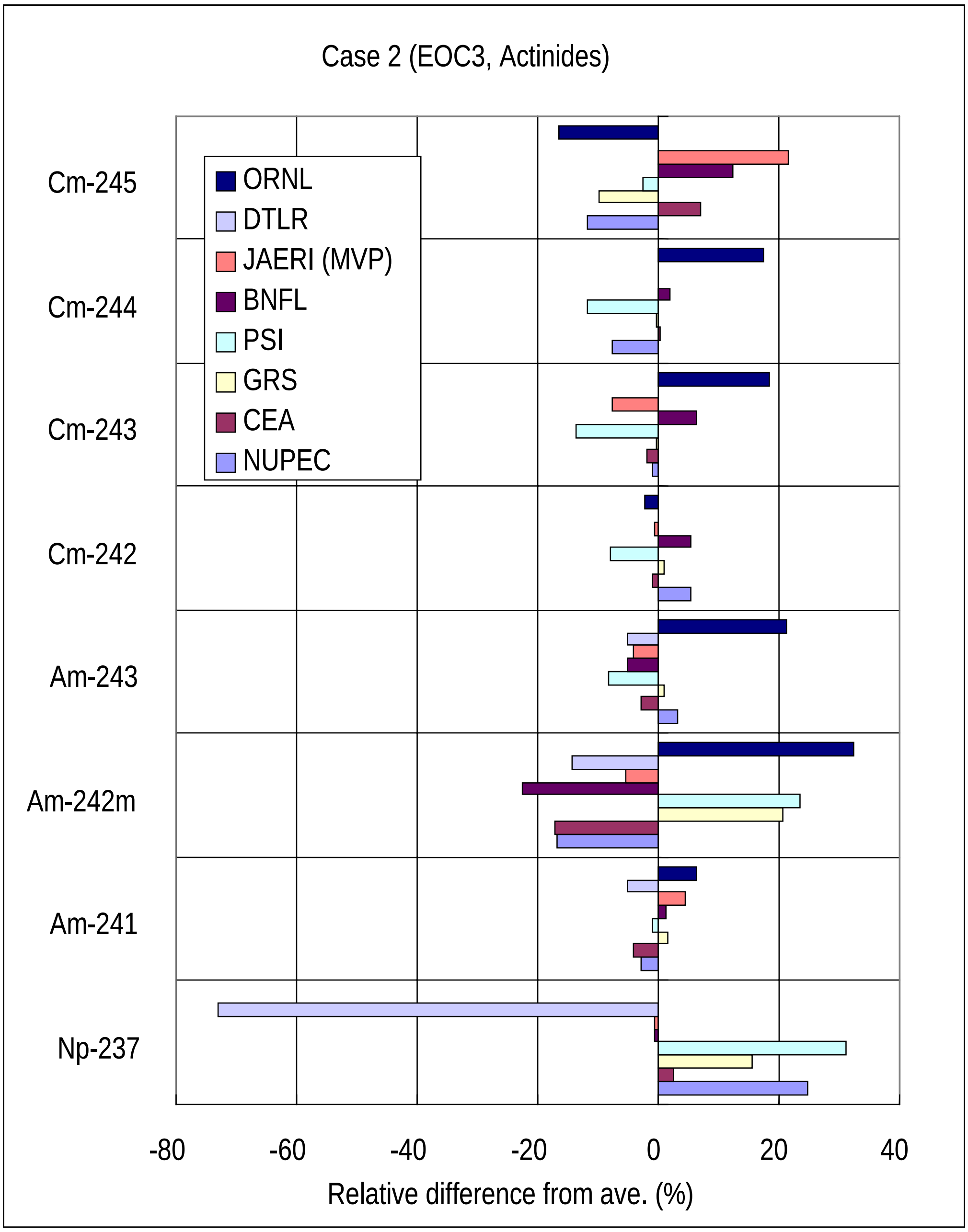


Figure G.4. Relative difference of fission product nuclide densities at the end of Cycle 3

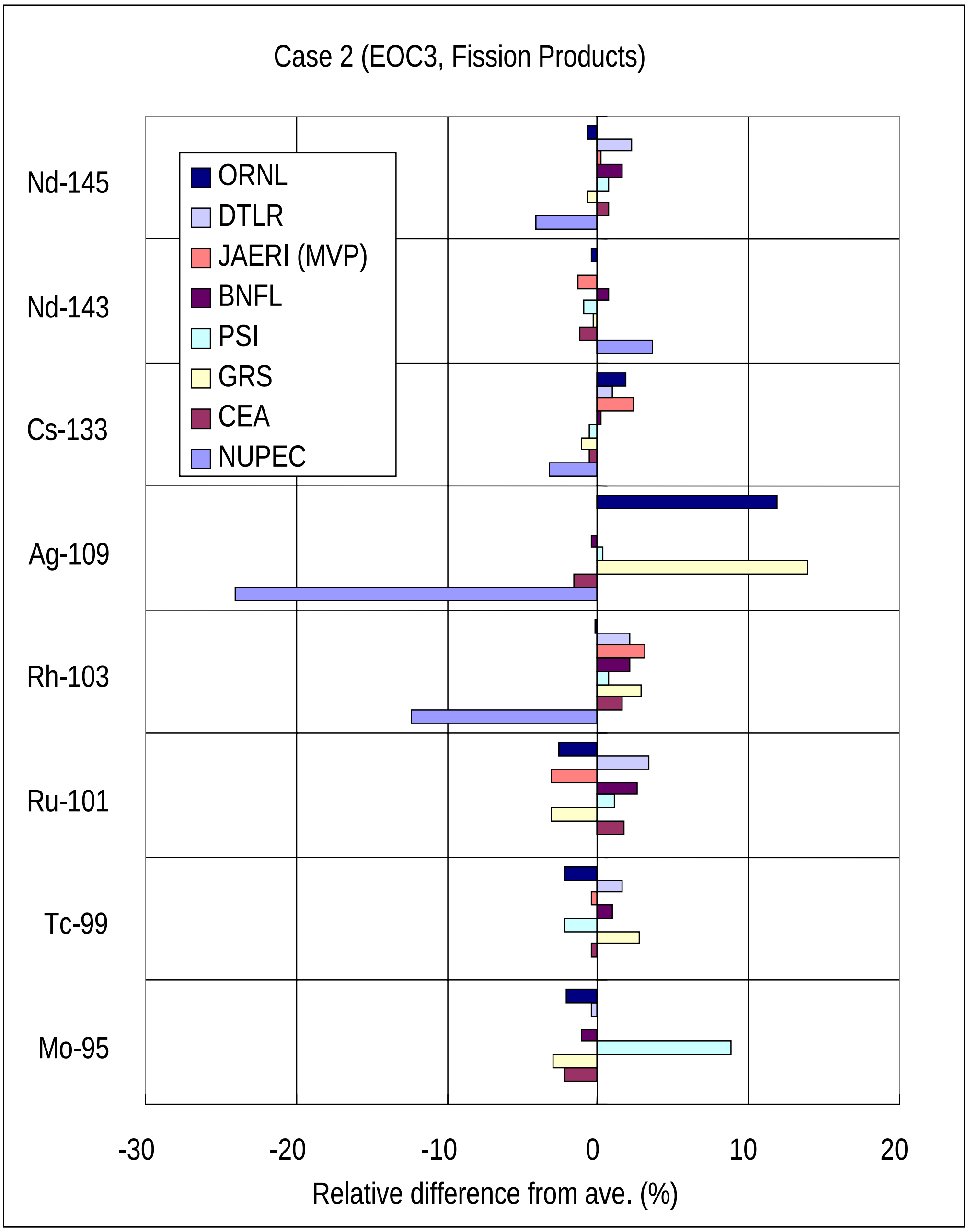


Figure G.4. Relative difference of fission product nuclide densities at the end of Cycle 3 (*cont.*)

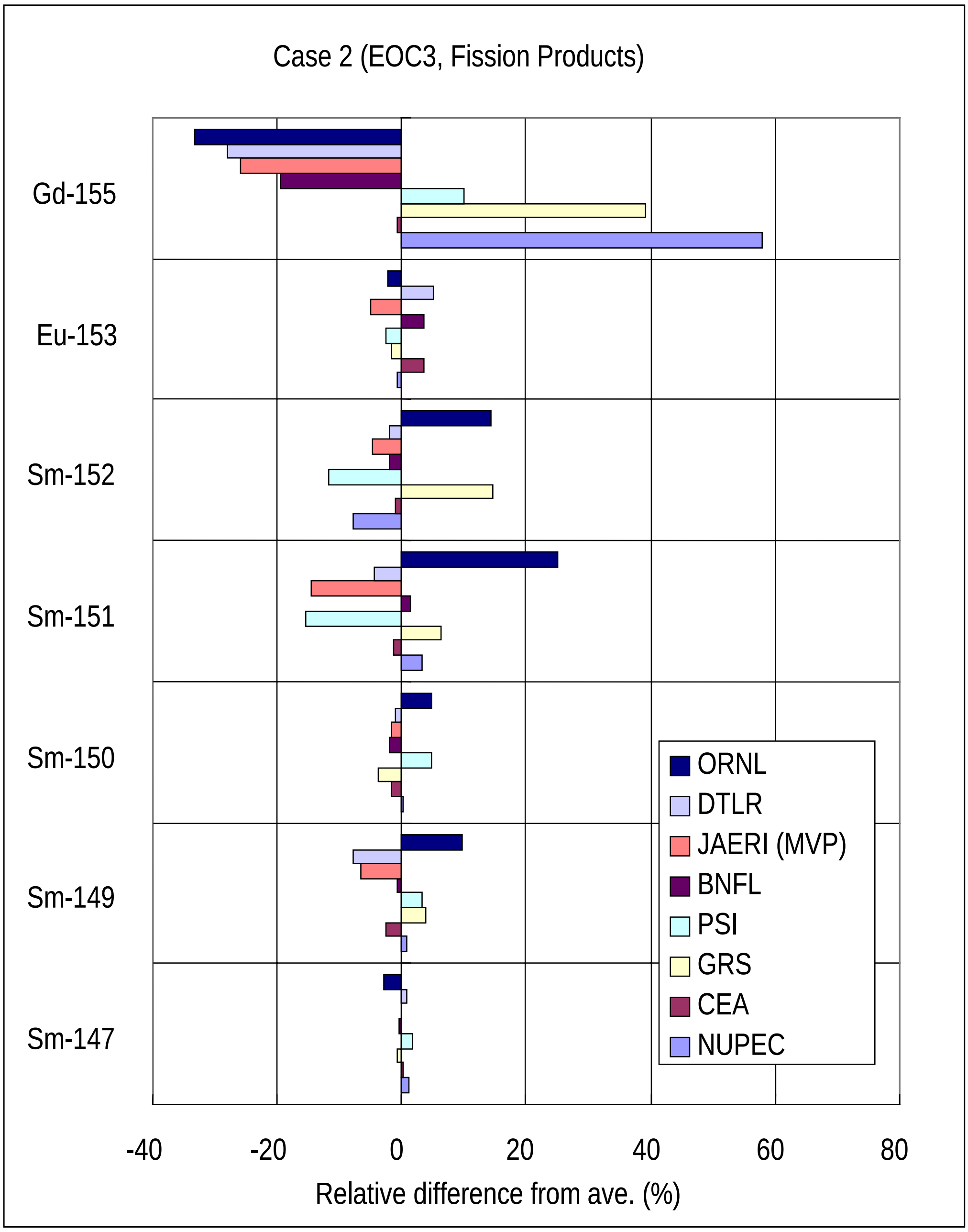


Figure G.5. Relative difference of actinide nuclide densities after 5 years cooling

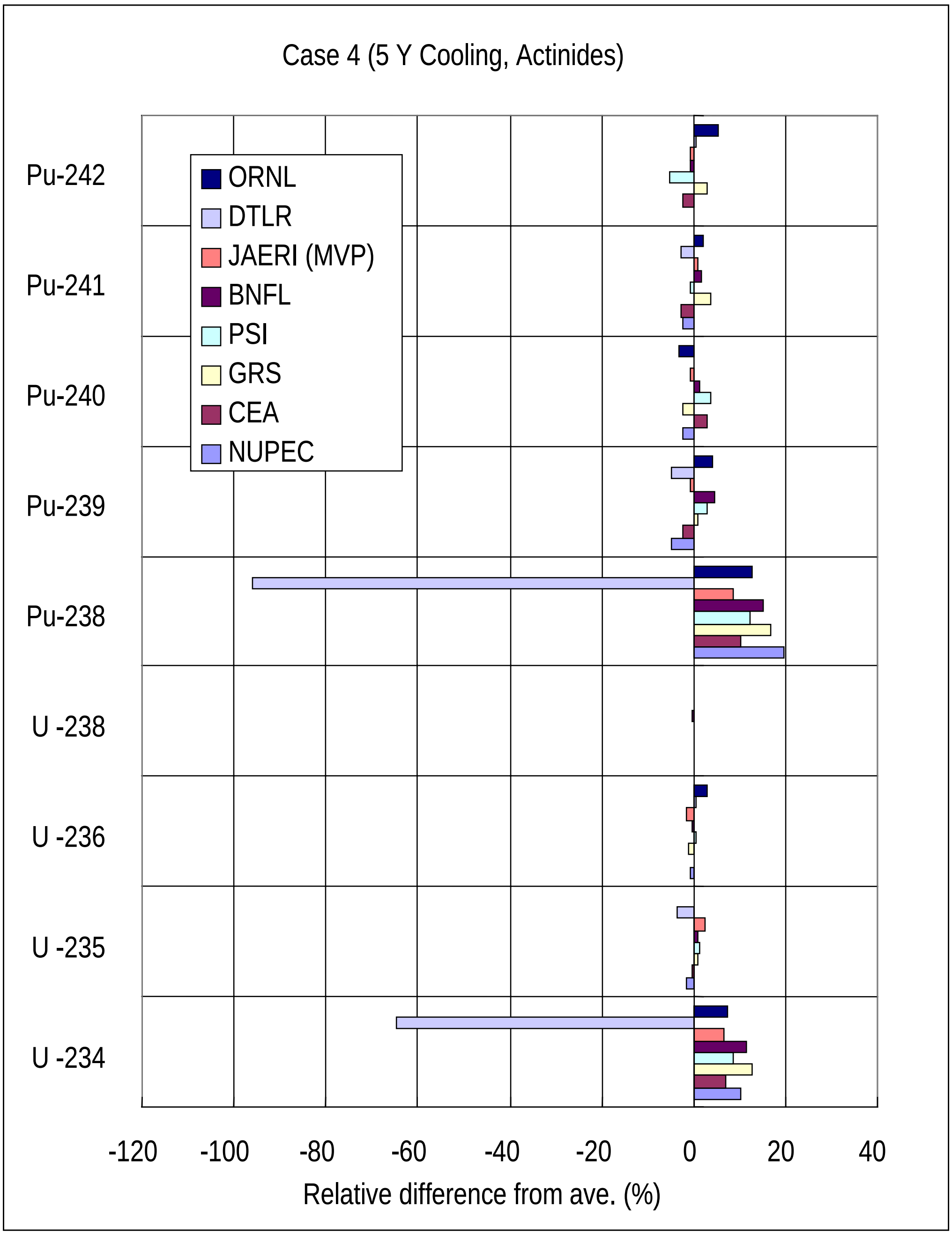


Figure G.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

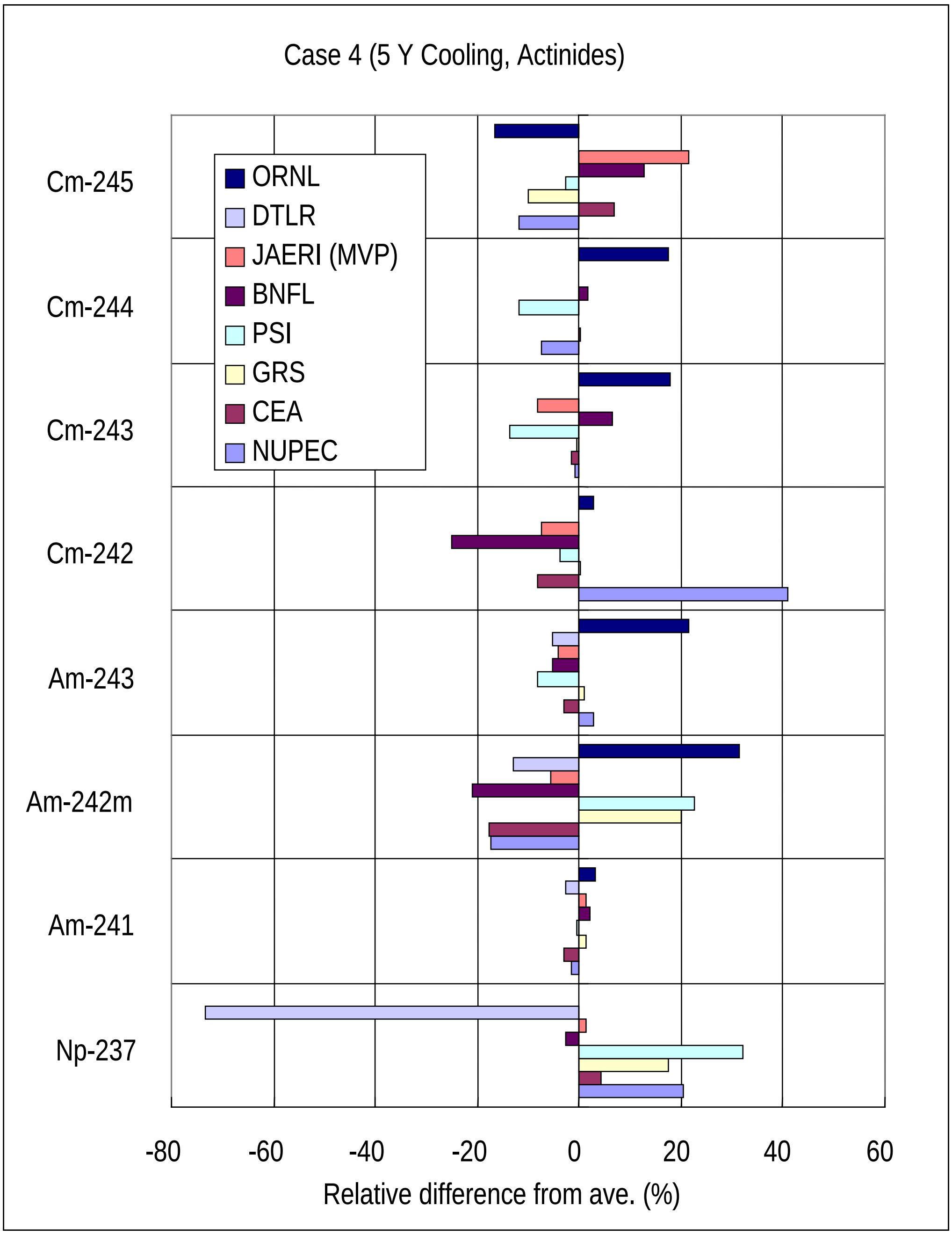


Figure G.6. Relative difference of fission product nuclide densities after 5 years cooling

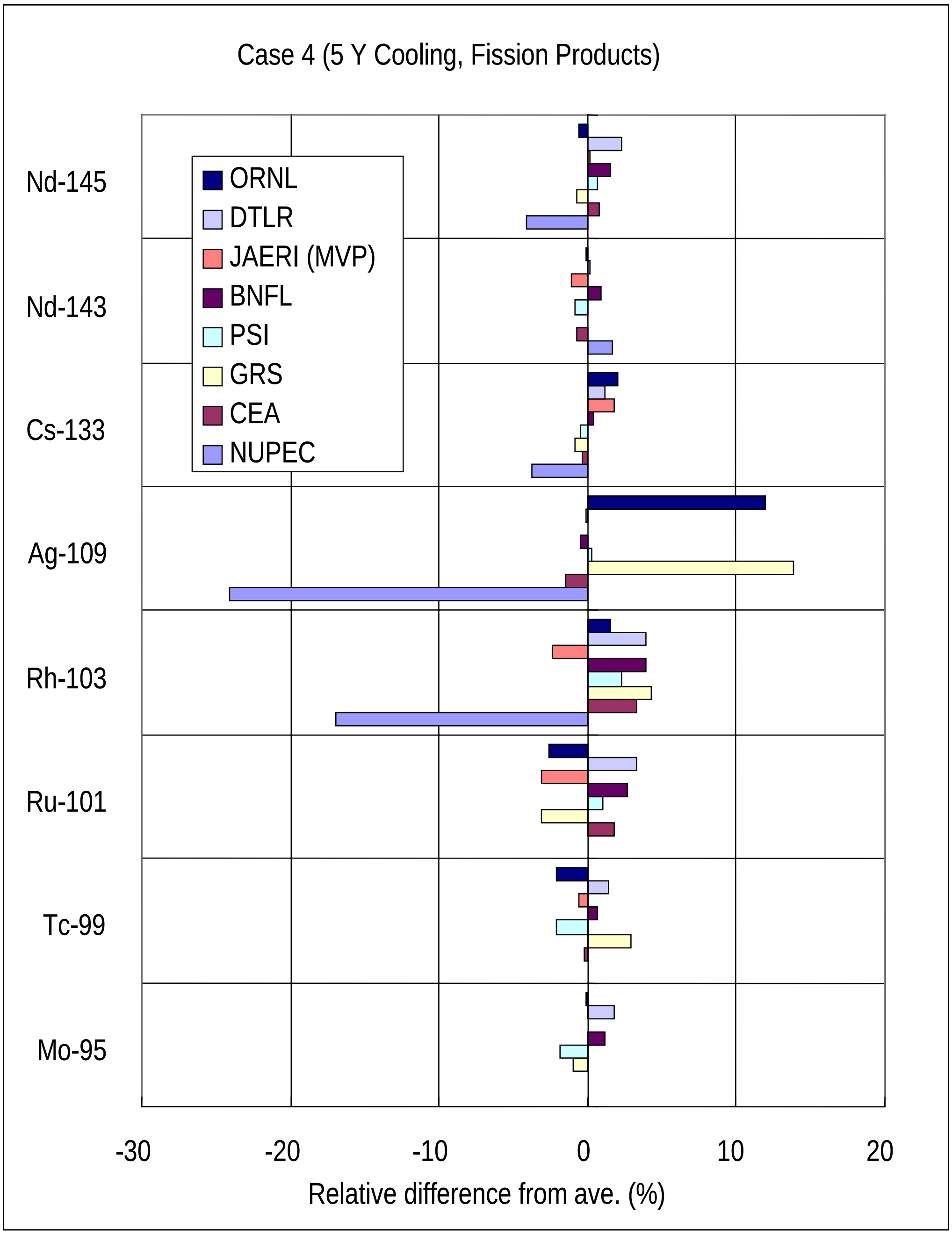
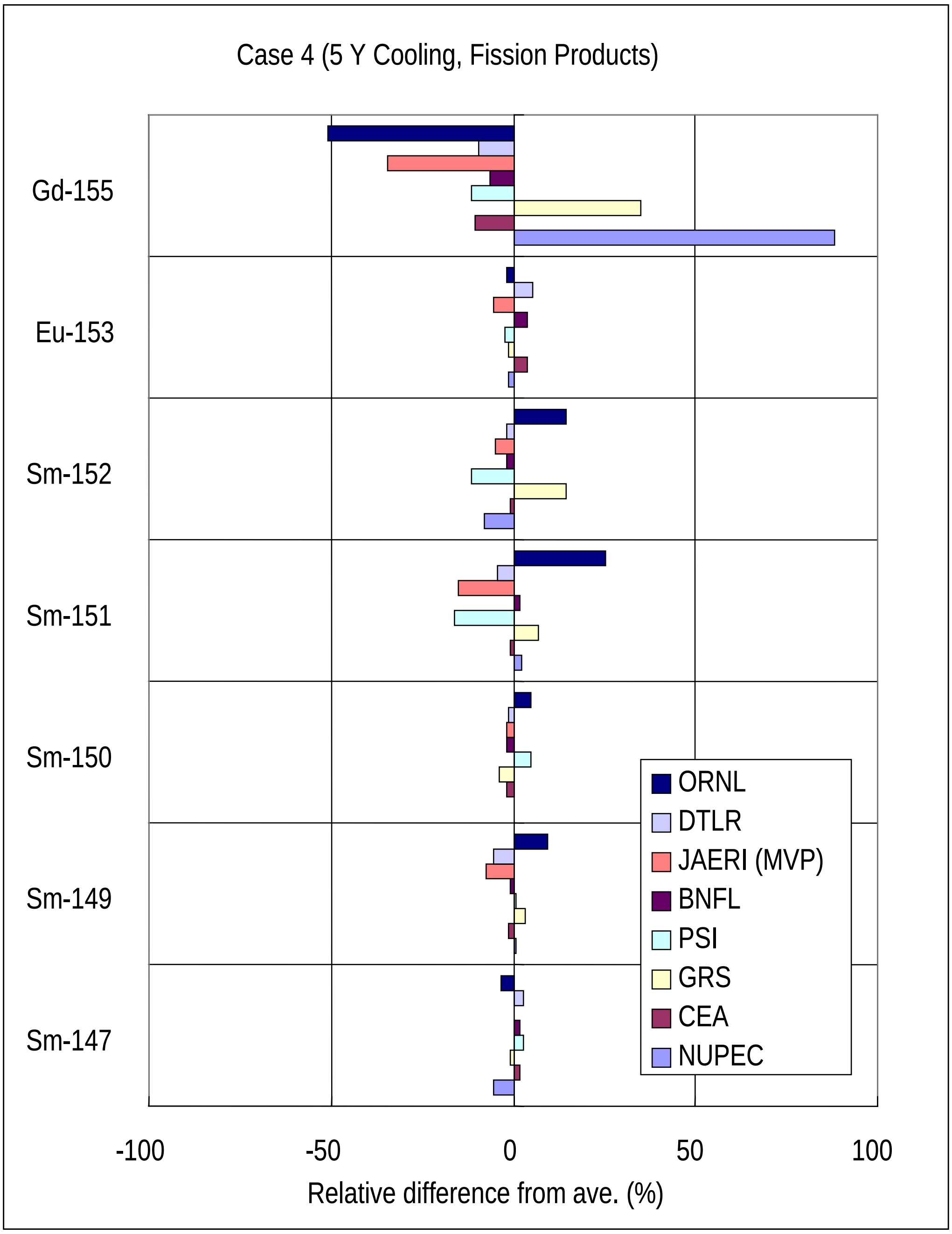


Figure G.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



Appendix H

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 3

Assembly model, first recycle MOX fuel

Figure H.1. Relative difference of actinide nuclide densities at the end of Cycle 1

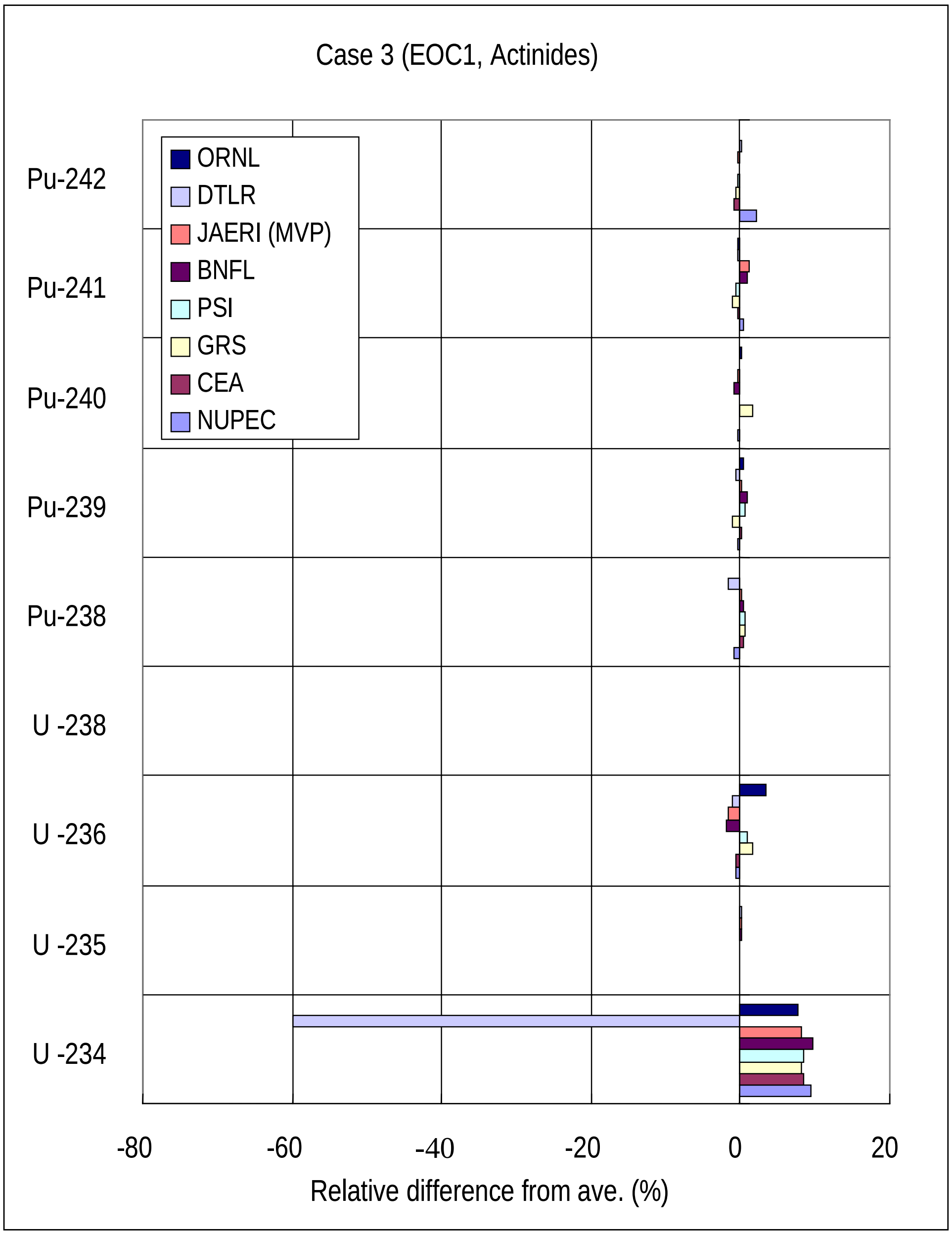


Figure H.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

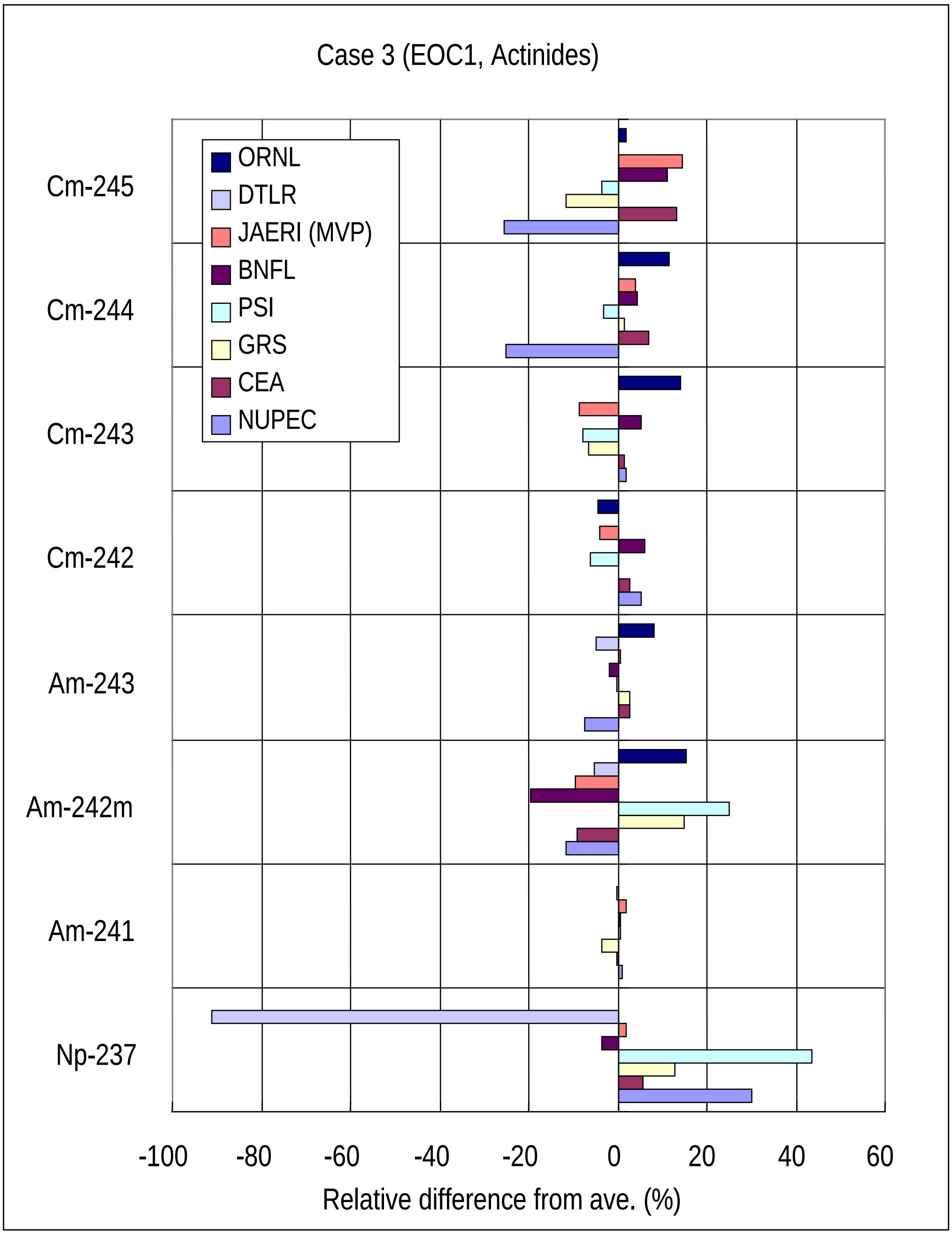


Figure H.2. Relative difference of fission product nuclide densities at the end of Cycle 1

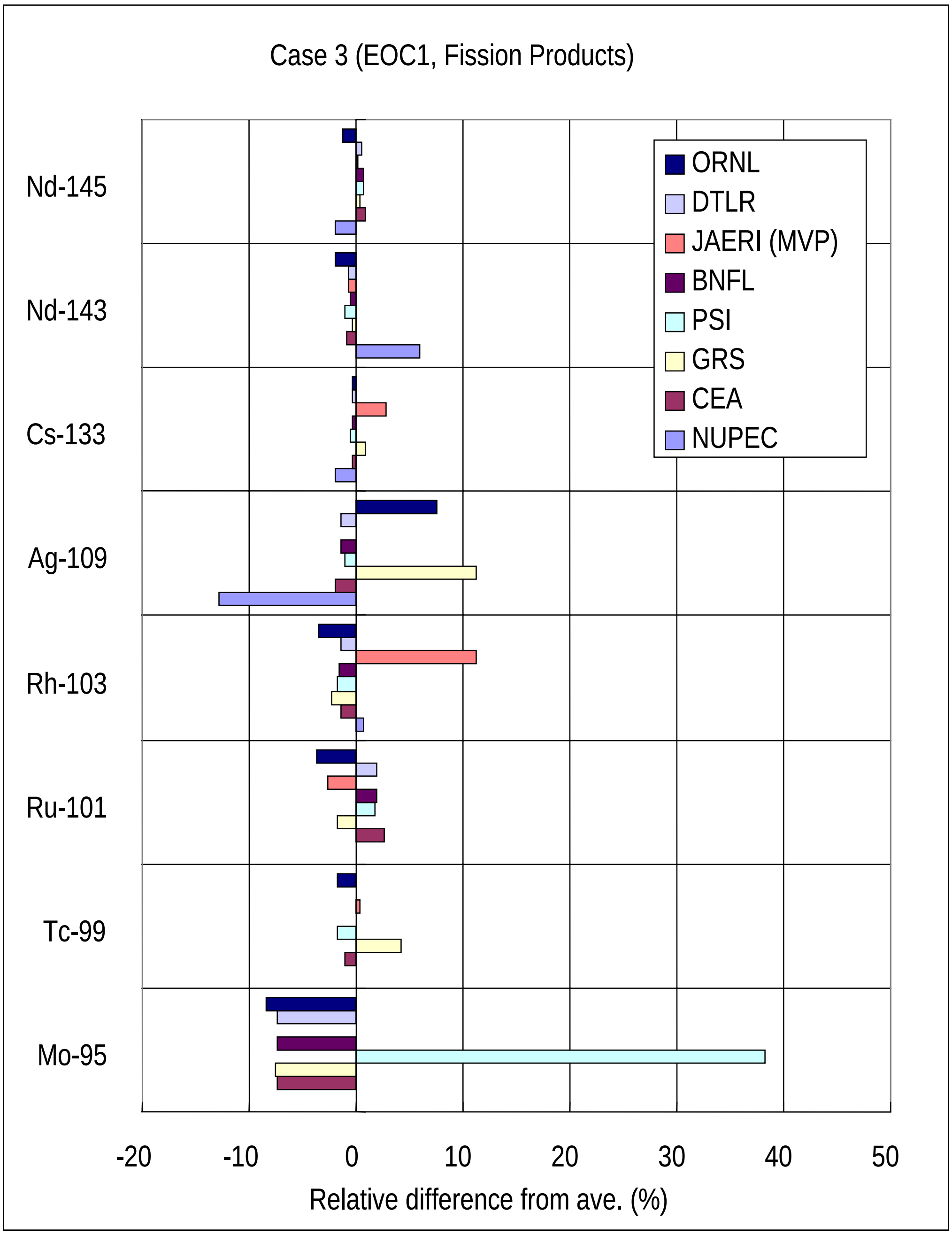


Figure H.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

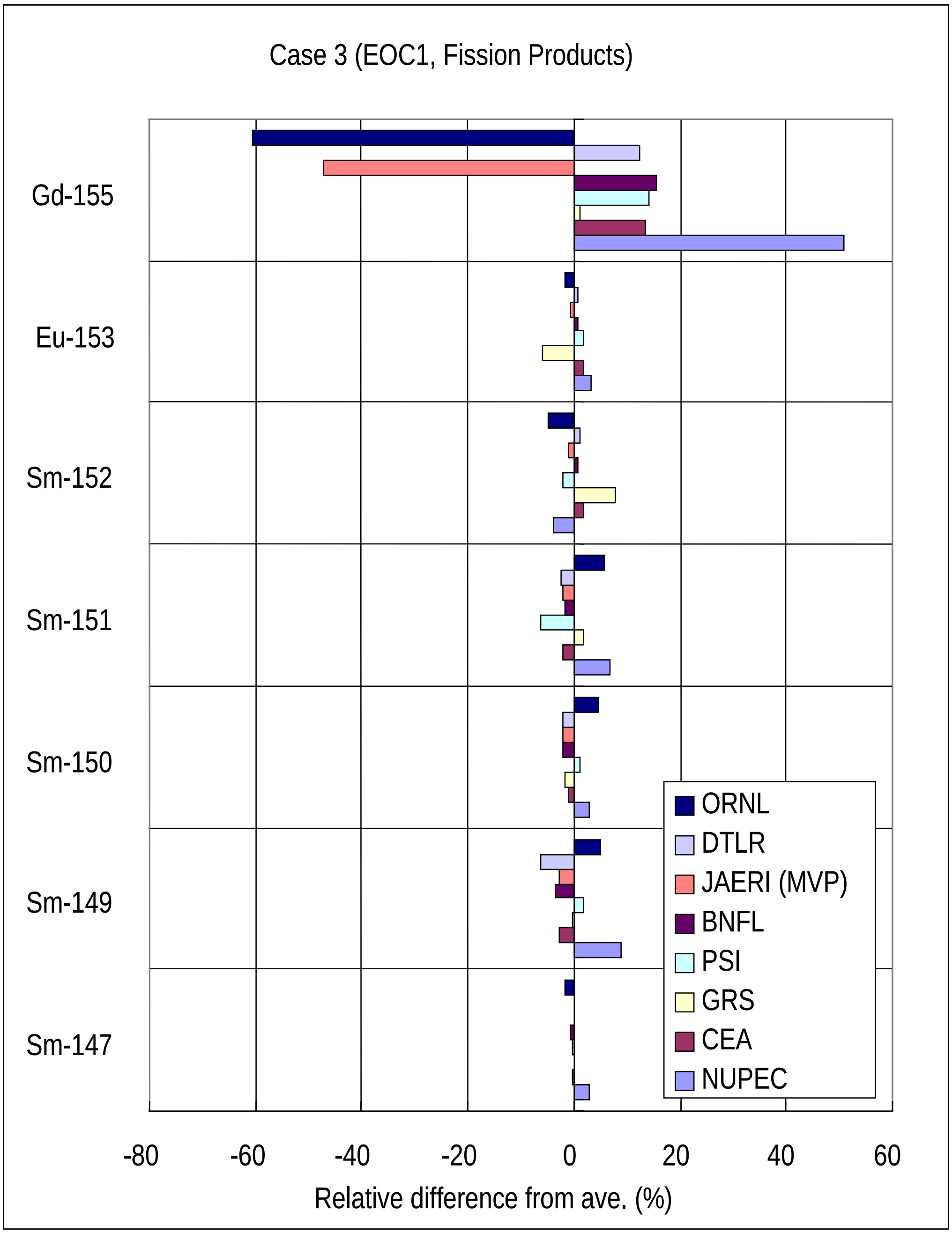


Figure H.3. Relative difference of actinide nuclide densities at the end of Cycle 3

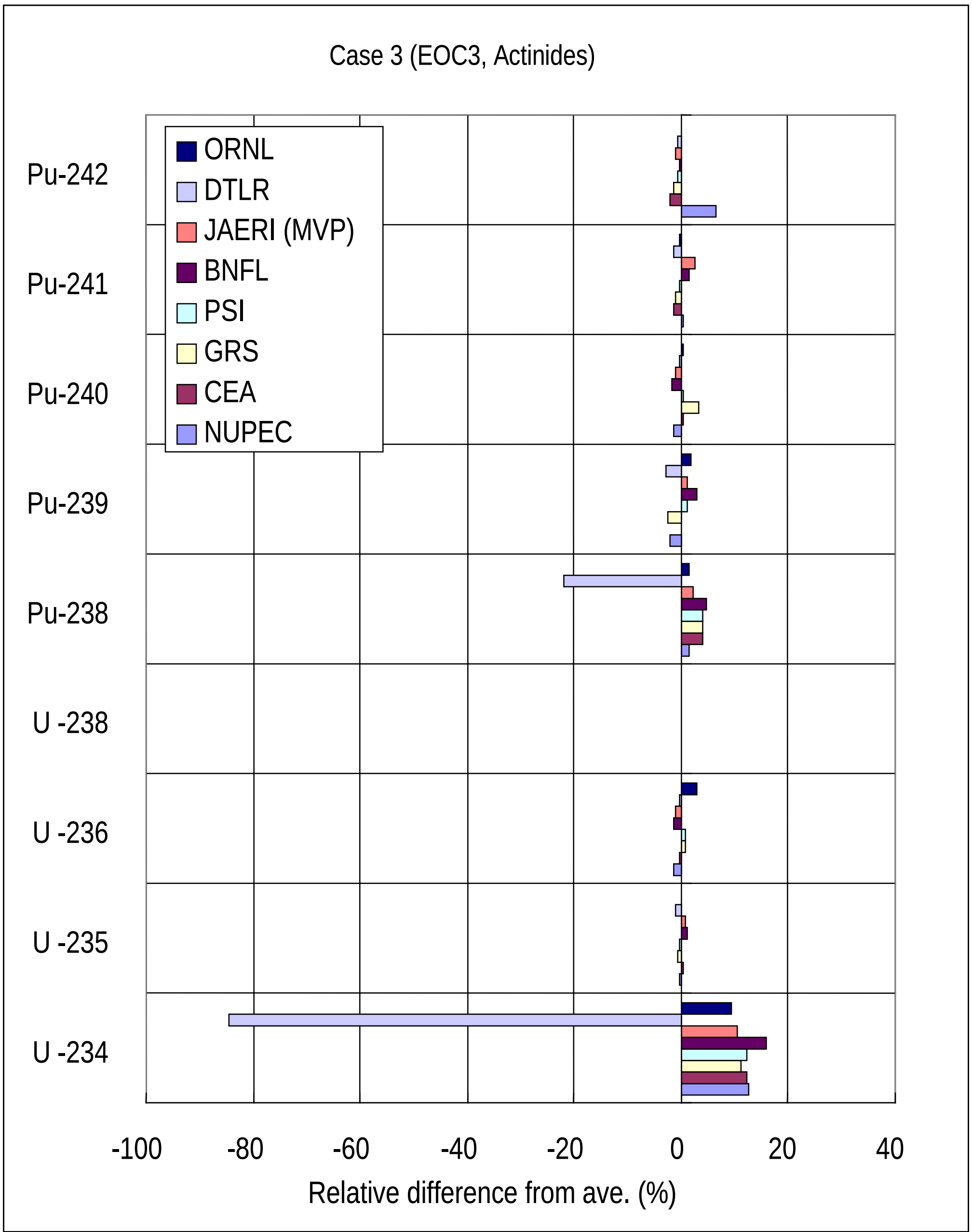


Figure H.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

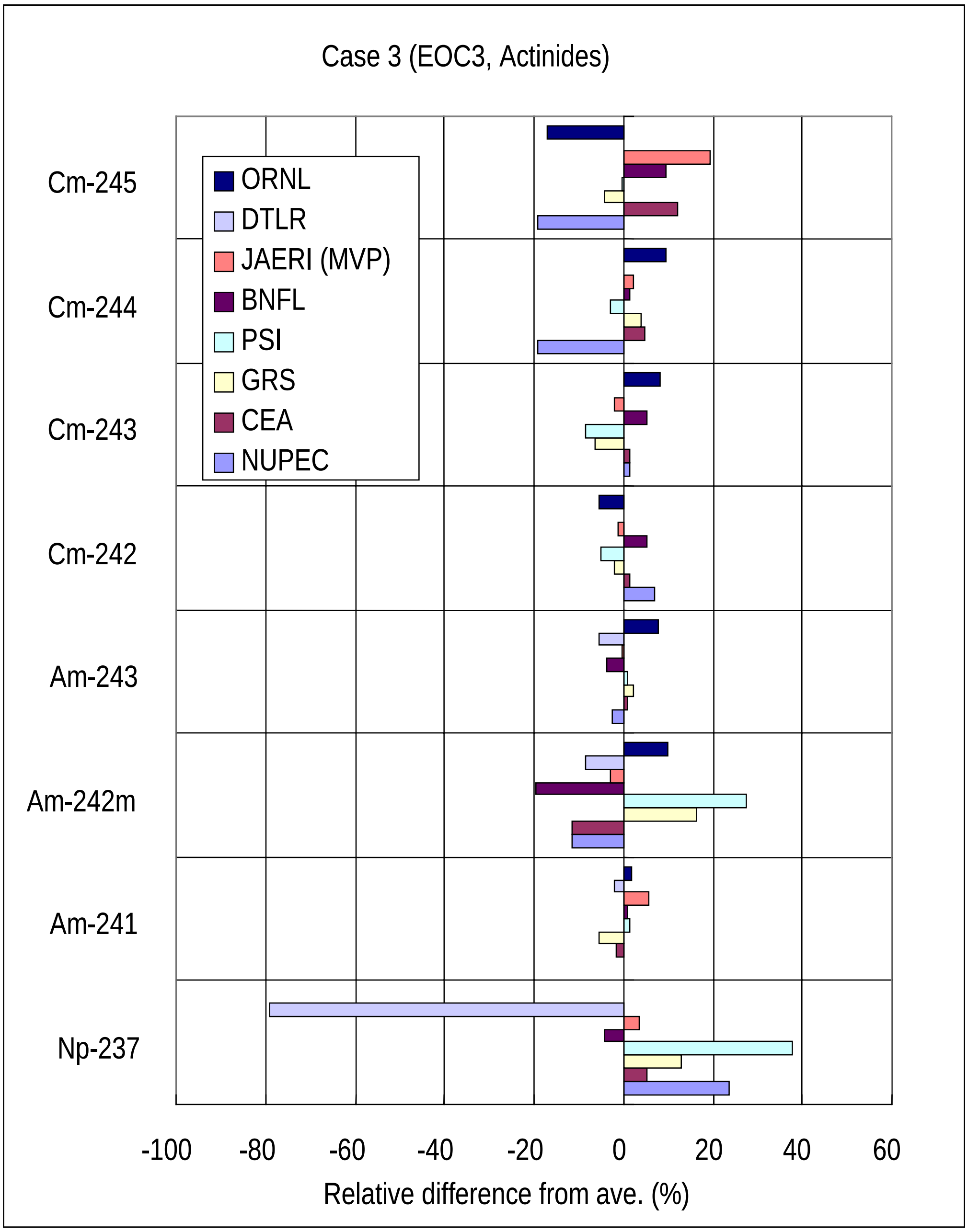


Figure H.4. Relative difference of fission product nuclide densities at the end of Cycle 3

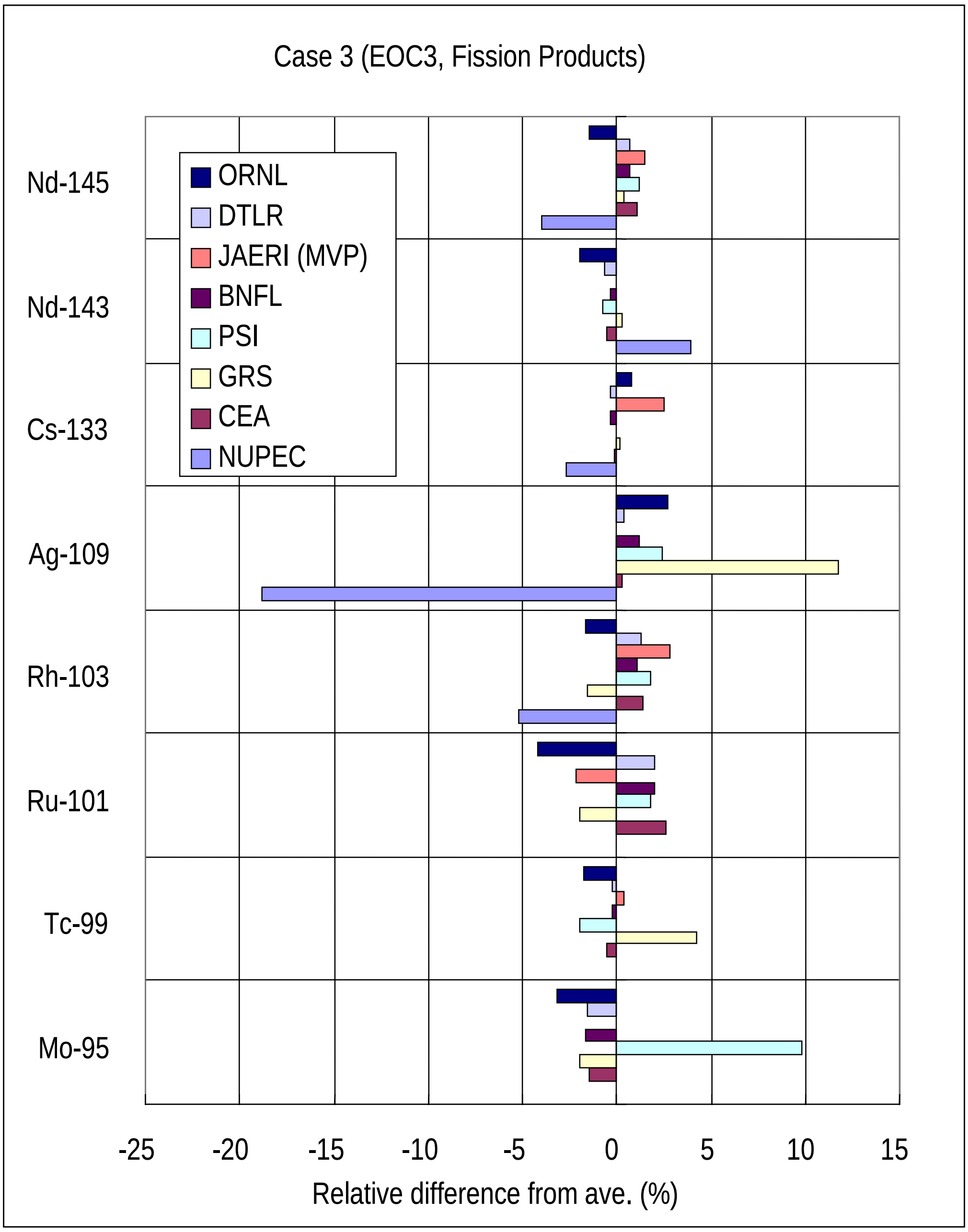


Figure H.4. Relative difference of fission product nuclide densities at the end of Cycle 3 (*cont.*)

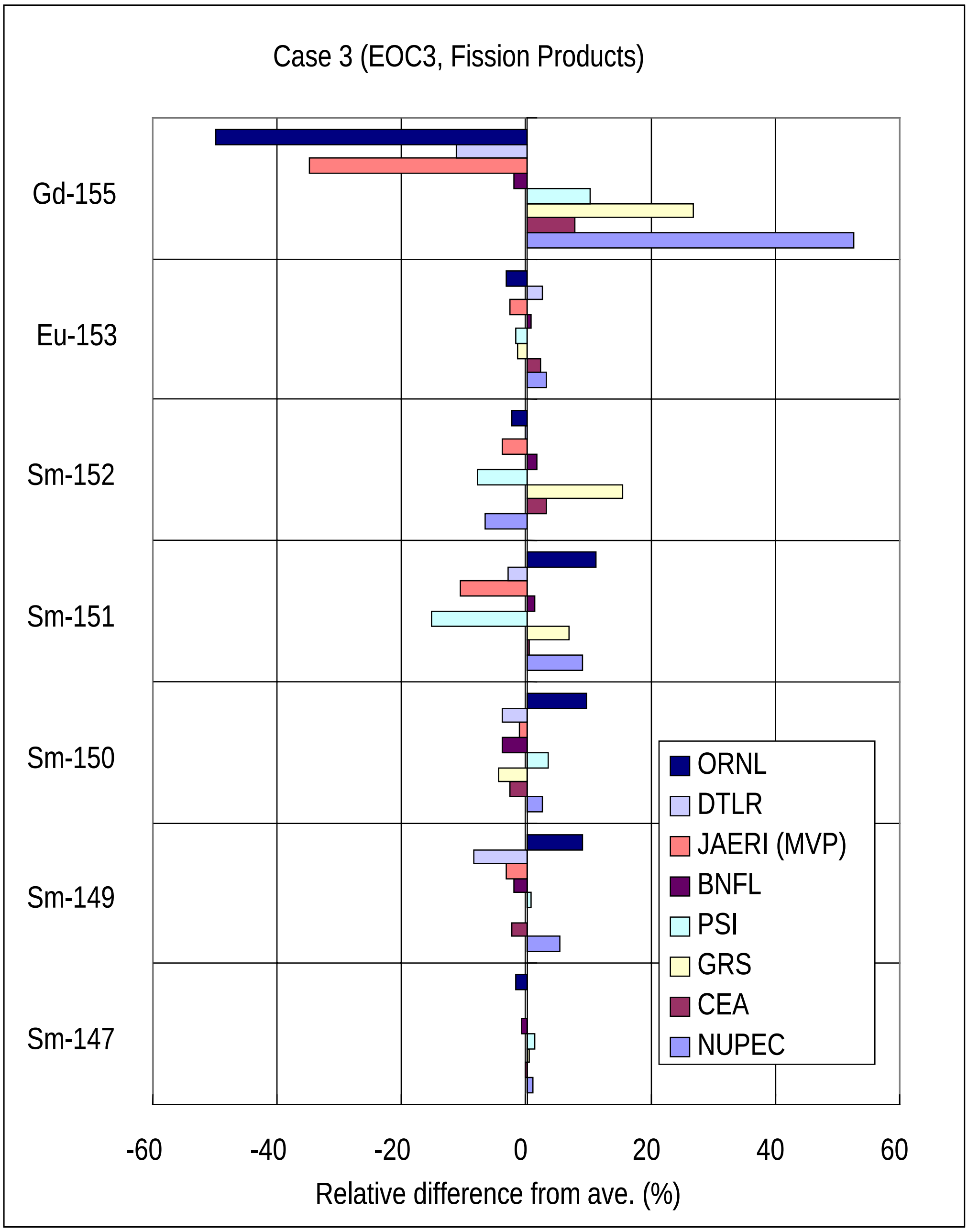


Figure H.5. Relative difference of actinide nuclide densities after 5 years cooling

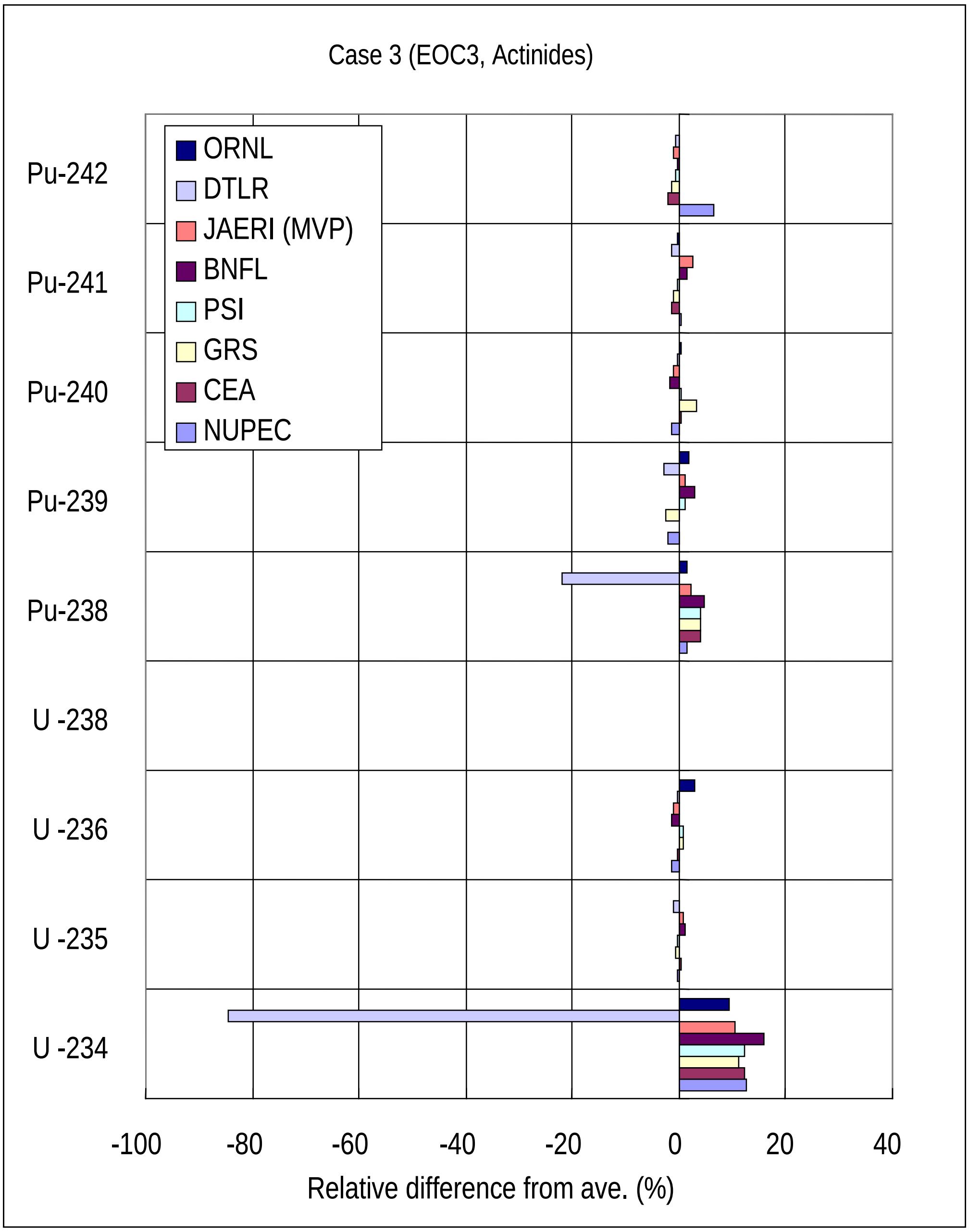


Figure H.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

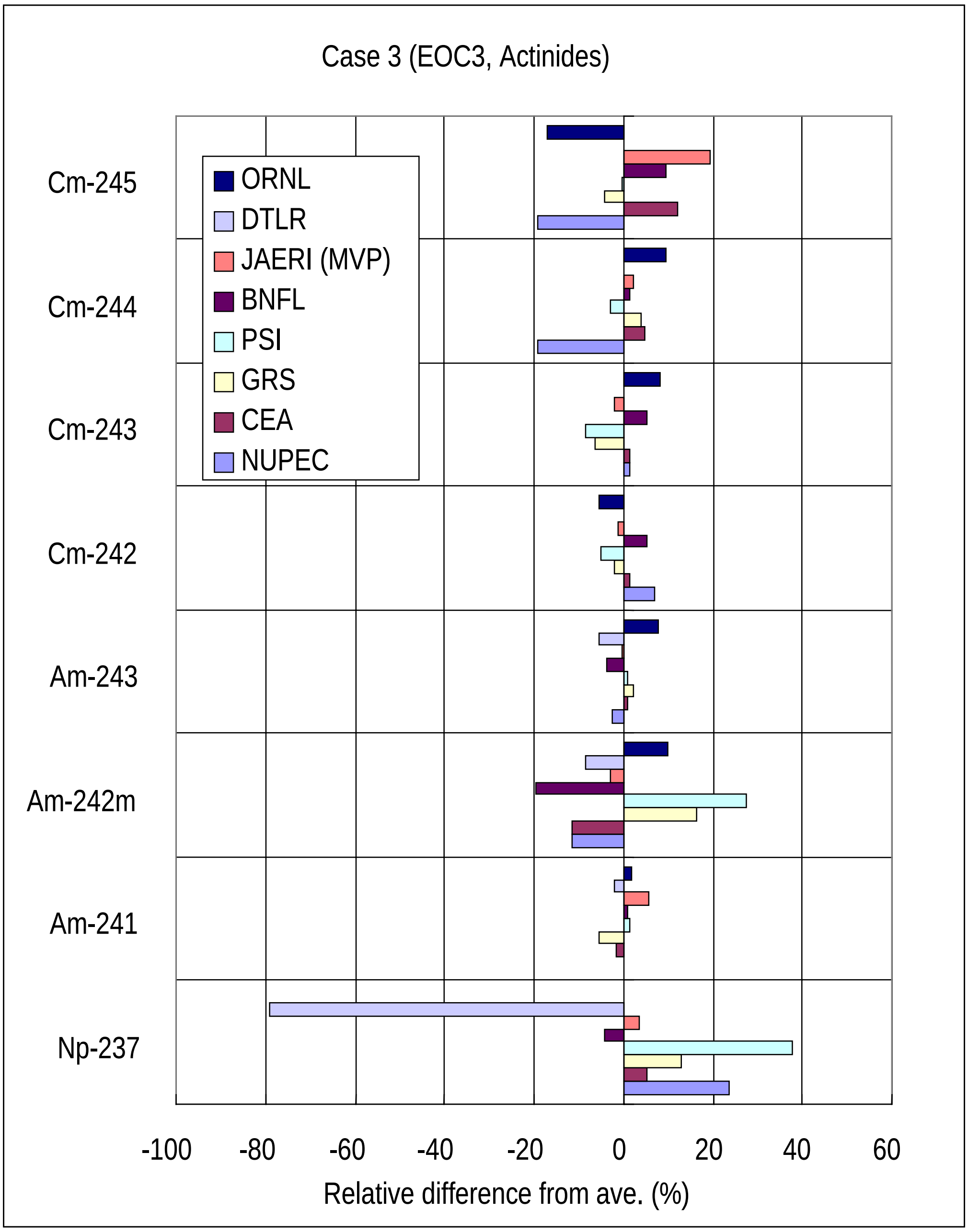


Figure H.6. Relative difference of fission product nuclide densities after 5 years cooling

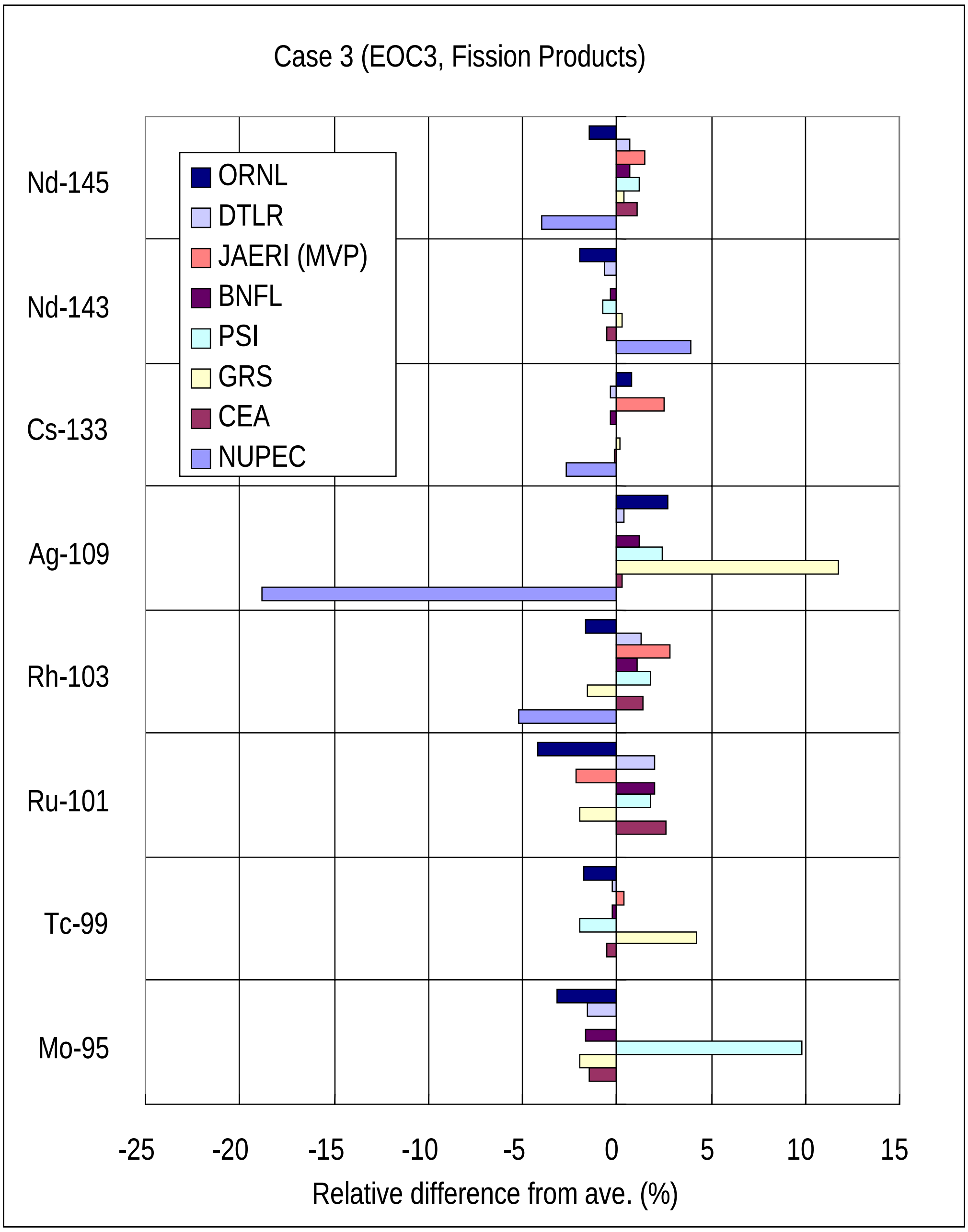
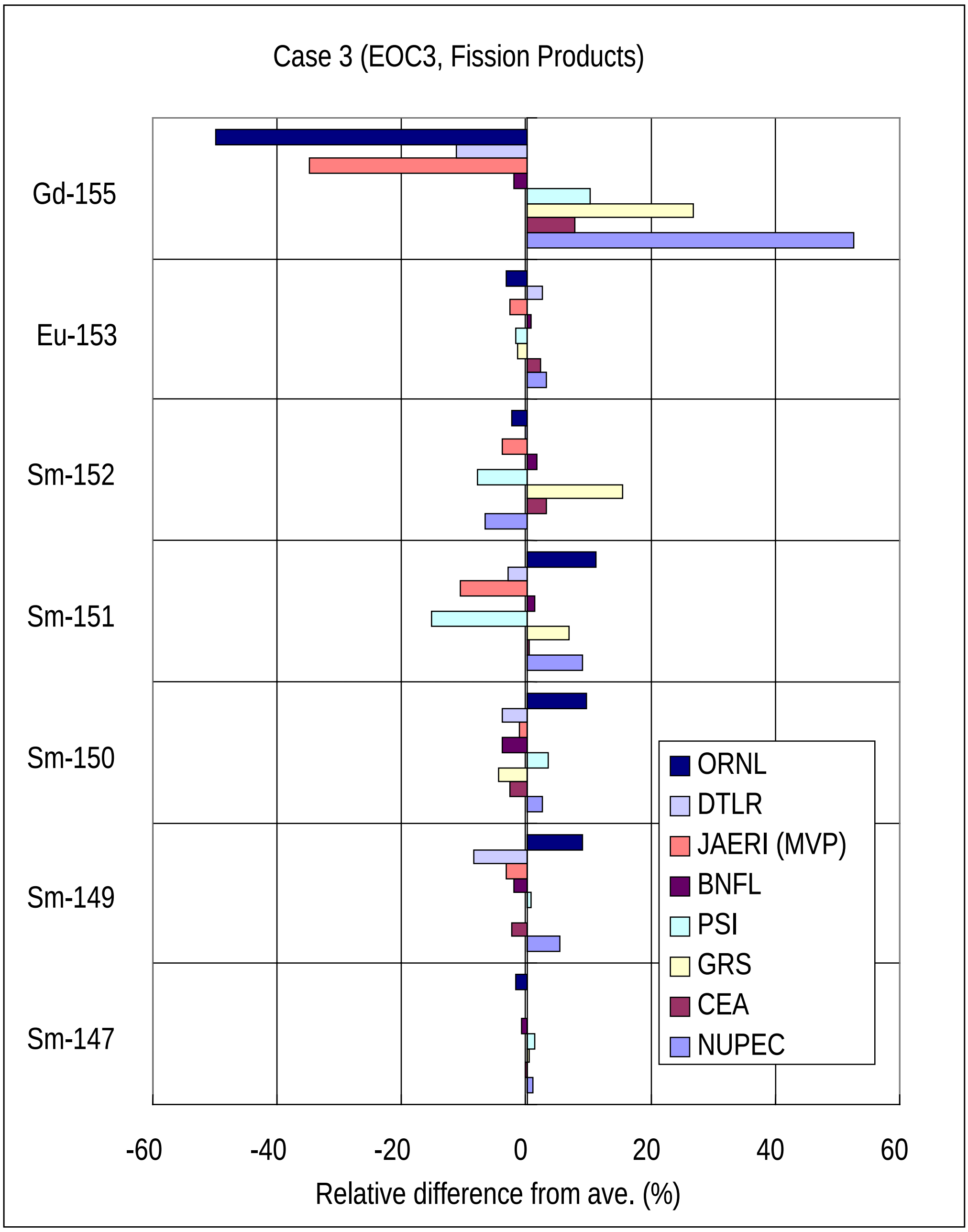


Figure H.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



Appendix I

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 4

Assembly model, weapons disposition MOX fuel

Figure I.1. Relative difference of actinide nuclide densities at the end of Cycle 1

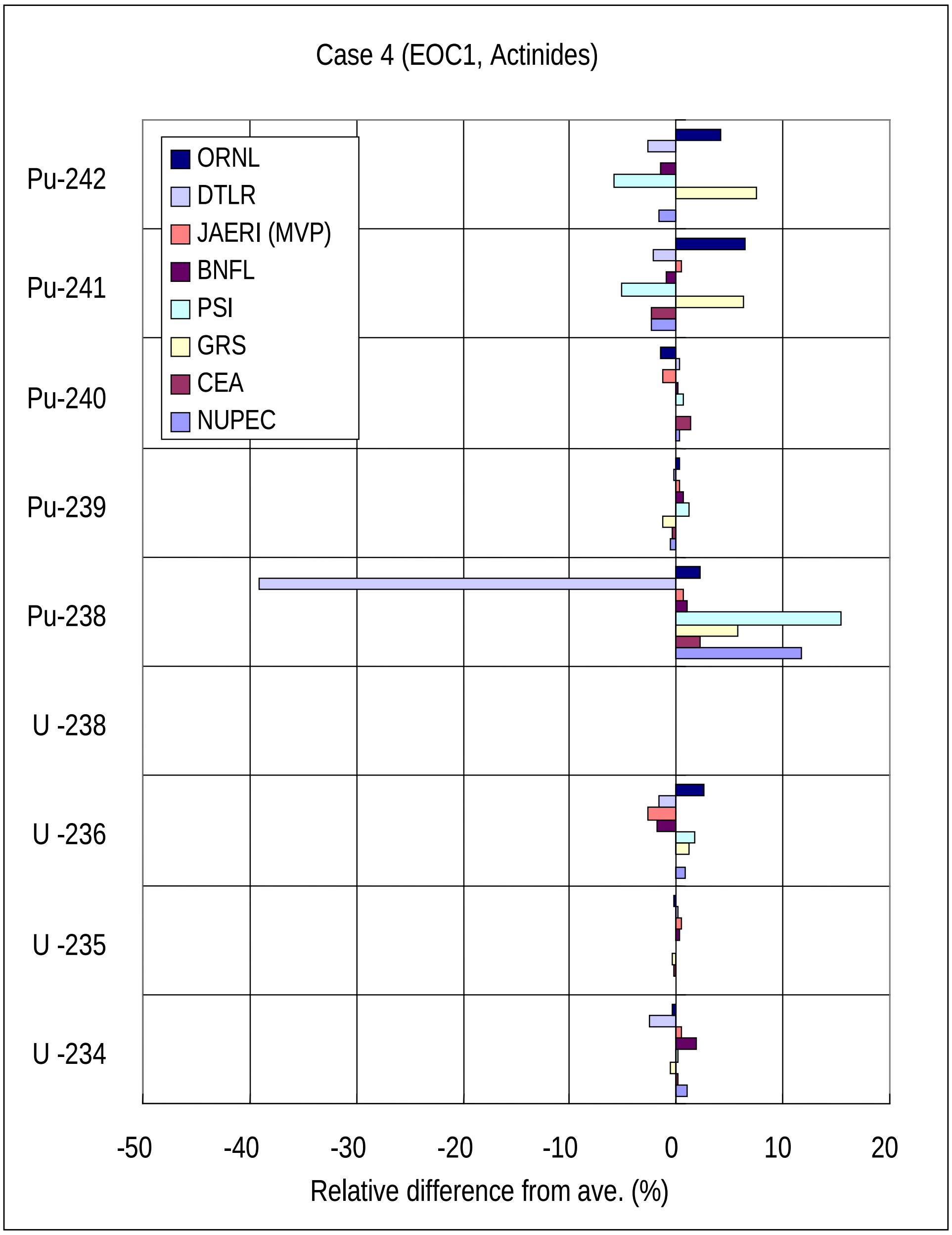


Figure I.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

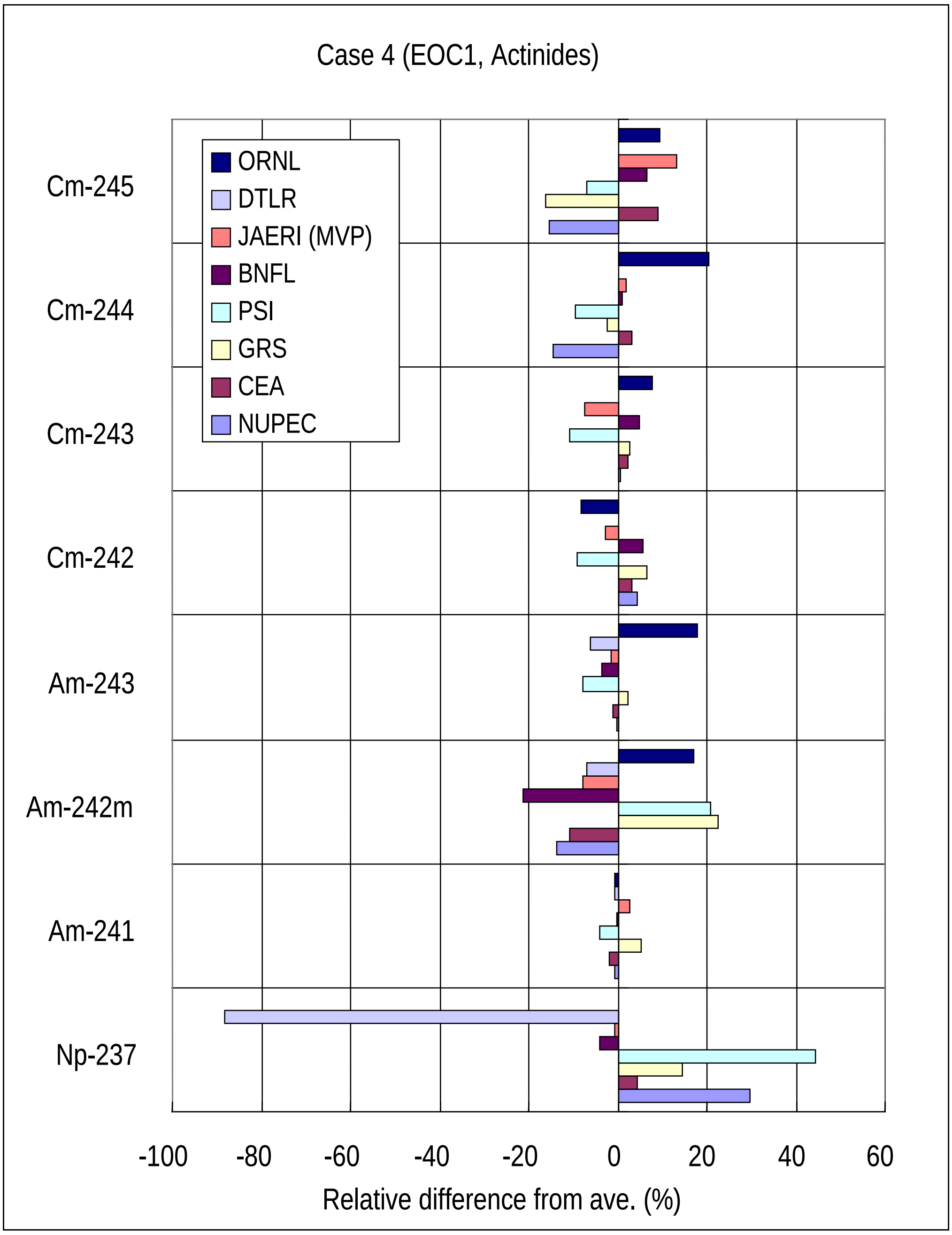


Figure I.2. Relative difference of fission product nuclide densities at the end of Cycle 1

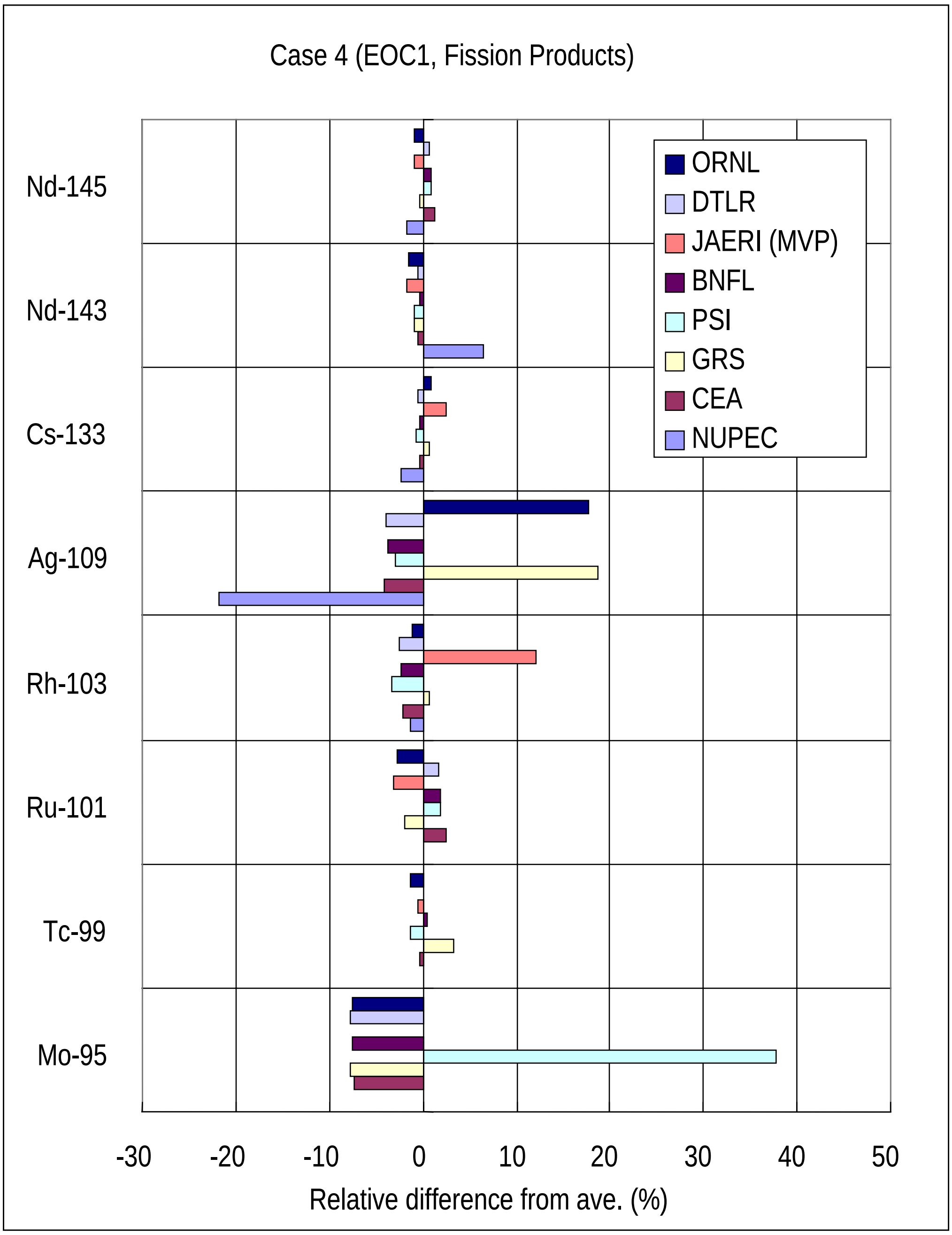


Figure I.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

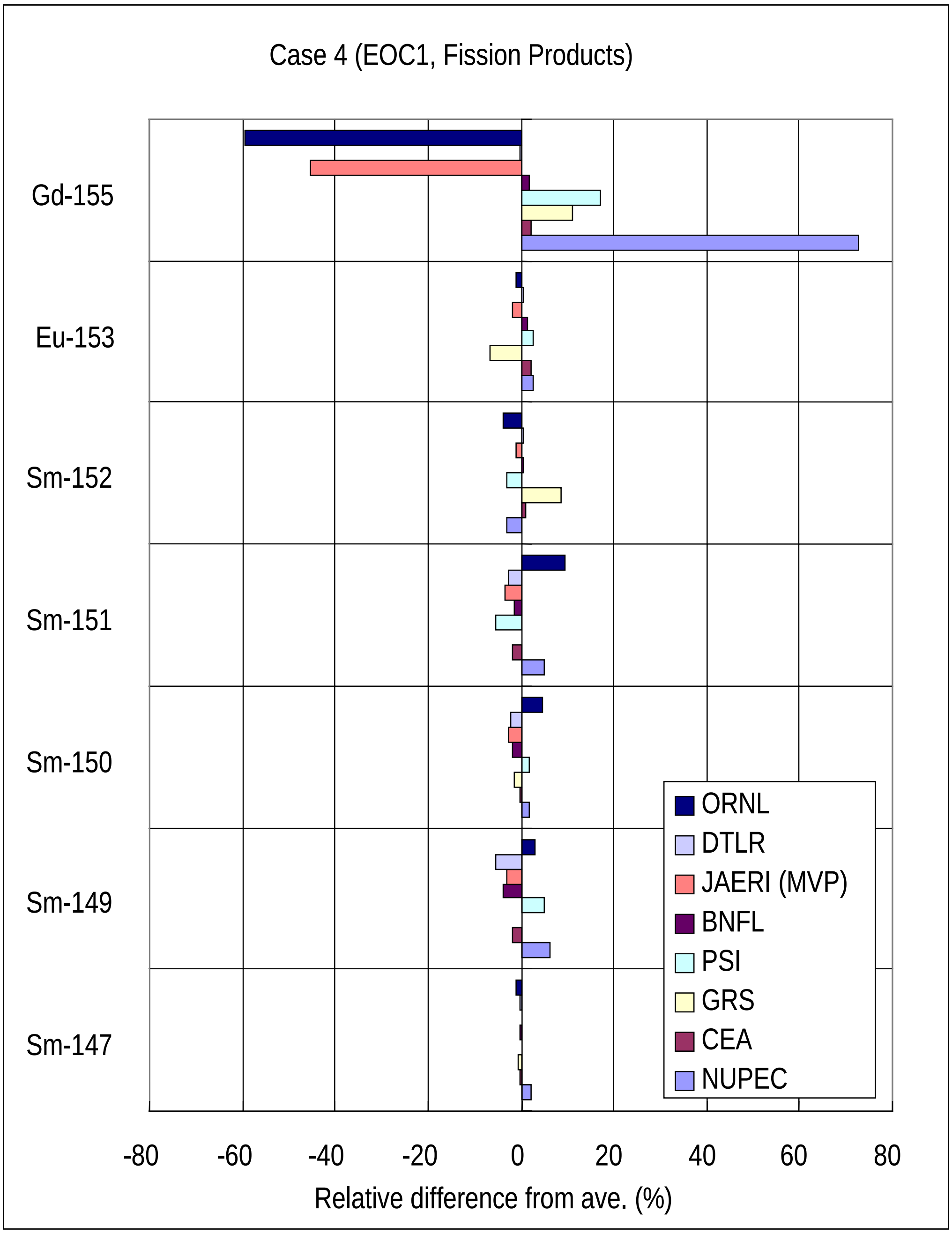


Figure I.3. Relative difference of actinide nuclide densities at the end of Cycle 3

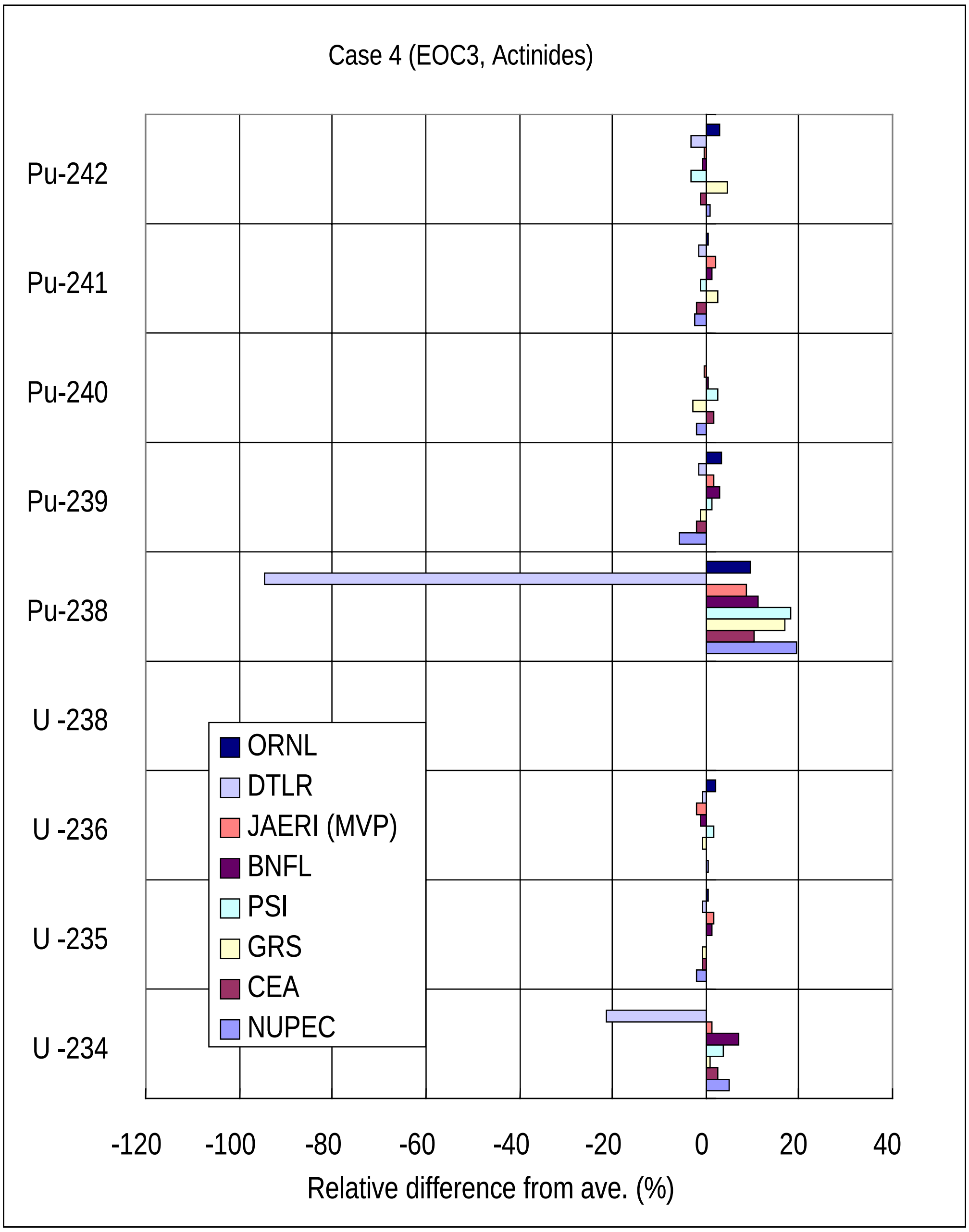


Figure I.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

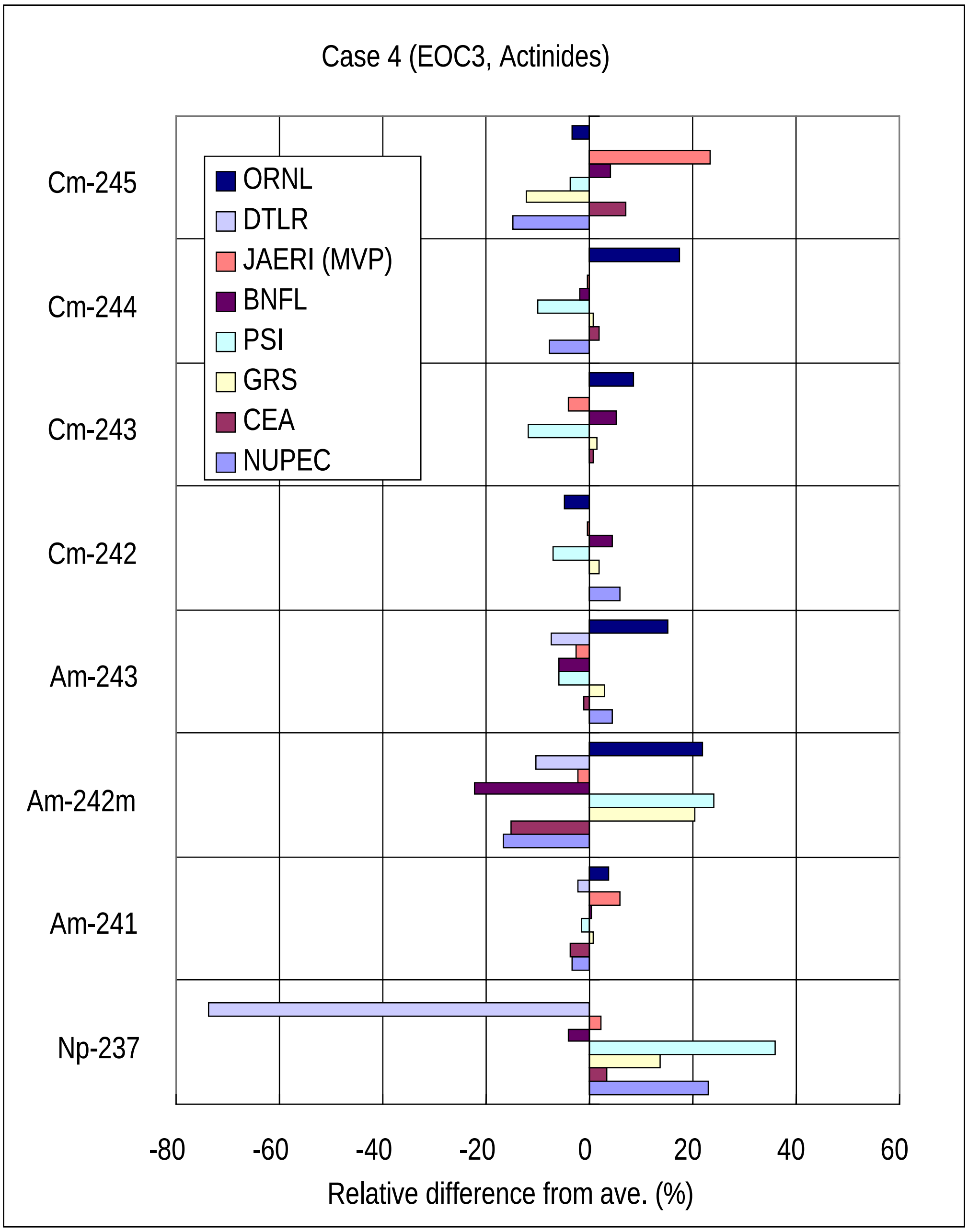


Figure I.4. Relative difference of fission product nuclide densities at the end of Cycle 3

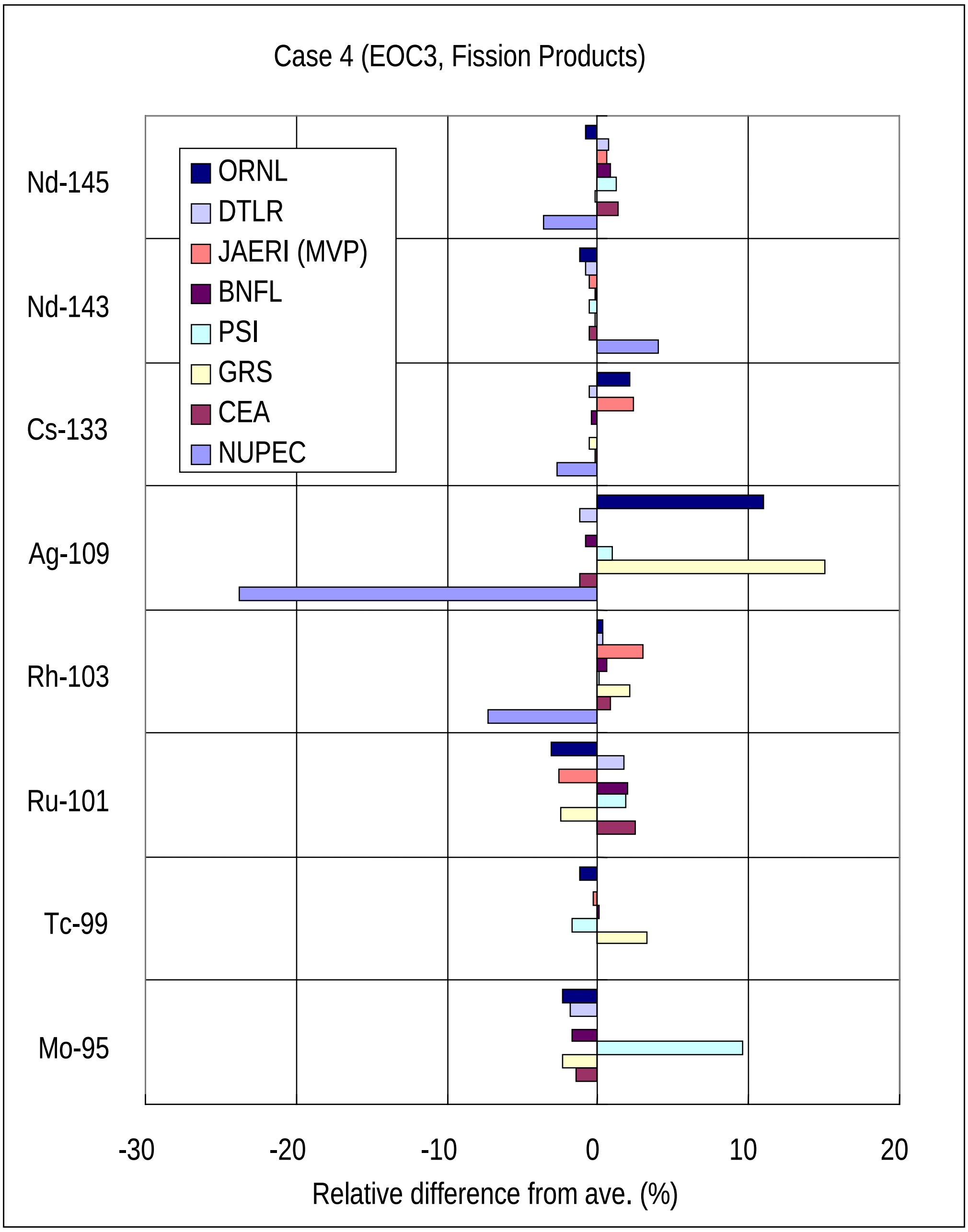


Figure I.4. Relative difference of fission product nuclide densities at the end of Cycle 3 (*cont.*)

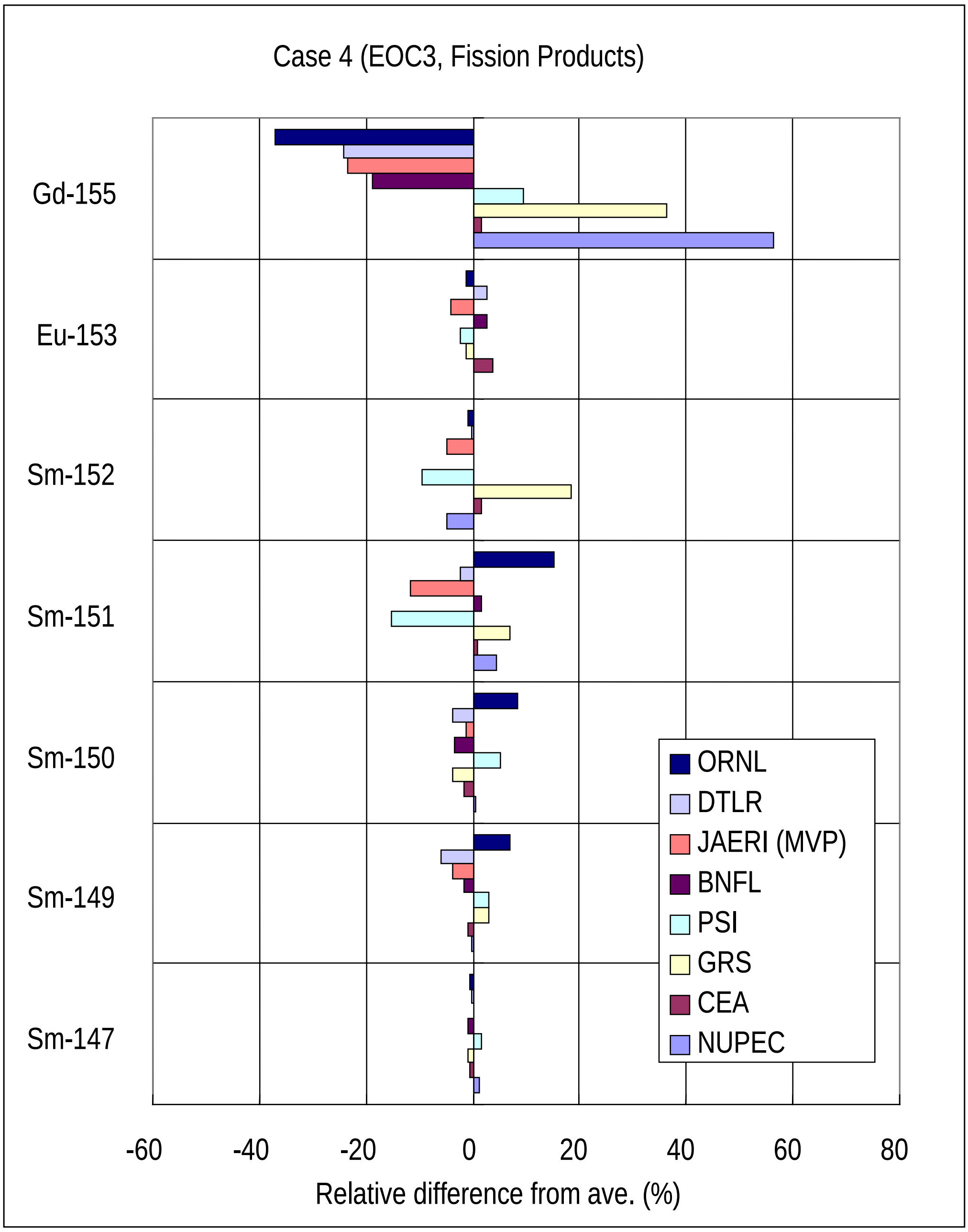


Figure I.5. Relative difference of actinide nuclide densities after 5 years cooling

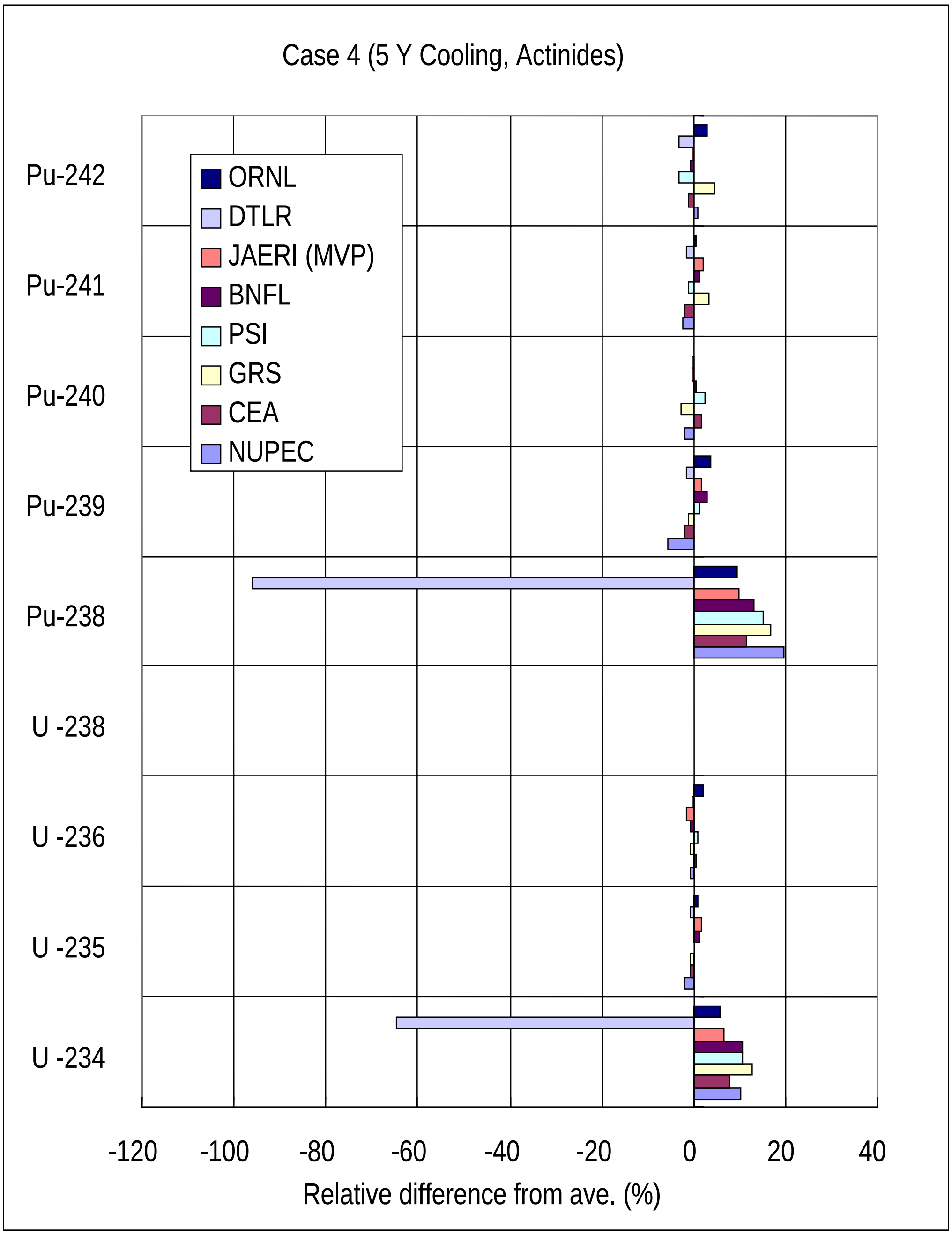


Figure I.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

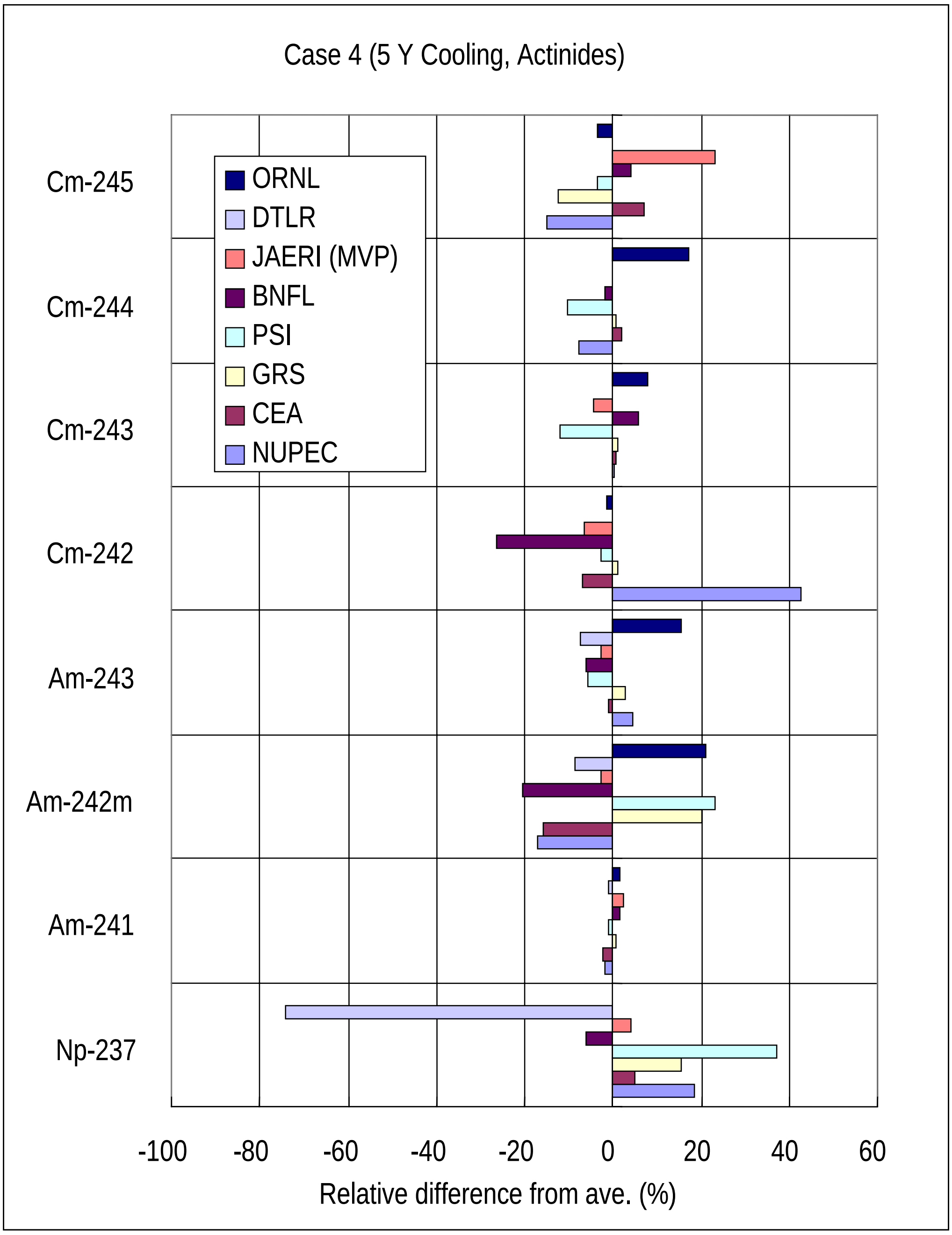


Figure I.6. Relative difference of fission product nuclide densities after 5 years cooling

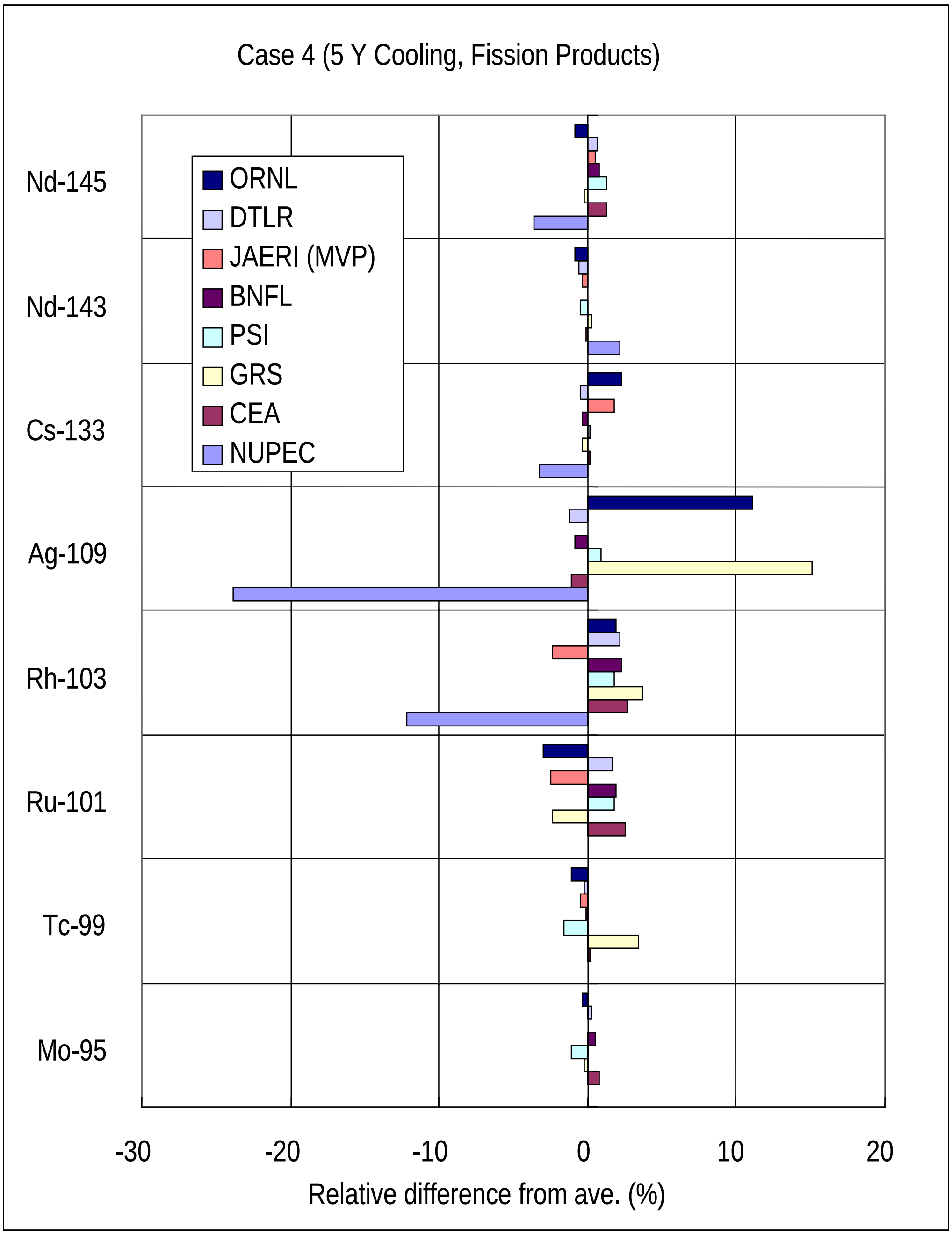
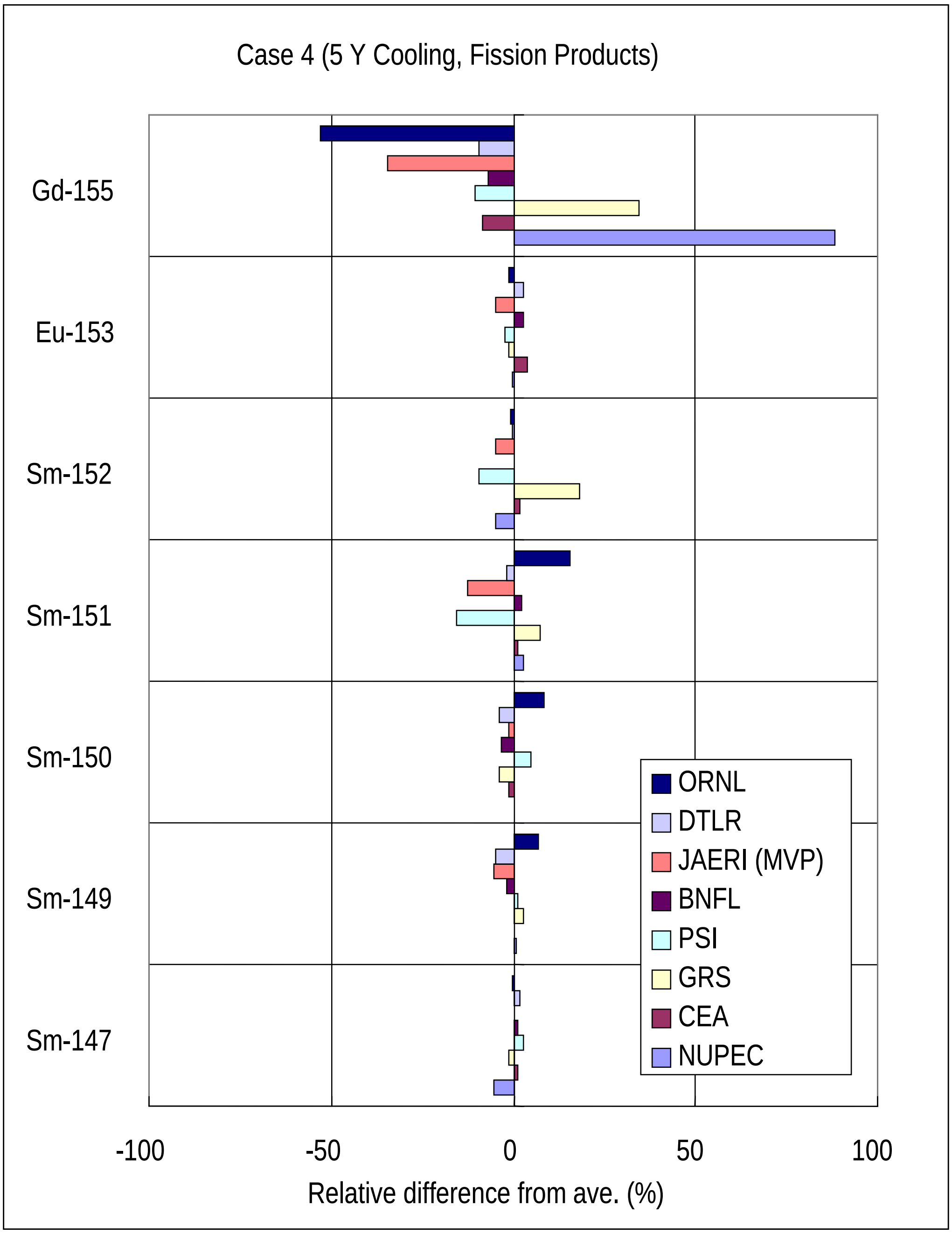


Figure I.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



Appendix J

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 5

Pin cell model, first recycle MOX fuel

Figure J.1. Relative difference of actinide nuclide densities at the end of Cycle 1

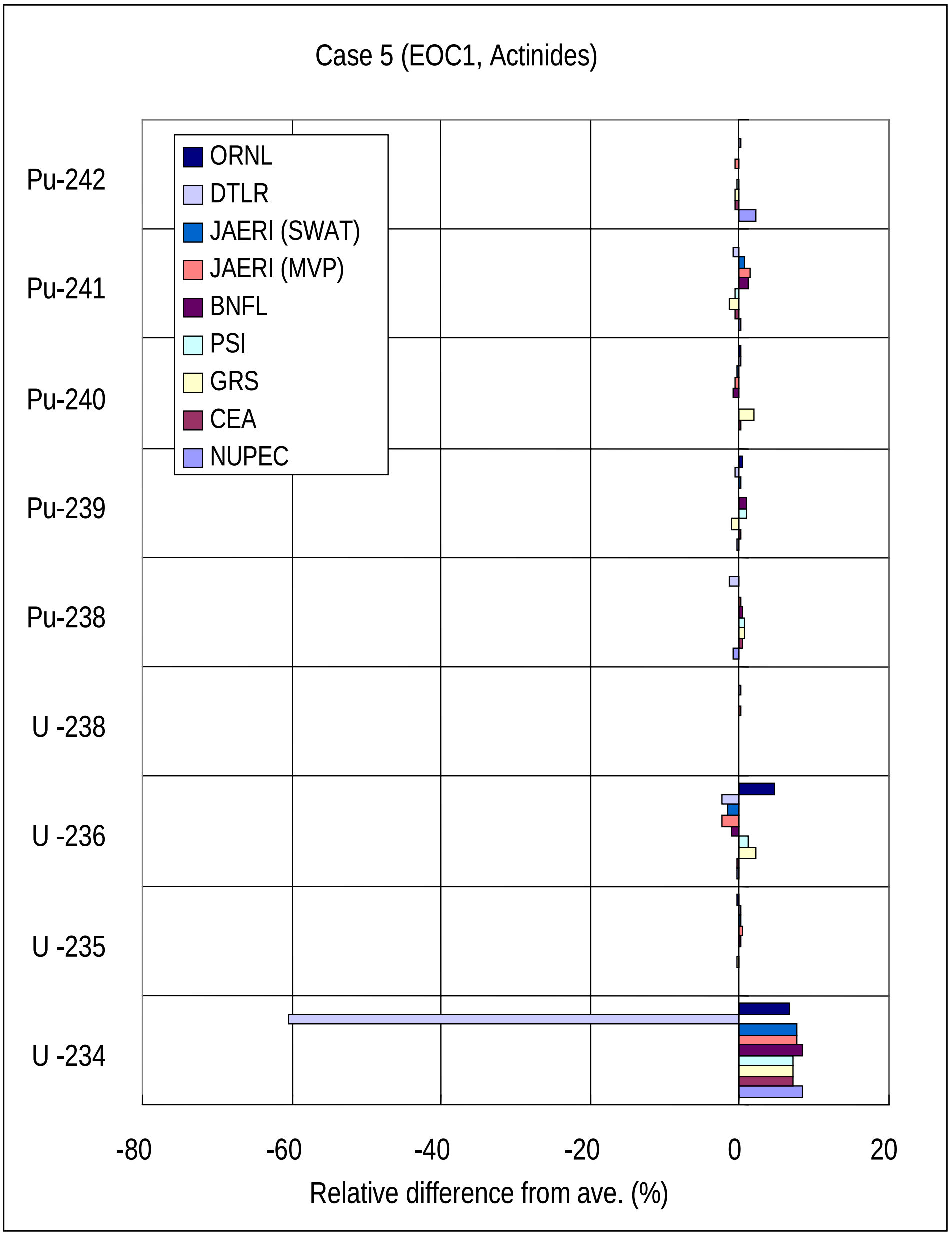


Figure J.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

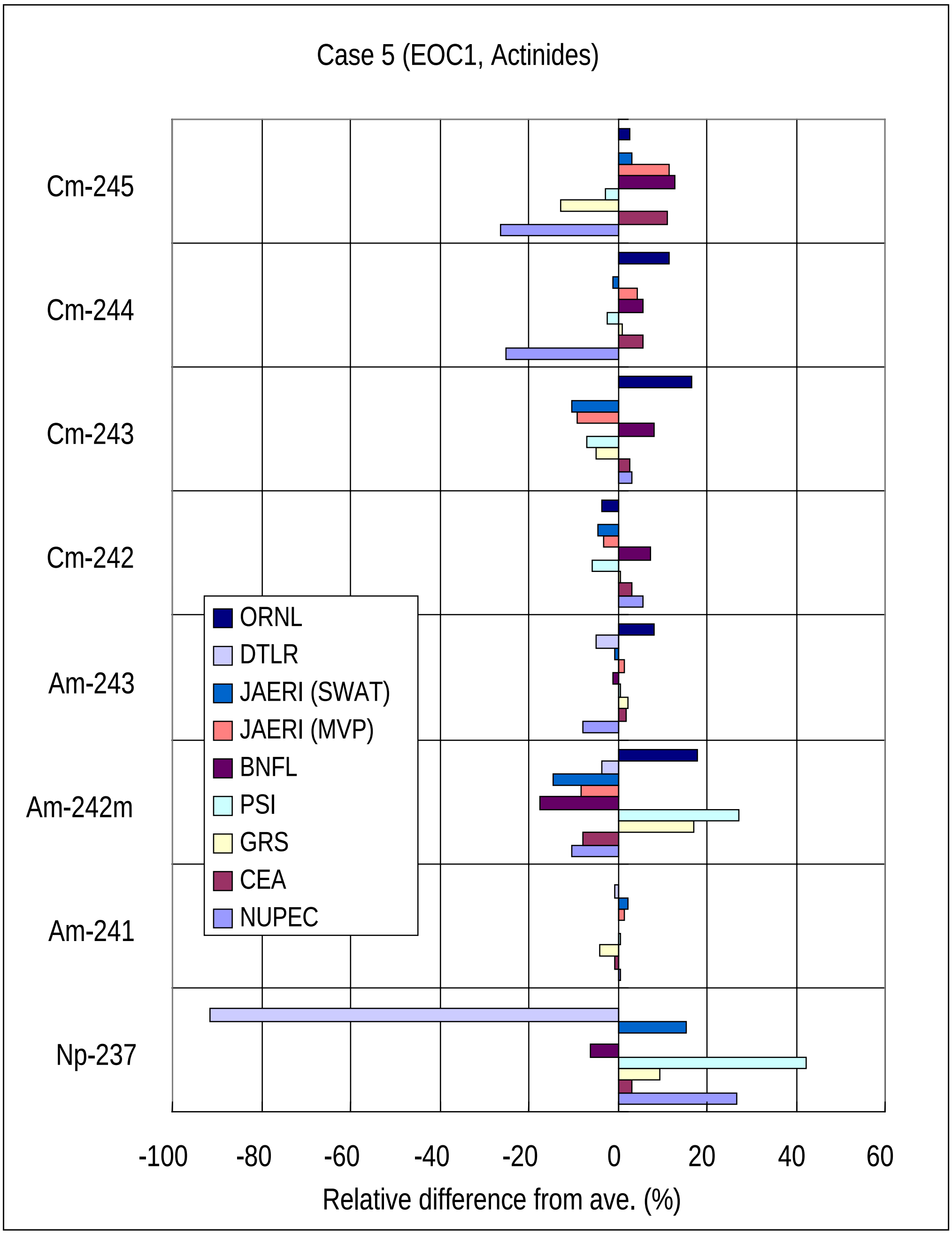


Figure J.2. Relative difference of fission product nuclide densities at the end of Cycle 1

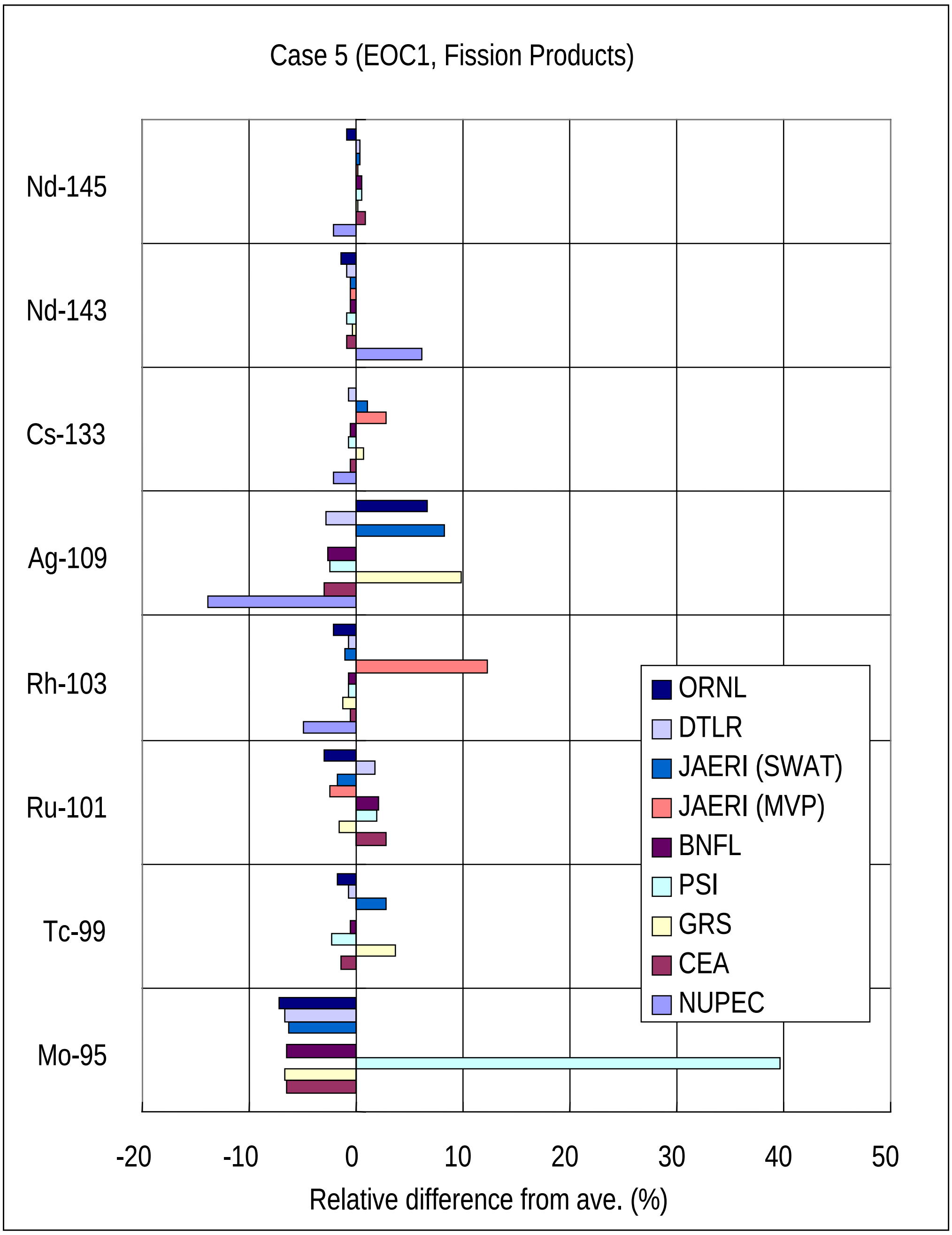


Figure J.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

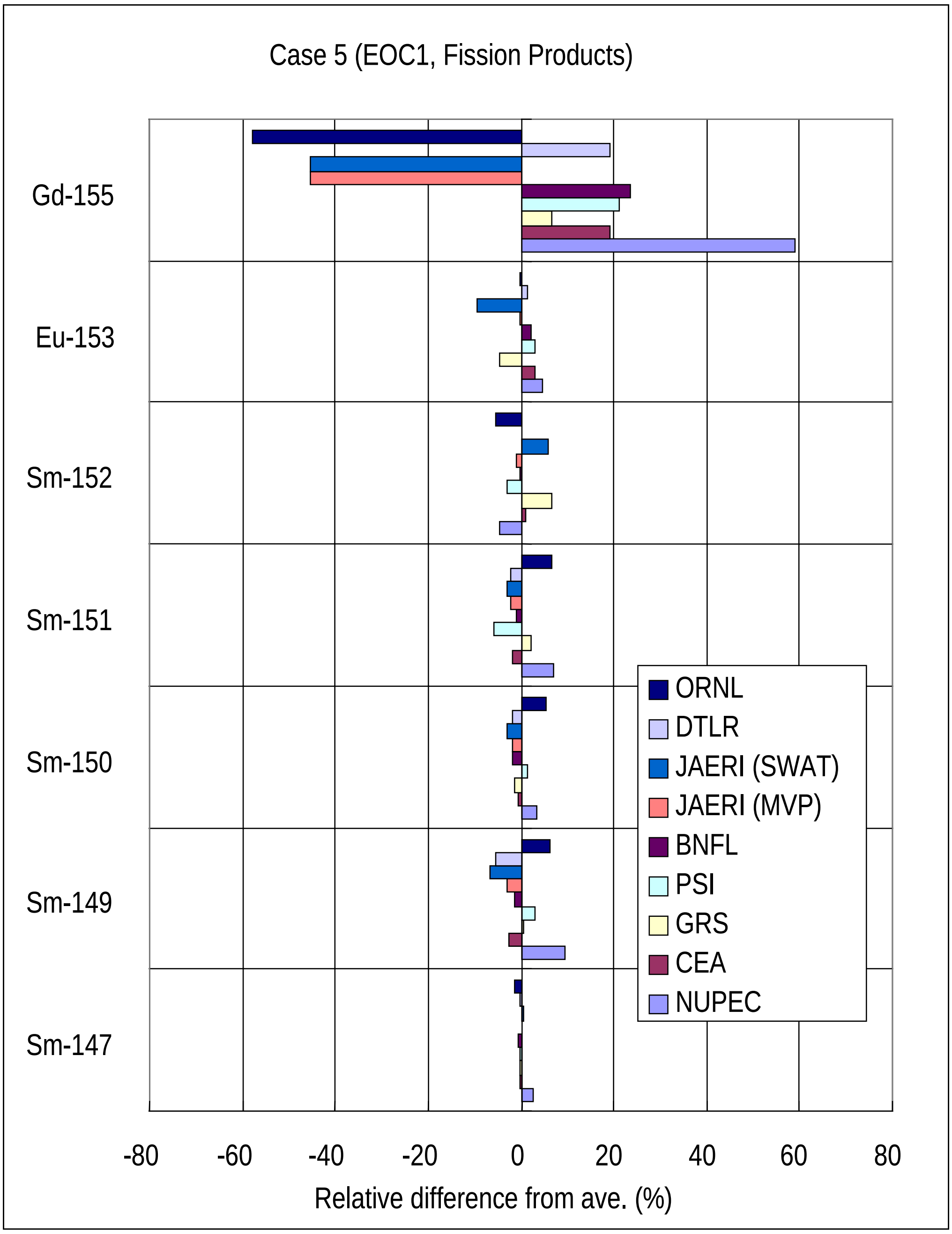


Figure J.3. Relative difference of actinide nuclide densities at the end of Cycle 3

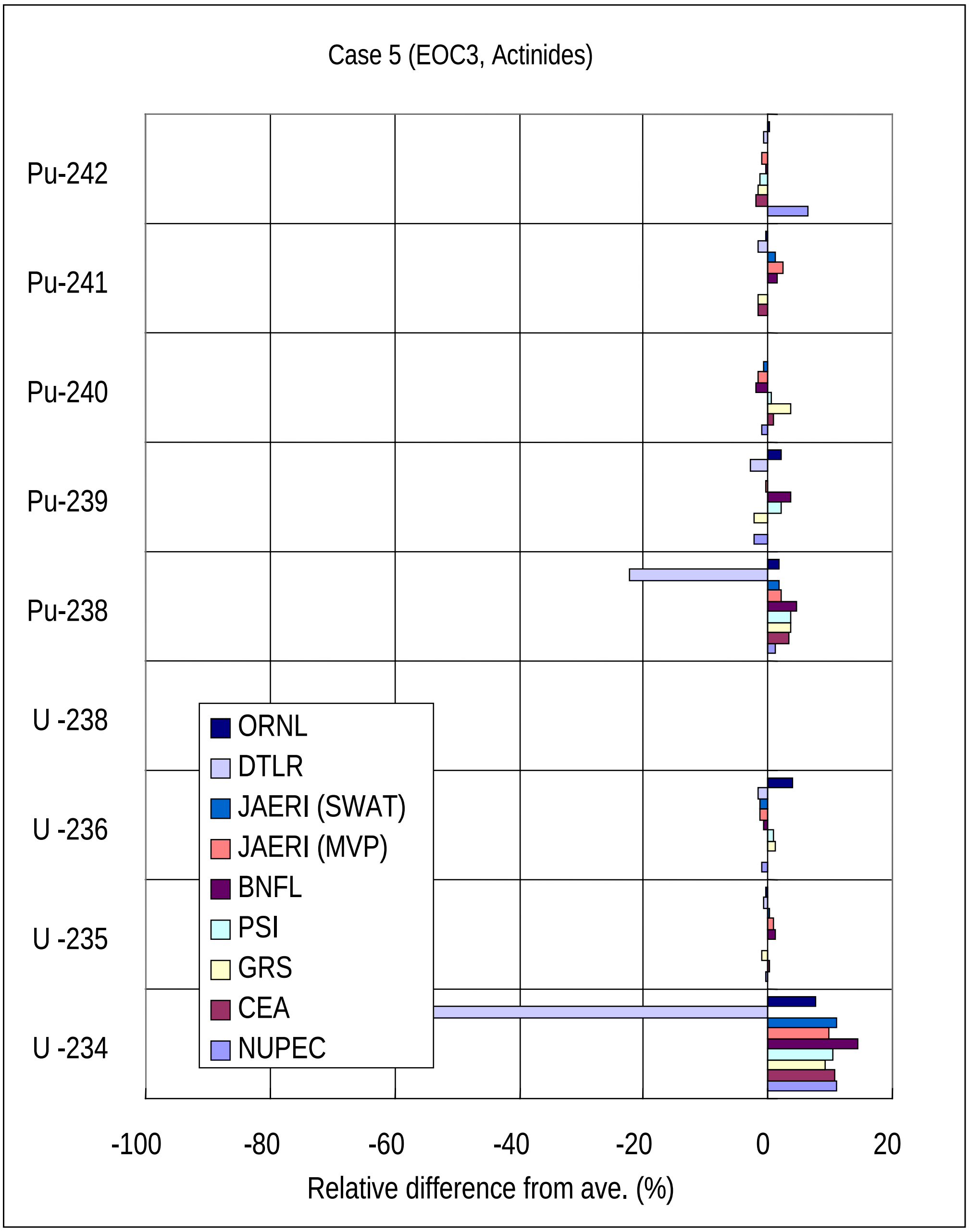


Figure J.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

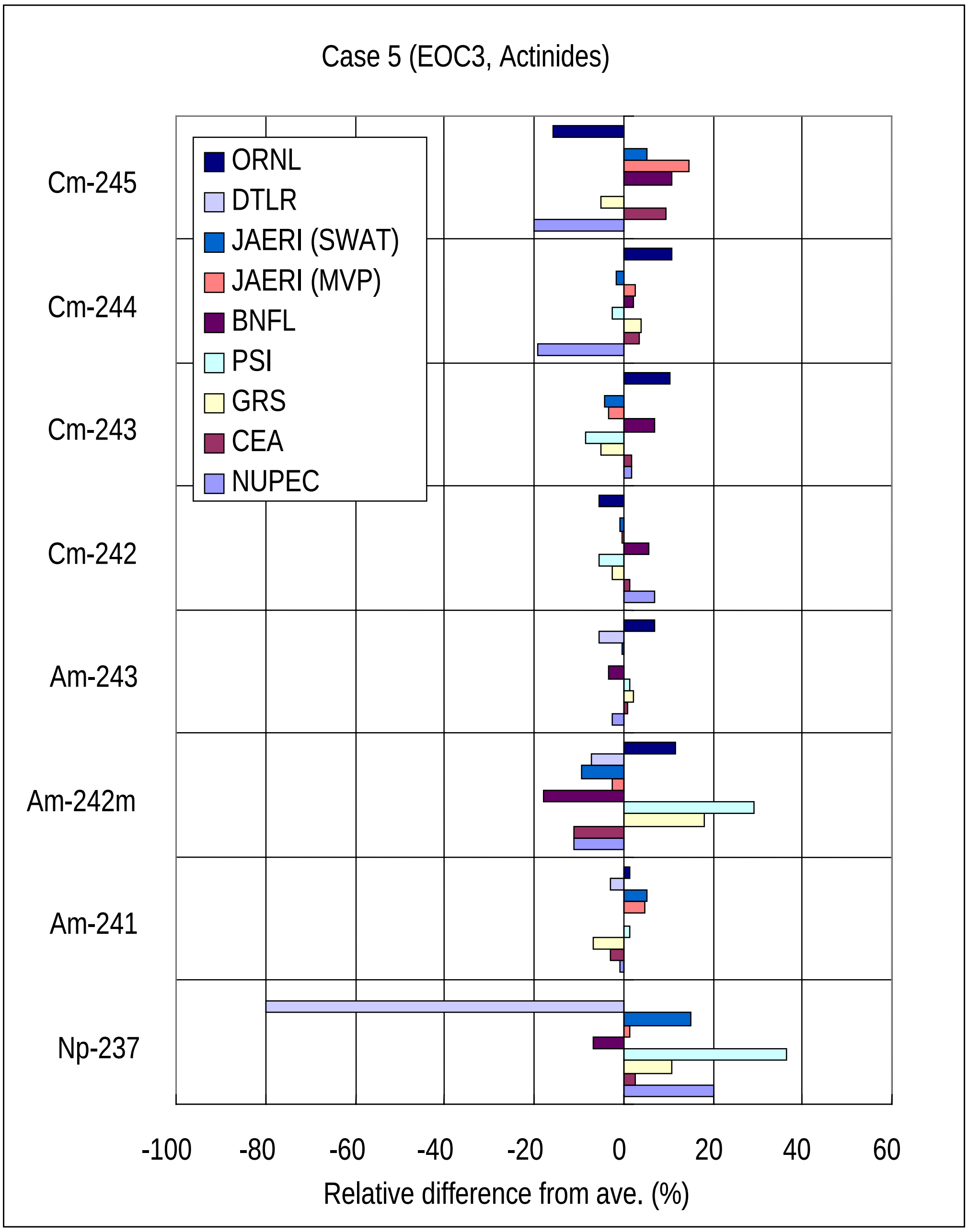


Figure J.4. Relative difference of fission product nuclides densities at the end of Cycle 3

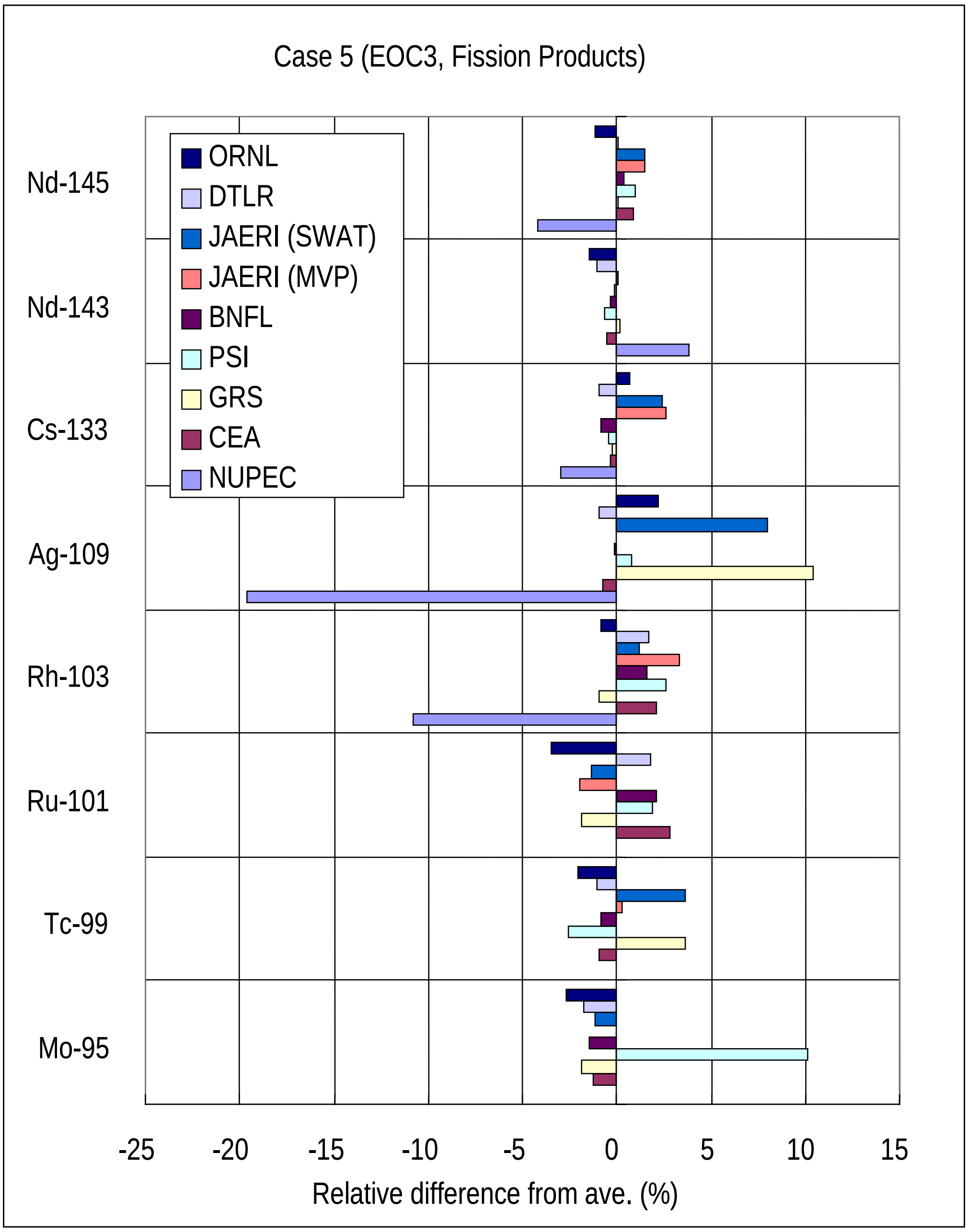


Figure J.4. Relative difference of fission product nuclides densities at the end of Cycle 3 (*cont.*)

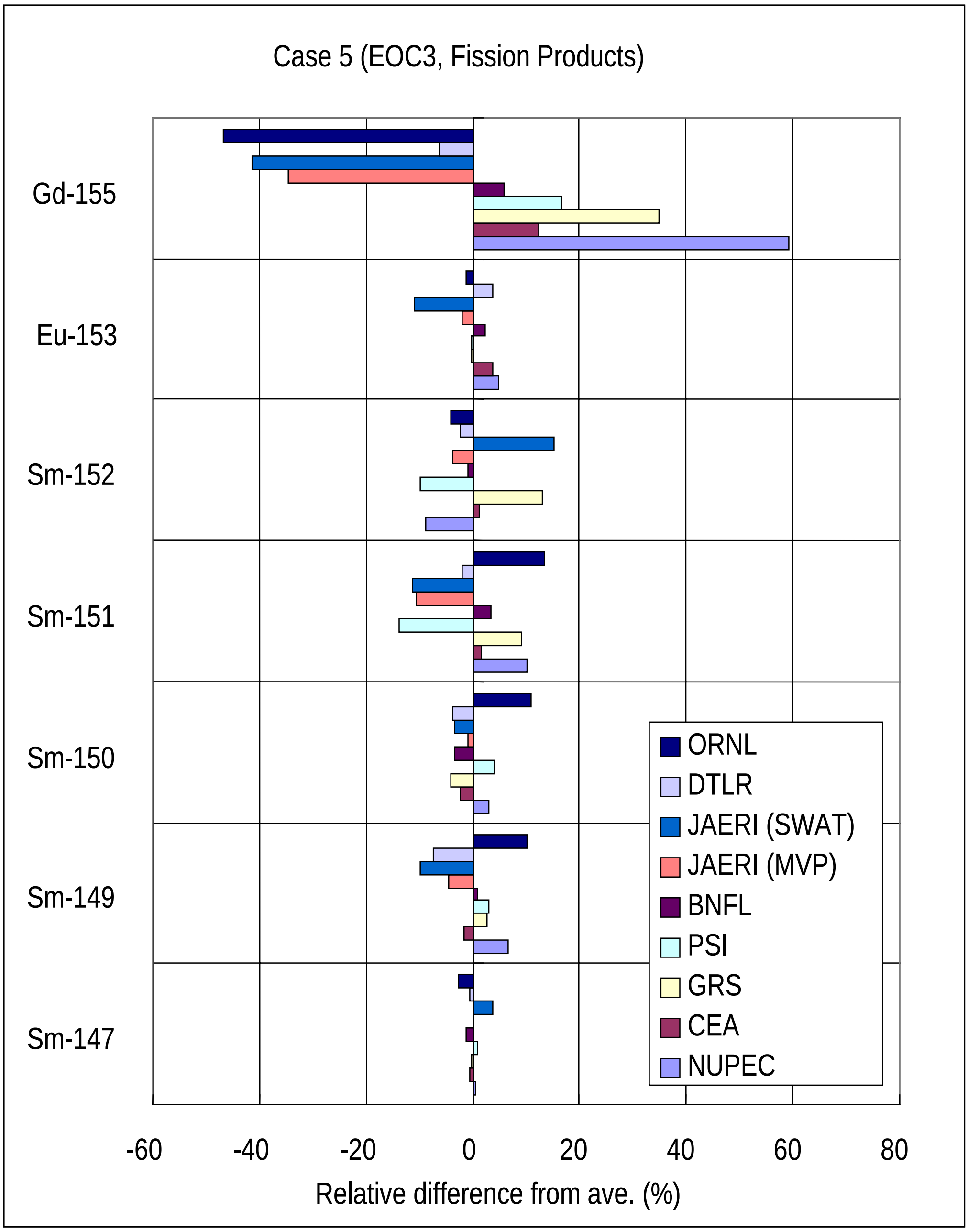


Figure J.5. Relative difference of actinide nuclide densities after 5 years cooling

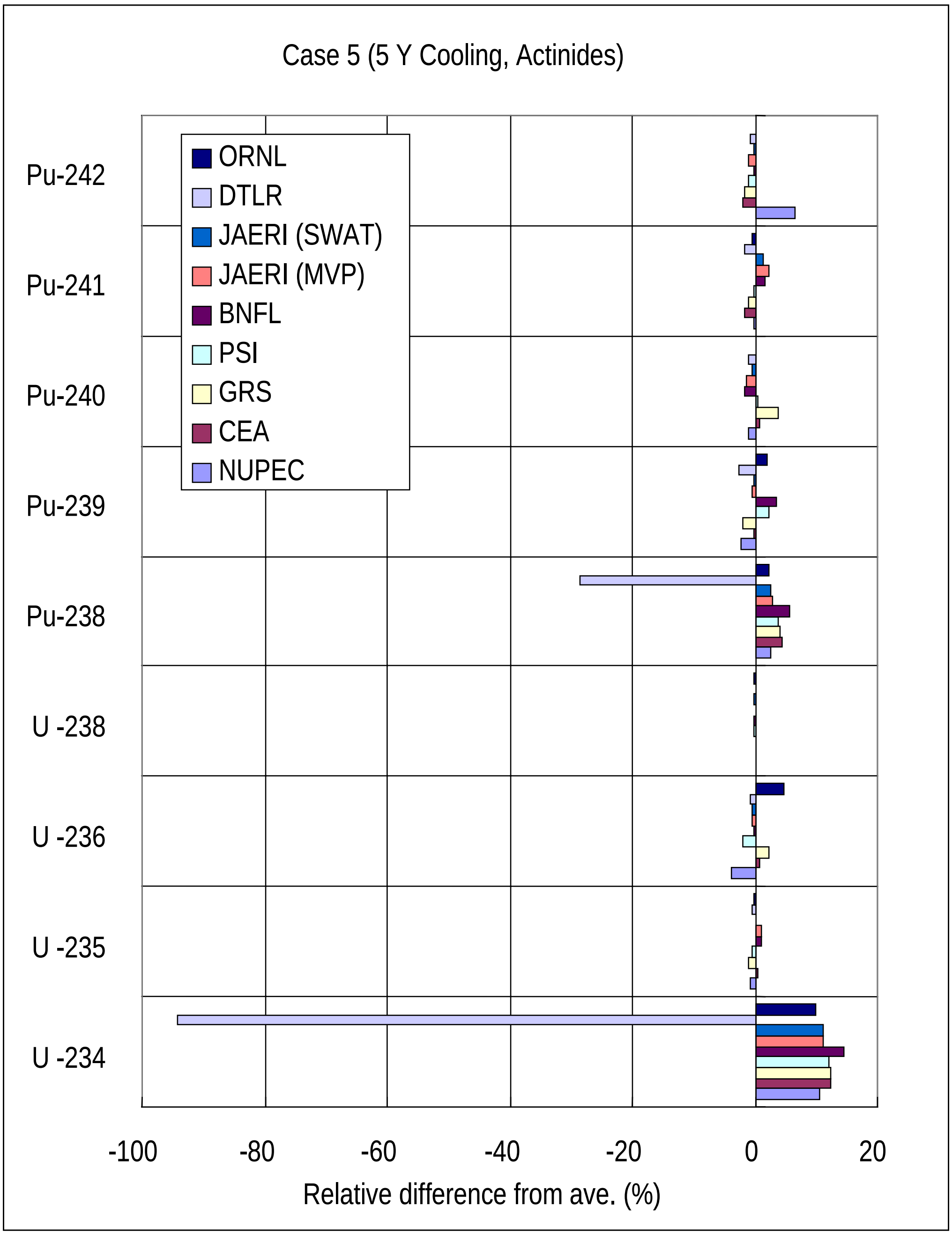


Figure J.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

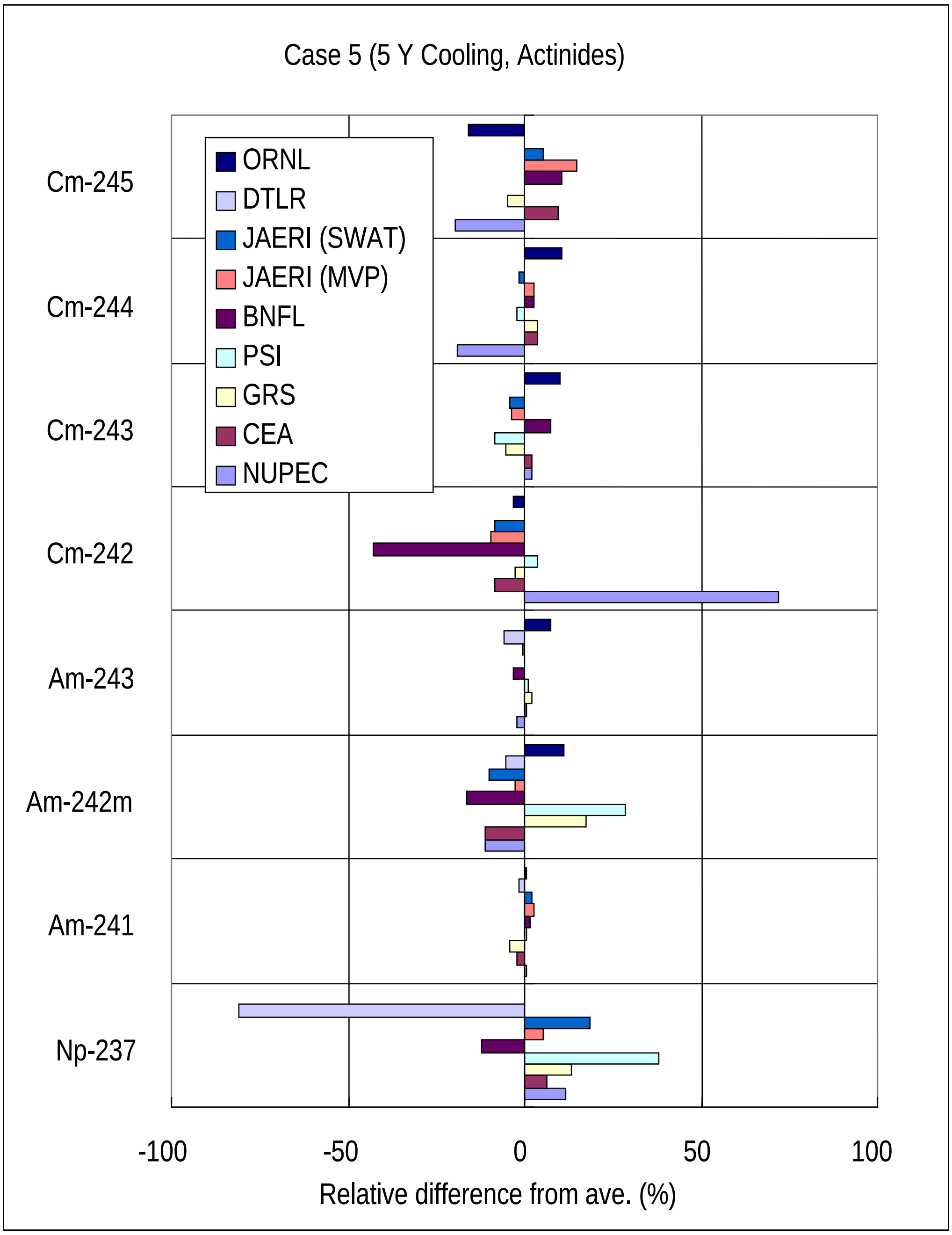


Figure J.6. Relative difference of fission product nuclide densities after 5 years cooling

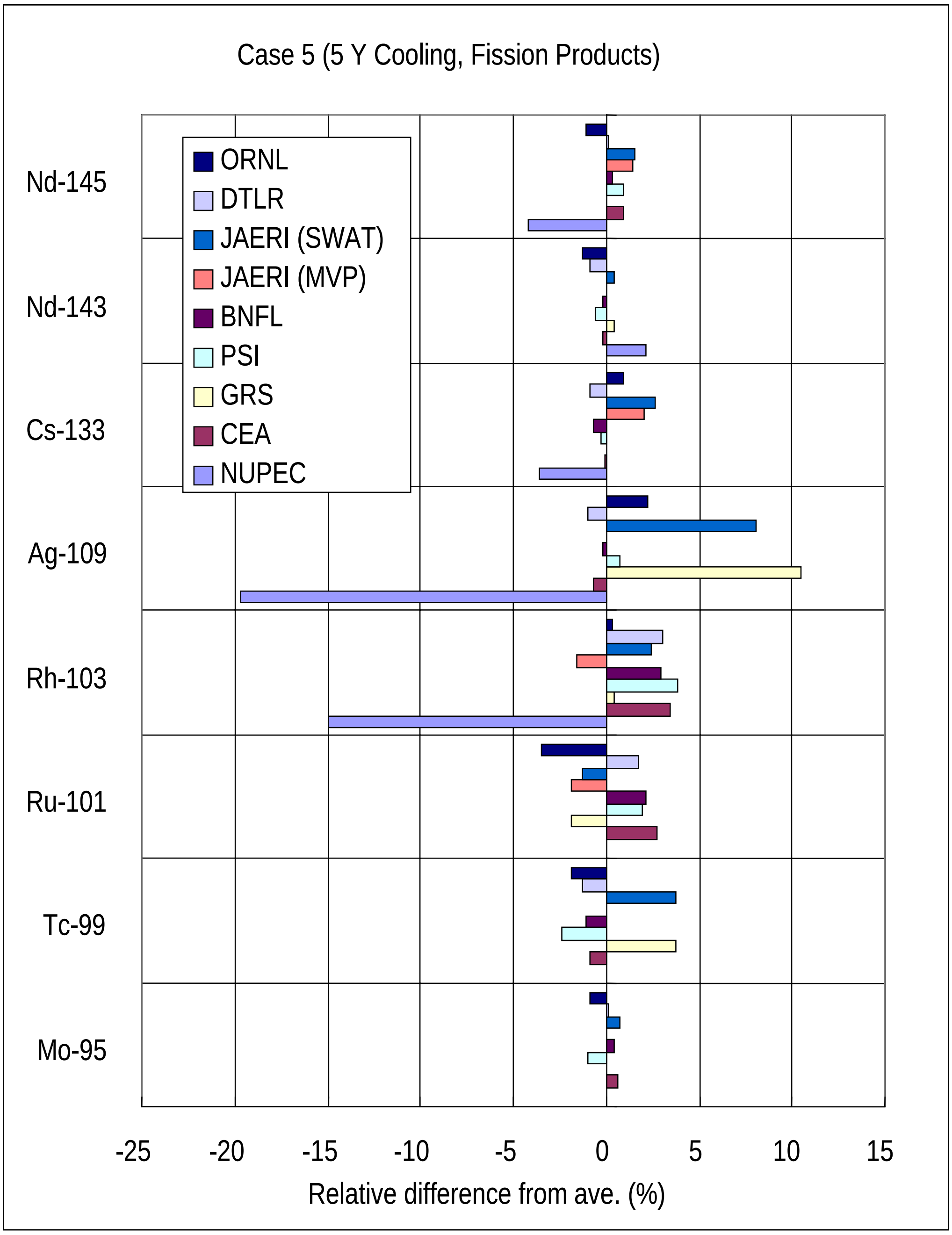
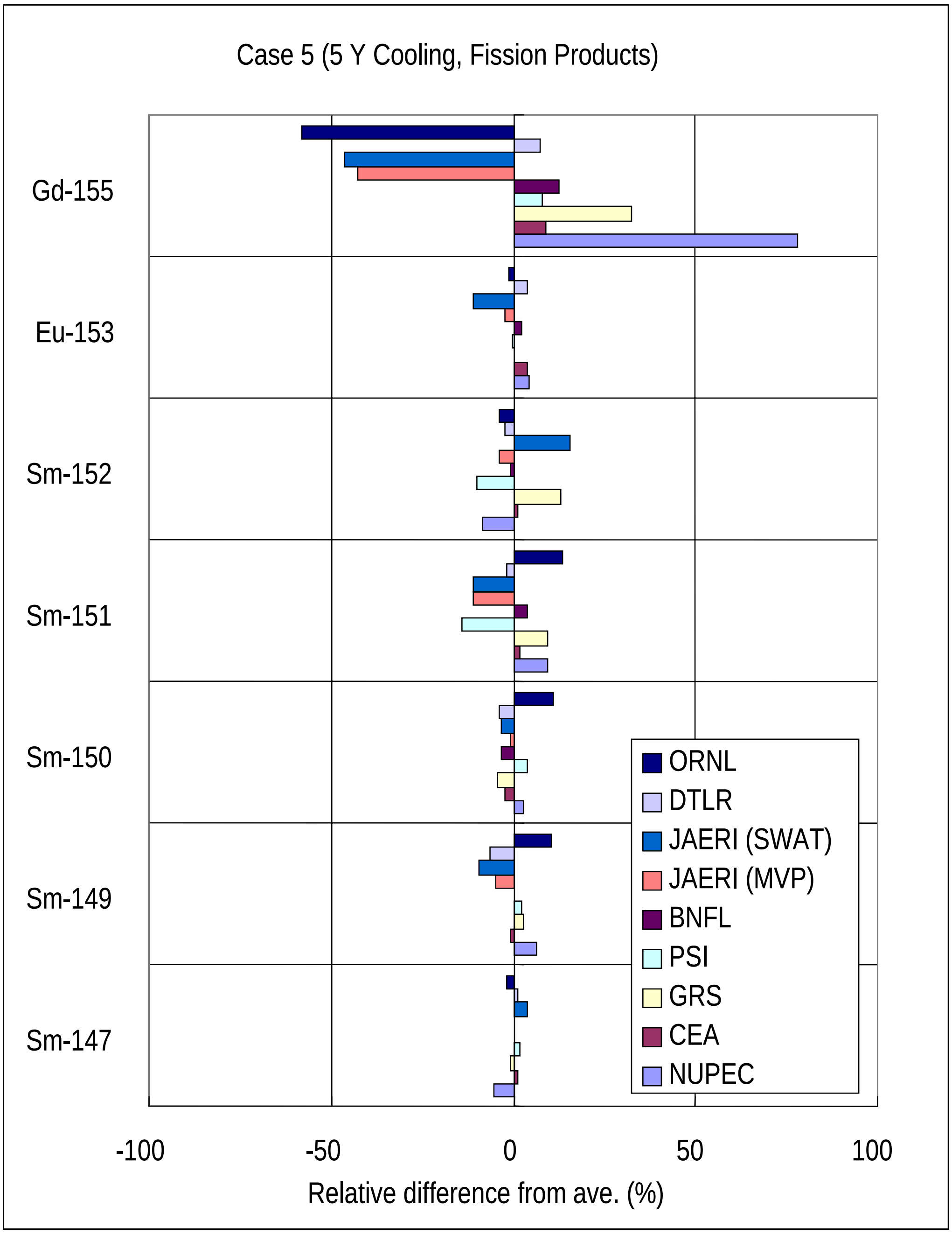


Figure J.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



Appendix K

COMPARISON GRAPHS FOR ACTINIDE AND FISSION PRODUCT NUCLIDE DENSITIES FOR CASE 6

Pin cell model, weapons disposition MOX fuel

Figure K.1. Relative difference of actinide nuclide densities at the end of Cycle 1

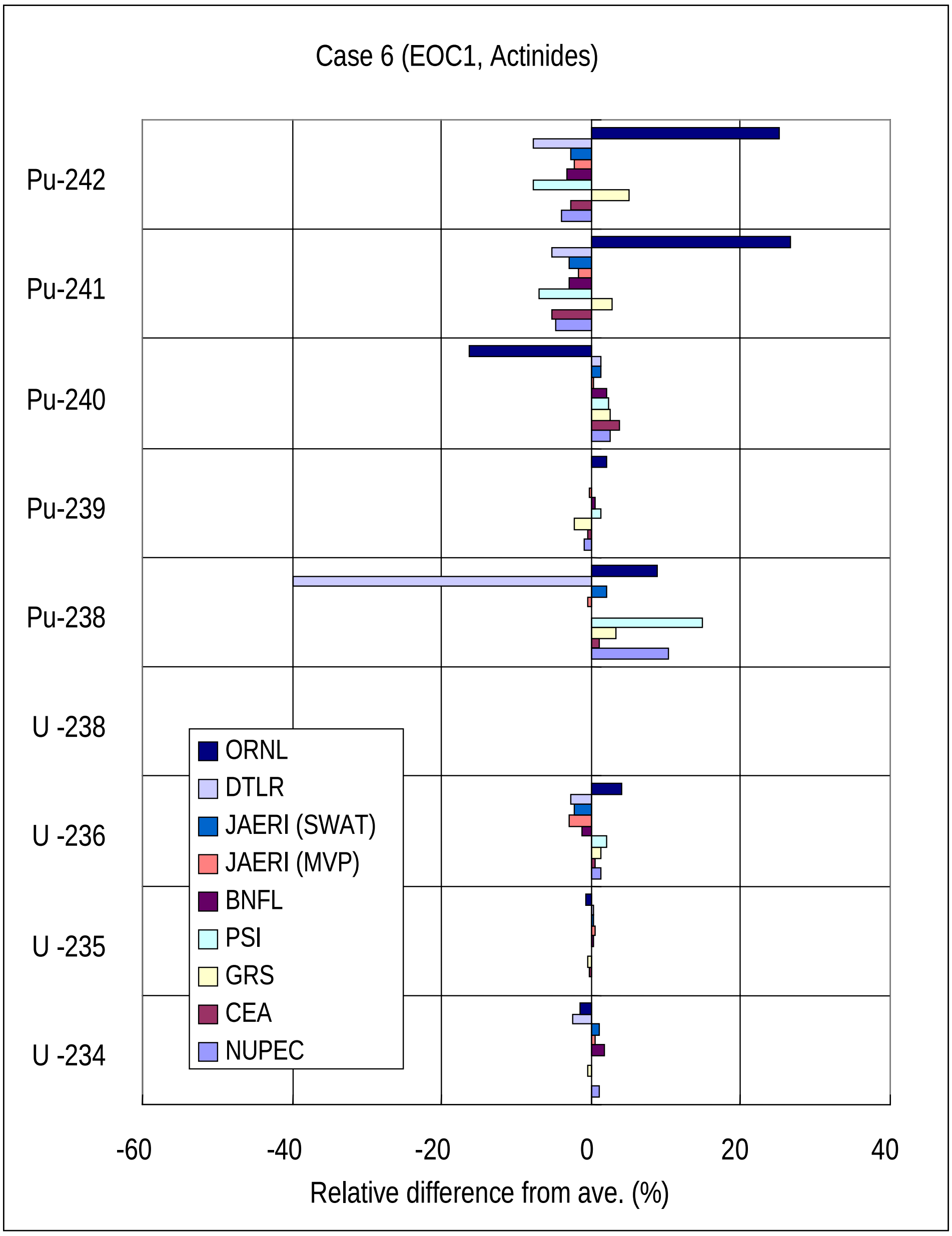


Figure K.1. Relative difference of actinide nuclide densities at the end of Cycle 1 (*cont.*)

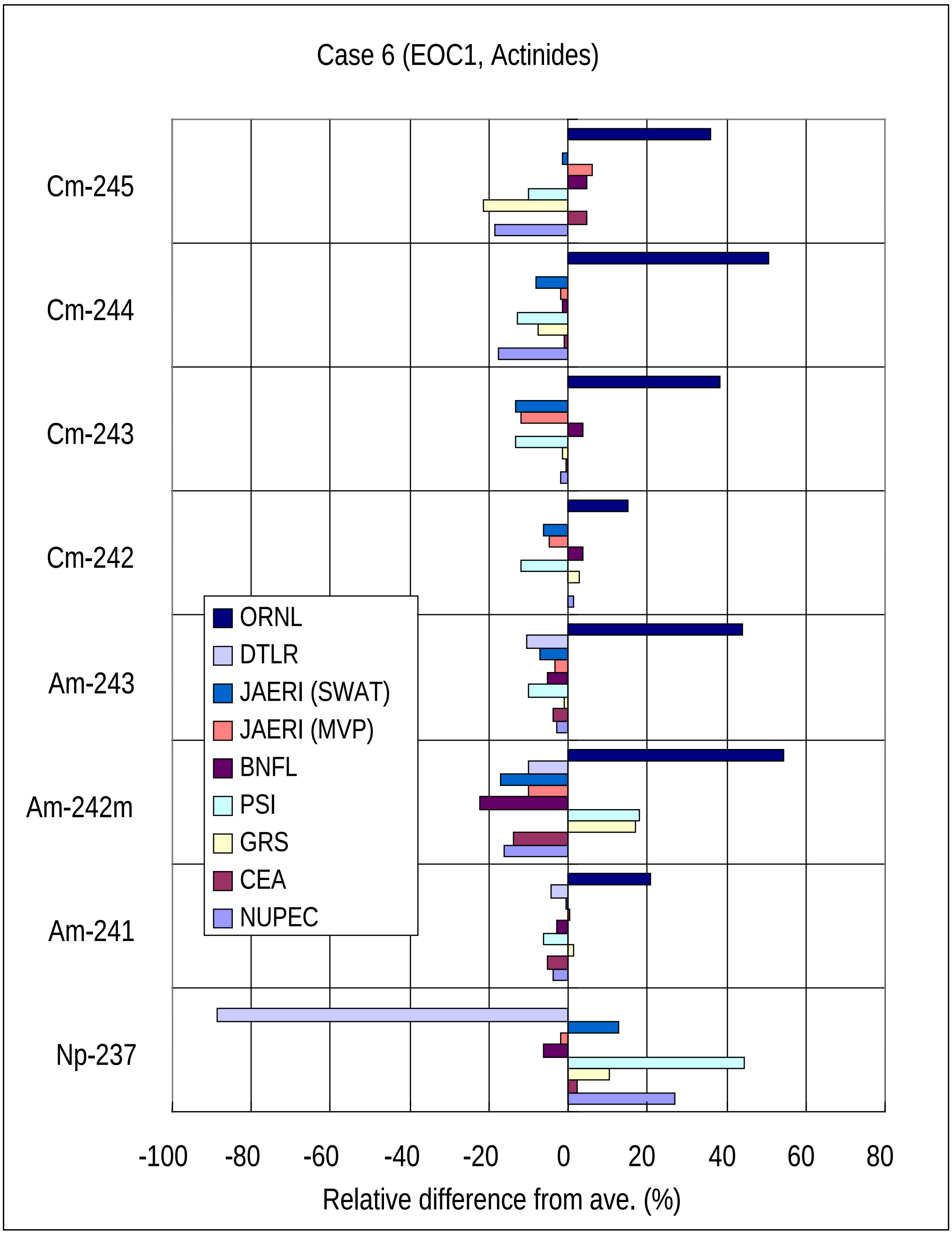


Figure K.2. Relative difference of fission product nuclide densities at the end of Cycle 1

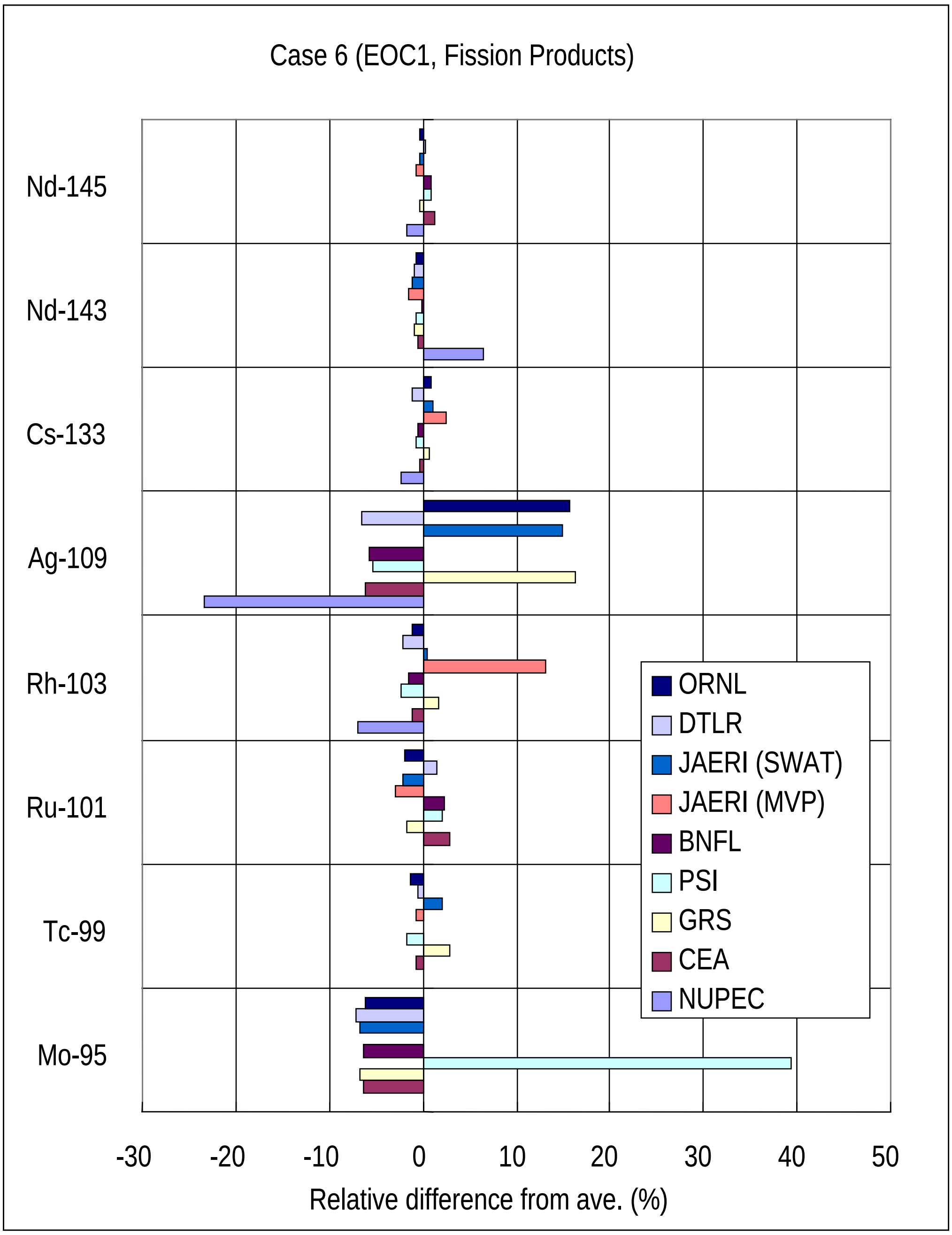


Figure K.2. Relative difference of fission product nuclide densities at the end of Cycle 1 (*cont.*)

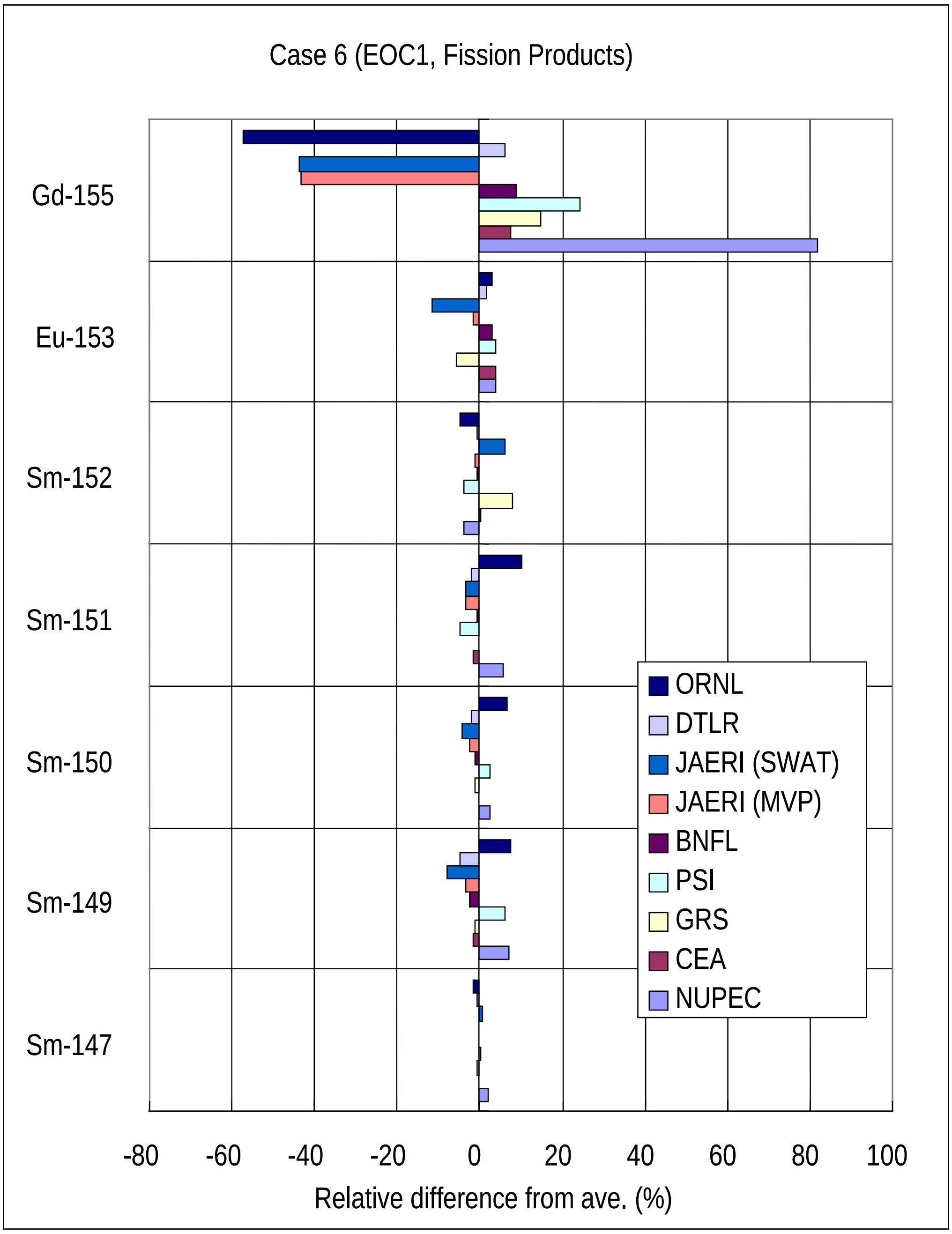


Figure K.3. Relative difference of actinide nuclide densities at the end of Cycle 3

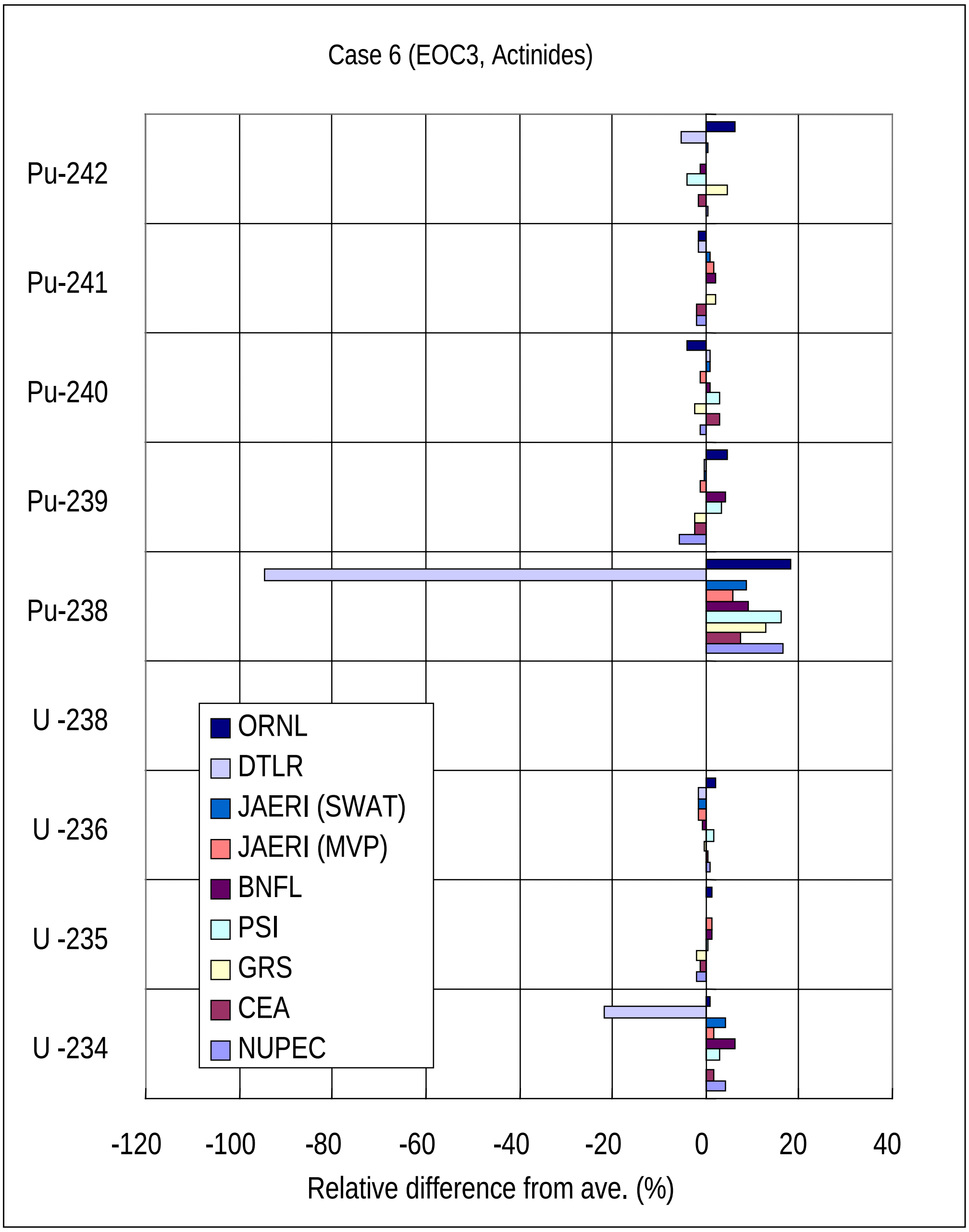


Figure K.3. Relative difference of actinide nuclide densities at the end of Cycle 3 (*cont.*)

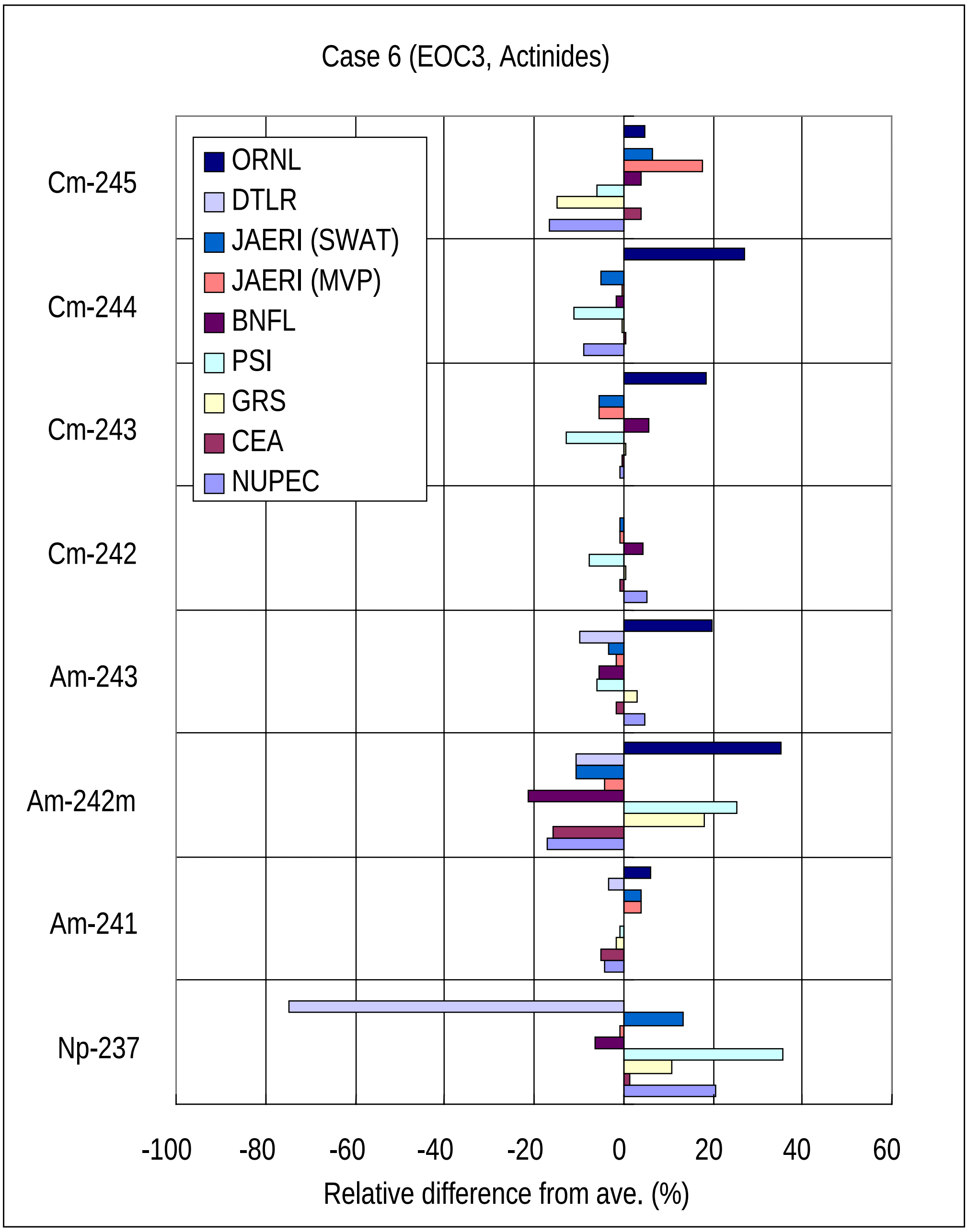


Figure K.4. Relative difference of fission product nuclide densities at the end of Cycle 3

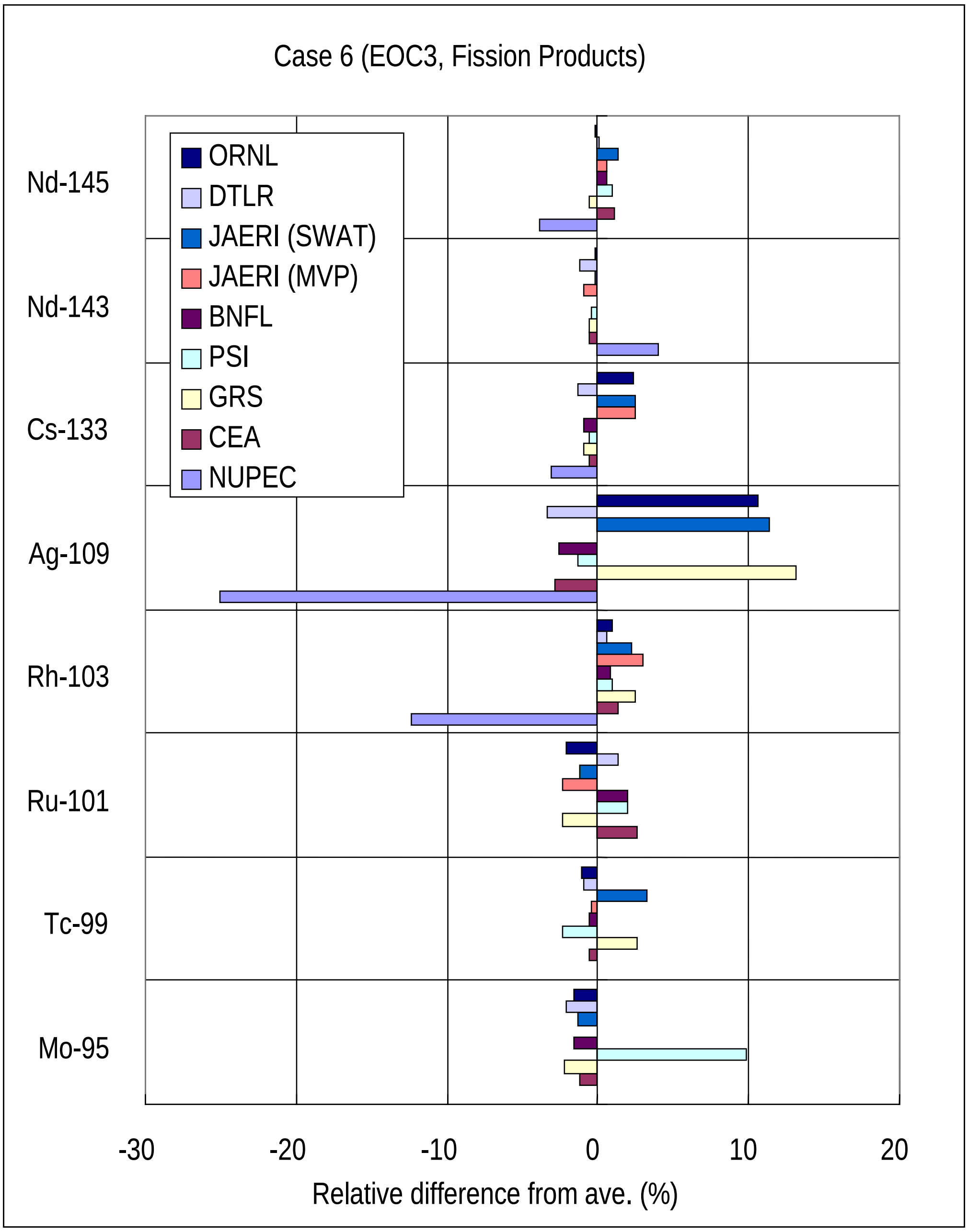


Figure K.4. Relative difference of fission product nuclide densities at the end of Cycle 3 (*cont.*)

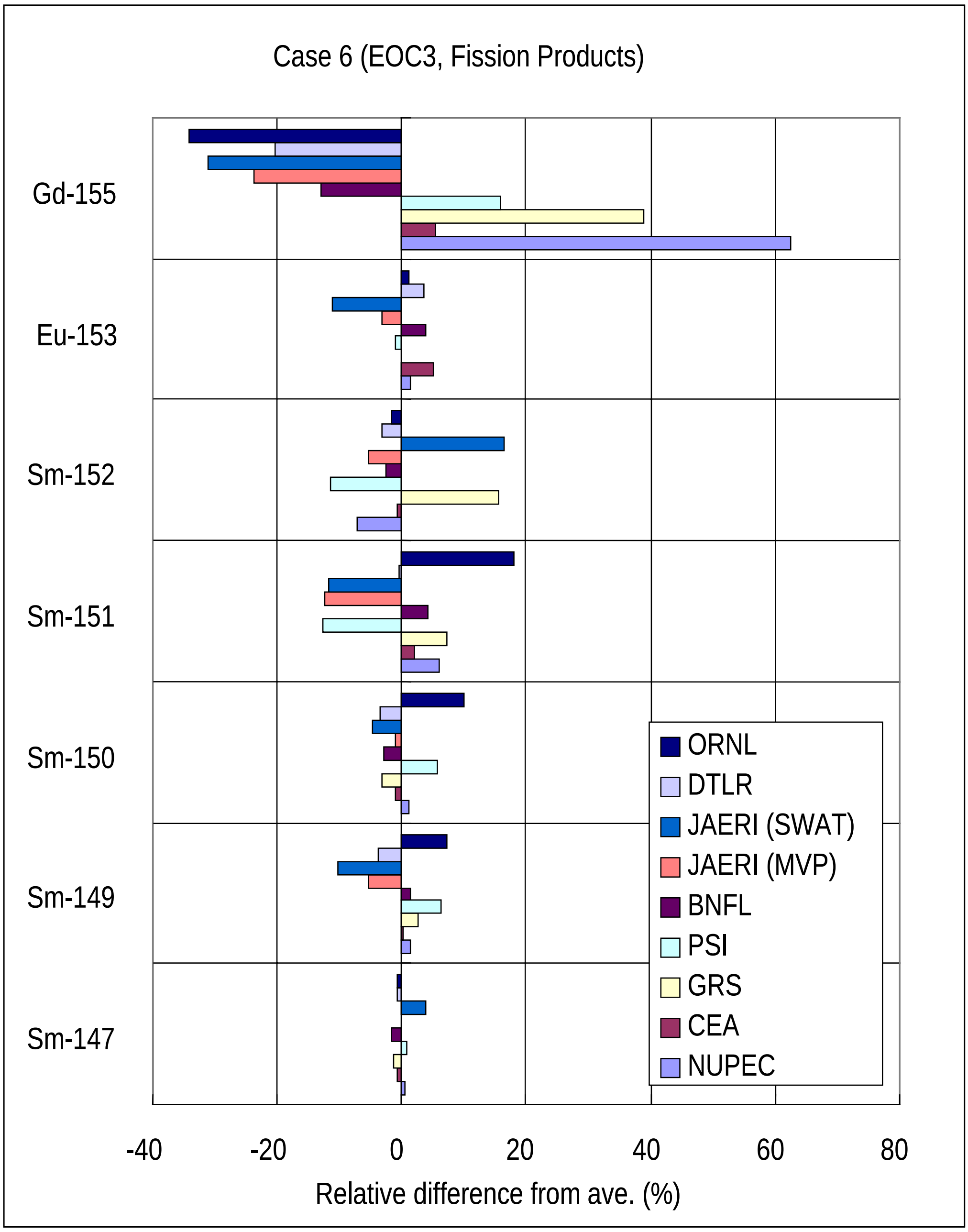


Figure K.5. Relative difference of actinide nuclide densities after 5 years cooling

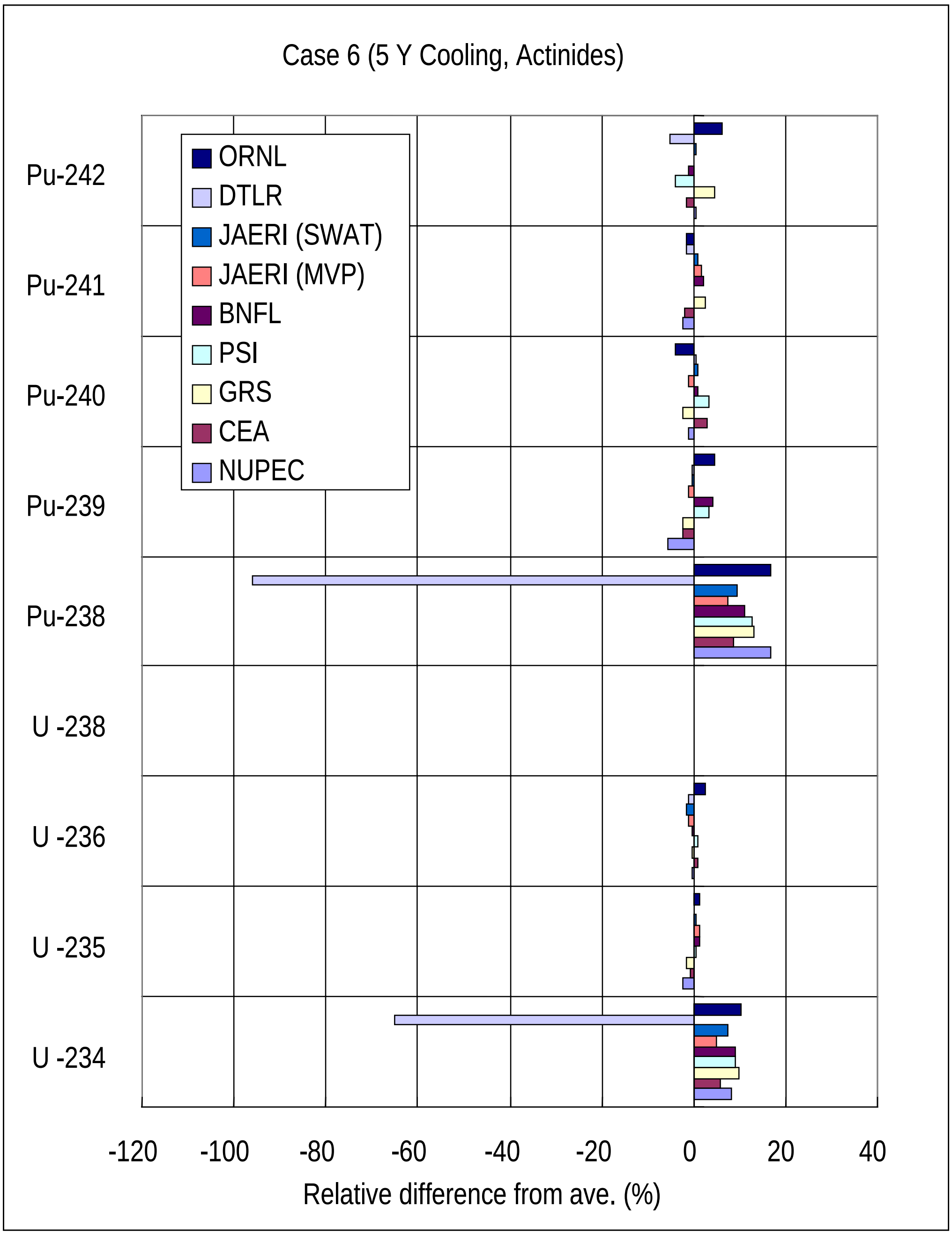


Figure K.5. Relative difference of actinide nuclide densities after 5 years cooling (*cont.*)

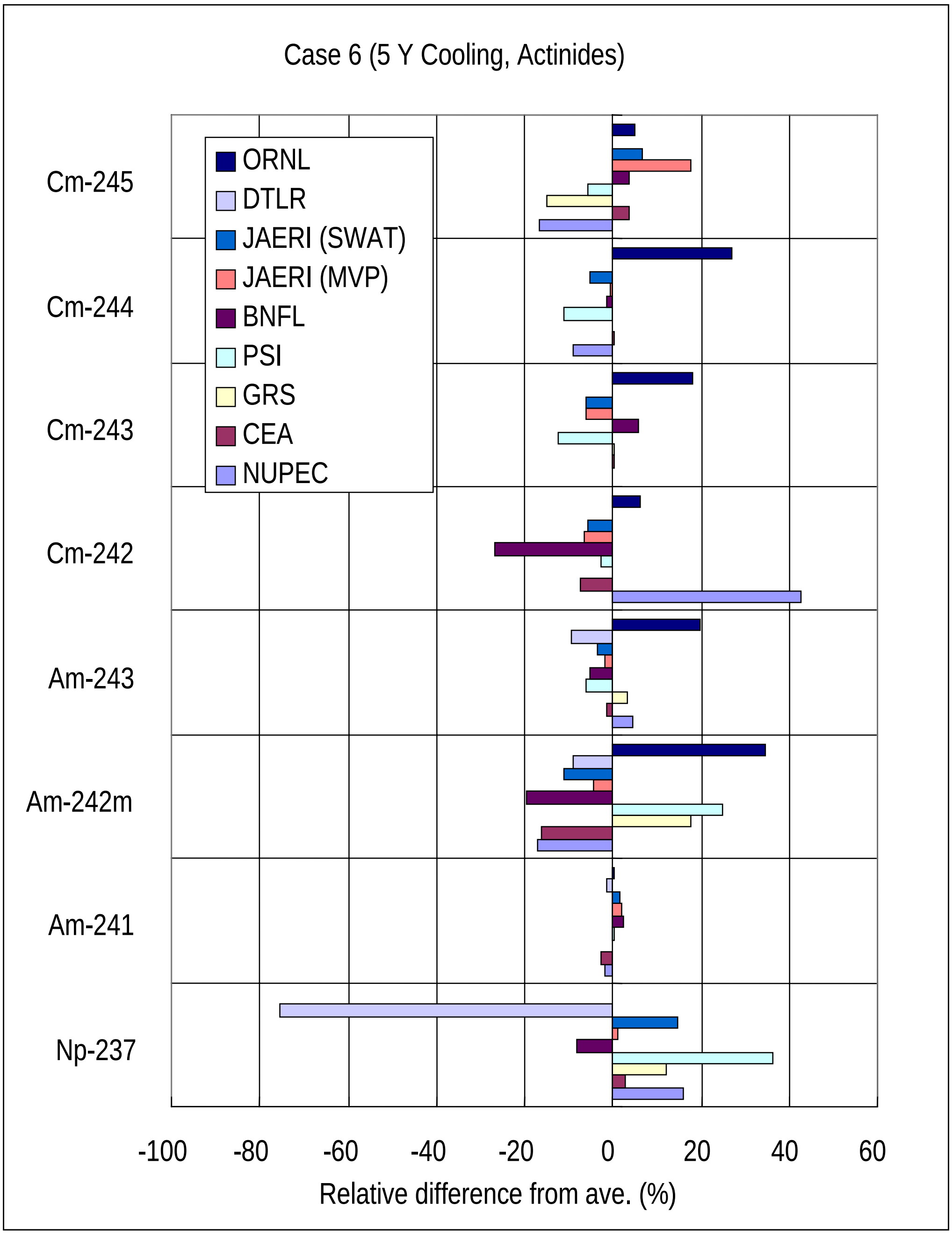


Figure K.6. Relative difference of fission product nuclide densities after 5 years cooling

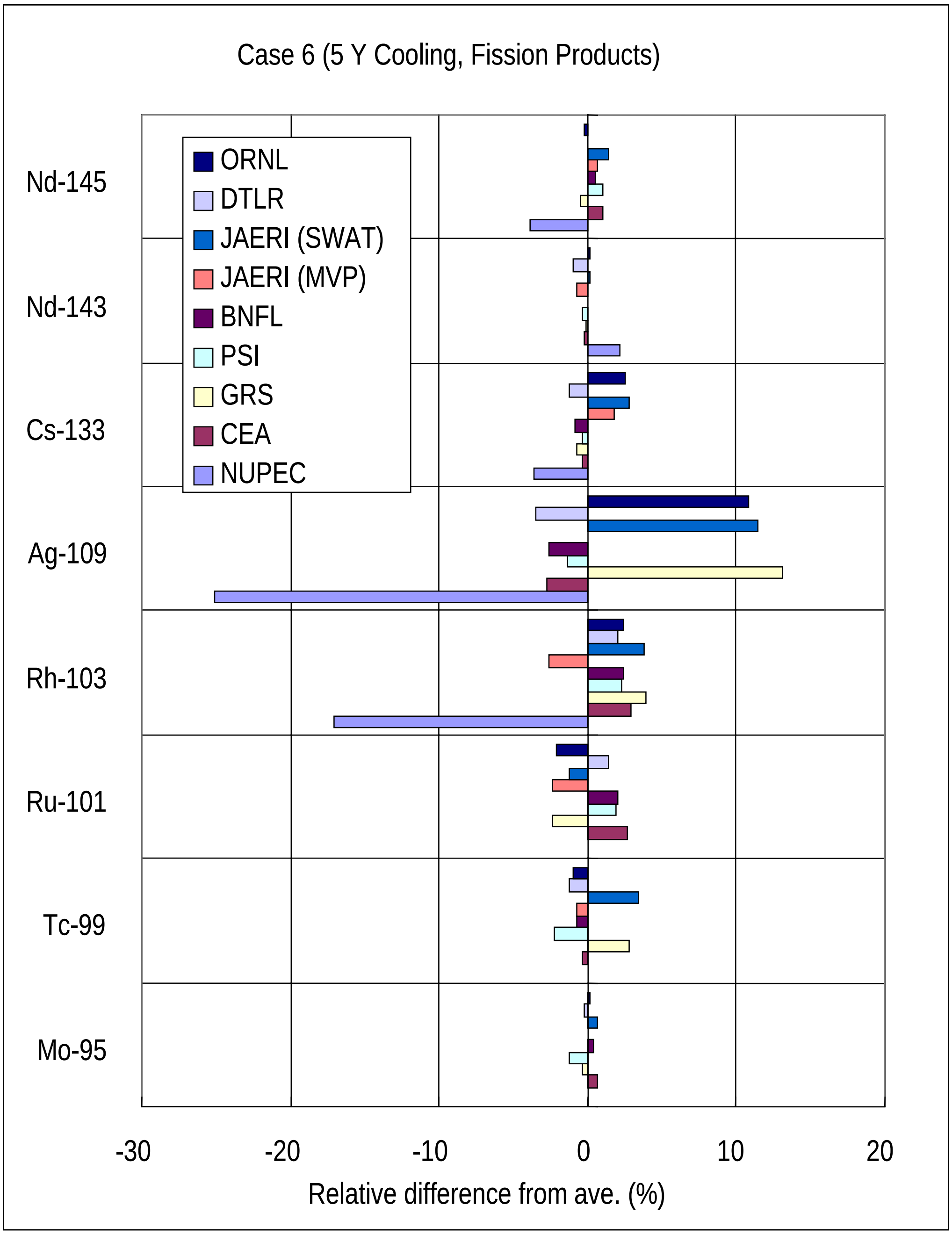
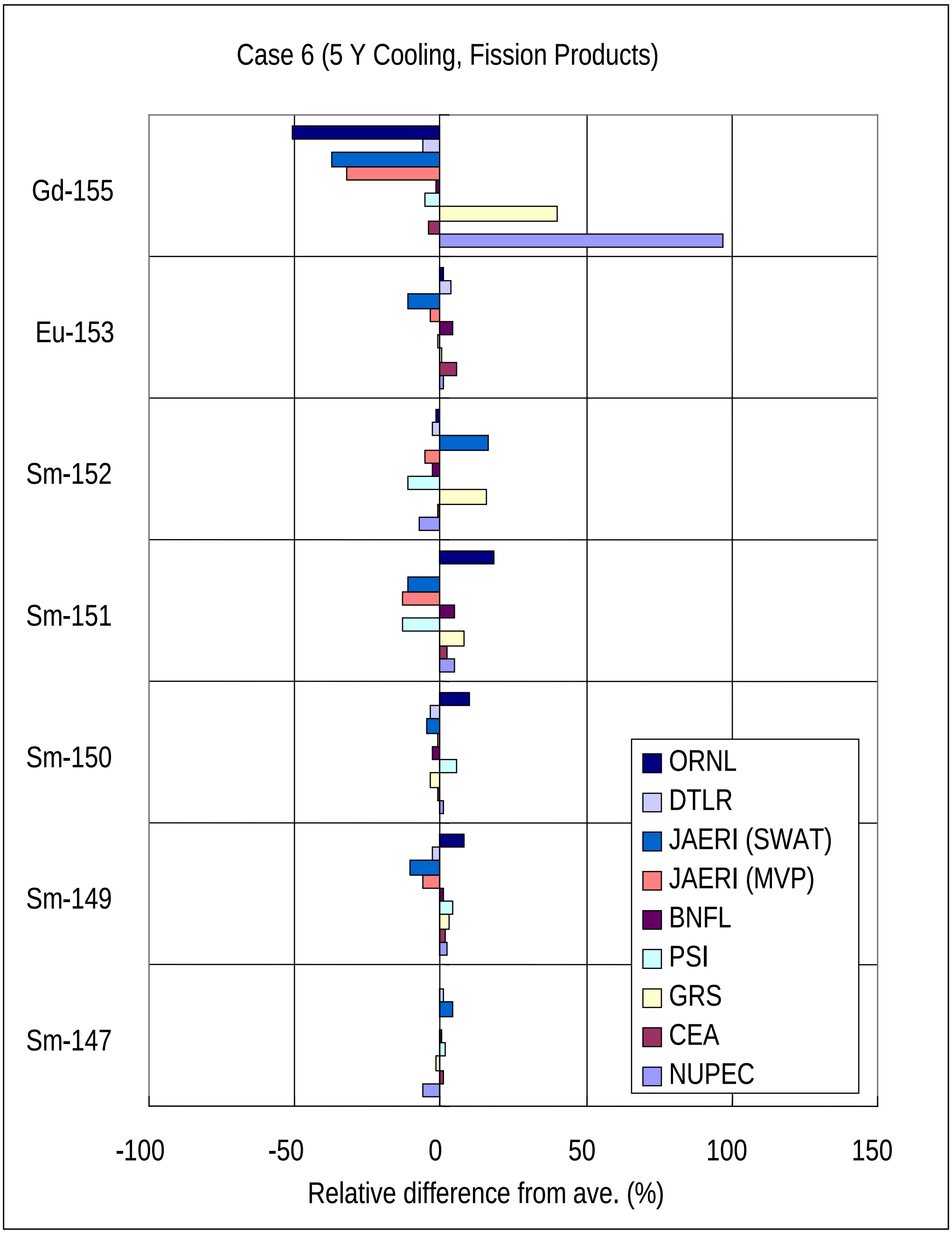


Figure K.6. Relative difference of fission product nuclide densities after 5 years cooling (*cont.*)



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