HTR-N

HTR-N & N1
High-Temperature Reactor Physics and Fuel Cycle Studies
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Document Title

Definition of reference coated particles and plutonium compositions (1st and 2nd generation Pu)

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1. REFERENCE COATED PARTICLE DEFINITIONS

The properties of the coated particles to be used in the analyses of HTR-N/N1 Work Package 3 have been defined in [1], while additional information on the fuel density and the coating layer dimensions has been obtained later on [2].

Reference fuel kernels

Fuel	Density [g cm^{-3}]	Diameter [mm]	Max. allowed burnup [MWd/kg]
UO_2	10.4	0.50	800
PuO_2	10.4	0.24	800
ThO_2	10.4	0.50	120
$(U\text{-}Th)O_2$	10.4	0.50	120
$(Pu\text{-}Th)O_2$	10.4	0.50	120

Coating material and dimensions

Coating layer material	Density [g cm^{-3}]	Thickness [mm]
C	1.05	0.095
C	1.90	0.040
SiC	3.18	0.035
C	1.90	0.040

The packing fraction in the compact/pebble should be derived from the desired fuel content per compact/pebble.

It should be noted that no impurities are assumed in the coated particles.

2. REFERENCE PLUTONIUM COMPOSITIONS

In the course of the HTR-N/N1 project a number of plutonium compositions have been defined, which are to be used in the envisaged analyses. These compositions are given below, together with 2 real (experimental) Pu compositions used in two Petten HFR irradiation experiments, viz. “THORIUM” [5] and “OTTO” [6].

Isotope	***1st generation* (original) (A)**	***1st generation* (alternative) (B)**	***2nd generation* (C)**	**“THORIUM”**	**“OTTO”**
Unit	**weight %**	**weight %**	**weight %**	**atom %**	**weight %**
^{238}Pu	1	2.59	4.9	1.74	0.60
^{239}Pu	62	53.85	26.9	59.49	68.18
^{240}Pu	24	23.66	34.3	24.92	21.54
^{241}Pu	8	13.13	15.3	7.43	7.01
^{242}Pu	5	6.78	18.6	5.74	2.67
^{241}Am	-	-	-	0.68	-

The *1st generation* (original) (A) Pu compostion is the one originally proposed by Rütten in [1] and agreed upon by the WP3 partners in [3]. The *1st generation* (alternative) (B) and *2nd generation* (C) Pu compositions were proposed by Bonin and Greneche in [4], and also agreed upon in [3]. It should be noted that the Pu composition of (C) is consistent with that of (B). The “THORIUM” and “OTTO” compositions have been listed as examples of real (experimental) Pu compositions, which can be used as variations on the base cases (to be analyed by interested WP3 partners).

As was confirmed in [3], the *1st generation* (original) Pu composition (A) will be the reference composition used in **HTR-N** Task 3.2a (“Fuel cycles with continuous reload – *1st generation* Pu”) and Task 3.3a (“Fuel cycles with batch-wise reload – *1st generation* Pu”) [7]. The alternative *1st generation* Pu (B) can be regarded as one of the variations on the base case (to be analysed by one partner).

The *2nd generation* (C) Pu composition will be the reference composition for based calculations in **HTR-N** Task 3.2b ("Fuel cycles with continuous reload - *2nd generation* Pu") and Task 3.3b ("Fuel cycles with batch-wise reload - *2nd generation* Pu").

The *1st generation* (alternative) (B) and *2nd generation* (C) Pu compositions (both!) will be the reference compositions for the "Pu cell burnup benchmark" of **HTR-N1** Task 3.1. [8]. However, the original *1st generation* reference composition can again be regarded as a variation on the base case (to be analysed by one partner).

4. REFERENCES

[1] H.J. Rütten, "Specification of HTR-MEDUL core for different fuel cycles", Document HTR-N-00/10-D-3.1.2 in SINTER, 17. October 2000.

[2] H.J. Rütten, private E-mail communication, 31. January 2001.

[3] J.C. Kuijper, Minutes of WP3 meeting d.d. 28. May 2002, NRG note NRG/FAI/jkuijper/20206131, 14. June 2002, Attachment 12 to HTR-N/N1 5th Project Management Meeting information in SINTER; see Appendix A

[4] B. Bonin & D. Greneche, "Isotopic composition of the plutonium coming from UOX and MOX fuel burning in light water reactors", Note attached to E-mail d.d. 12. December 2001 from B. Bonin (COGEMA) to W. von Lensa (FZJ) and J.C. Kuijper (NRG); see Appendix B

[5] R. Conrad, K. Bakker, R. Schram & C.M. Sciolla, "THORIUM CYCLE – Irradiation Experiment on Thorium Based Fuel Targets in a SHIFT Sample Holder at the HFR Petten", TECHNICAL MEMORANDUM HFR/01/4661, EC/JRC Petten, 21. August 2001 (*confidential*).

[6] K. Bakker, R. Conrad, C.M. Sciolla & R.P.C. Schram, "OTTO – Design & Safety Report", NRG Report 20003/00.35216/C, 5. September 2000 (*confidential*).

[7] J.C. Kuijper & W. von Lensa, "Revised work program for WP3: Physics Analysis of Different Fuel Cycles", Document HTR-N-01/6-D-3.0.1 in SINTER, 20. June 2002.

[8] H.J. Rütten & J.C. Kuijper, "Plutonium cell burnup benchmark (first and second generation Pu)", Document HTR-N1-02/06-S-3.1.1 in SINTER.

APPENDIX A

J.C. Kuijper, Minutes of WP3 meeting d.d. 28. May 2002 [3].

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NOTE NRG/FAI/jkuijper/20206131

Author : Kuijper J.C. (NRG Petten)

To : HTR-N/N1 WP3 partners

Copy to : -

Date : 14-Jun-2002

Directory : /user1/jkuijper/00projec/2001/20570/53/wpman/WP3_meeting_20020528

Project : HTR-N and HTR-N1

Subject : Minutes WP3 meetings d.d. 24 April 2002 and 28 May 2002

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== WP1/2/3 meeting Petten d.d. 24 April 2002 ==

* Agenda

1. Opening/agenda
2. Minutes of WP3 meeting on 20. November 2001 (Juelich)
3. Arrangements for forthcoming PMM in Pisa (27/28 May 2002)
4. Present status of activities/contributions to management report
   a. WP1
   b. WP2
   c. WP3
5. Status of pending actions/update of action list(s)/actions to be completed before PMM in Pisa
6. Final version of revised WP3 work program
7. Common parameters (common output; Pu-vectors)
8. Pu cell burnup benchmark
9. Any other business
10. Closing

* Announcements/Discussion

The mid-term review will be at the end of 2002. A special area in SINTER is reserved for illustrations (to be used in the mid-term report). All partners should provide illustrations.

The mid-term report will also be sent to external reviewers. Making a good impression is important as it coincides with the call for proposals for the 6th FP.

All contributions to WP3 should use the new format cover page as designed by Ansaldo.

The expected completion dates in the "Revised work program for WP3" (SINTER document HTR-N-01/6-D-3.0.1) should be adapted to the actual situation in order to avoid late deliveries. Mr. Kuijper will take care of this.

Sylvie Casalta (ex-JRC Petten) is the new administrative officer in Brussels for the HTR-N and HTR-N1 projects.

== WP3 meeting Pisa d.d. 28 May 2002 ==

* Agenda

1. Work program (revision)
2. Common (output) parameters
3. Reference Pu vector(s) and coated particle dimensions
4. Pu cell burnup benchmark
5. Action list

* Announcements/Discussion

The WP3 partners agree to the latest revised edition of the "Revised work program for WP3" (SINTER document HTR-N-01/6-D-3.0.1). Some final adjustments to the expected completion dates were made. Mr. Kuijper will put these adjustements into the final version of the document.

The definition of common output parameters for intercomparison is being discussed (SINTER document HTR-N-01/2-D-3.1.5). It is agreed upon that the main emphasis is on the data items concerned with mass balances and fuel/waste composition. It is agreed that a list of specific nuclides is added for which mass balances etc. have to be calculated. The WP3 partners also agree on the proposed format. Mr. Kuijper will include these extensions in the final version of the document. It is the responsability of the partners to supply data for intercomparison to the Work Package Manager in the correct form.

The WP3 partners agree on the proposed 1st and 2nd generation Pu vectors, as summarised in the E-mail of Mr. Kuijper of 21. December 2001. The relevant part of the text of that E-mail is given below:

QUOTE>>
...
* The origin of the Pu-I composition as proposed by Mr. Bonin (viz. 2.59/53.85/23.66/13/13/6.78 weight%) is clear, which is an advantage compared to the reference Pu-I composition agreed upon in the "common parameters" (viz. 1/62/24/8/5 weight%). The proposed Pu-II composition is consistent with the newly proposed Pu-I composition.

* However, the 1/62/24/8/5 reference Pu-I composition has already been used in a large part of the analysis work (mainly by FZJ and IRI).

So I propose the following:

* The original 1/62/24/8/5 Pu-I composition remains the reference Pu-I composition for the "Pu-I" based calculations in HTR-N Task 3.2a ("Fuel cycles with continuous reload - 1st generation Pu") and Task 3.3a ("Fuel cycles with batch-wise reload - 1st generation Pu"). However, the newly proposed Pu-I composition can be regarded as one of the variations on the base case (to be analysed by one partner).

* The proposed Pu-II composition (4.9/26.9/34.3/15.3/18.6 weight%) will be the reference composition for "Pu-II" based calculations in HTR-N Task 3.2b ("Fuel cycles with continuous reload - 2nd generation Pu") and Task 3.3b ("Fuel cycles with batch-wise reload - 2nd generation Pu").

* The newly proposed Pu-I and Pu-II compostions (both!) will be the reference compositions for the "Pu cell burnup benchmark" of HTR-N1 Task 3.1. However, the original reference Pu-I compostion can again be regarded as a variation on the base Pu-I case (to be analysed by one partner).
...
<<UNQUOTE

The WP3 partners also agree on the proposed coated particle dimensions (as stated in SINTER document HTR-N-00/10-D-3.1.2).

The HTR-N1 WP3 "Pu cell burnup benchmark" was discussed. This benchmark has been defined by Mr. Ruetten (FZJ). It is agreed that the calculations will be performed for both 1st and 2nd generation Pu (see above). Mr. Kuijper will add a list of nuclides and a required data format to the benchmark specification and transform it into the new document format. The WP3 partners also agree that the proposed Pu cell burnup benchmark will also be used for the sensitivity studies in the framework of HTR-N WP2. This has to be confirmed by the HTR-N WP2 Work Package Manager.

Mr. Kuijper will check and update the WP3 action list and subsequently send it to the WP3 partners for review.

APPENDIX B

B. Bonin & D. Greneche, “Isotopic composition of the plutonium coming from UOX and MOX fuel burning in light water reactors” [4].

Isotopic composition of the plutonium coming from UOX and MOX fuel burning in light water reactors

Bernard Bonin and Dominique Grenèche, COGEMA, Direction de la Recherche et du Développement

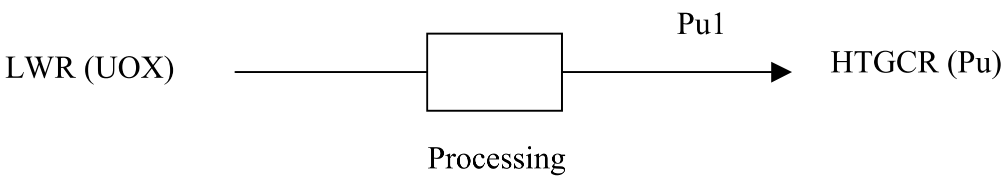
High Temperature, Gas-Cooled Reactors (HTGCR) have long been recognized as promising plutonium burners. In order to assess this potentiality, the HTR-Collaboration intends to revisit core physics and fuel cycle scenarios for plutonium-burning HTGCRs, with modern methods and in the light of the most recent data.

These studies require an important input, *i.e* the isotopic composition of the plutonium fuel to be burnt in the HTGCR.

In the present note, we propose a set of isotopic vectors for this Pu fuel, assuming a realistic origin for the plutonium.

In fact, two realistic sources of plutonium can be envisaged :

I. "Plutonium1", coming from the processing of the UOx fuel spent in present light Water Reactors (LWRs).



For calculating the "Pu1" isotopic composition, we assume the following characteristics for its origin :

Use of a PWR reactor (REP900-type), burning UOx fuel with an enrichment of 3.7%, with a cycle length of 274 full power equivalent days, and a staying time of 4 cycles for each fuel element. This corresponds to a burnup of 41.2 GWd/t, representative of the current day practice.

The isotopic composition of the Pu1 has been calculated with the code CESAR (ref. 1).

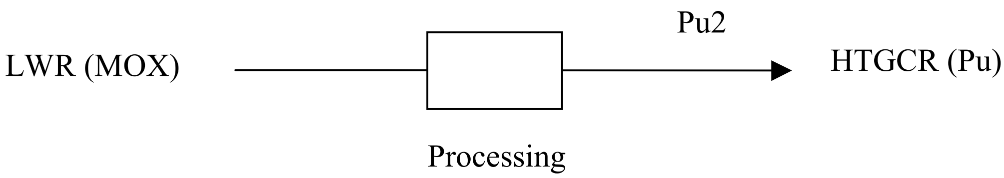
After a cooling time of 3 years following the end of the irradiation, the calculated composition is as follows (last column of Table 1):

Pu1	% (weight) (HTR-N Benchmark)	% (weight) (CESAR)
238	1	2.59
239	62	53.85
240	24	23.66
241	8	13.13
242	5	6.78

Table 1. The isotopic composition of first generation Plutonium. The middle column is the Pu1 composition assumed so far by the HTR benchmark; The right column is the Pu1 composition as calculated by the code CESAR with the hypotheses described in the text.

The isotopic composition of Pu1 has been agreed upon in the frame of the "Pu benchmark" of HTR-N (ref. 2). As can be seen from Table 1 (middle column), this plutonium is very rich in fissile isotopes. The hypotheses underlying its composition are not clear, and cannot be found in ref. 2. Extrapolation of the CESAR calculations enables to trace back the origin of this isotopic vector : the corresponding plutonium could come from irradiation of UOx fuel at a low burnup, of the order of 25 GWd/t. Unless a very "rich" Pu vector is found desirable for the benchmark, we recommend to restart the exercise with a more realistic isotopic composition, like the one calculated by CESAR, given in Table 1, with the hypotheses described above.

II. "Plutonium2" coming from the processing of 1-loop MOX fuel spent in LWRs.



For calculating the "Pu2" isotopic composition, we assume the following characteristics for its origin :

-Use of PWR reactors (EPR-type) burning 100% MOX fuel, with an initial composition consistent with the Pu1 given in Table 1, taking into account 2 additional years delay for MOX fuel fabrication.

-Uranium support for this MOX fuel was assumed to be depleted U (0.25%), and the Pu concentration in the mixture was assumed to be 7.49%.

-The residence time of a fuel element was assumed to be 5 cycles, with a cycle length of 254 full power equivalent days. This corresponds to a burnup of 56 GWd/t, hopefully representative of the future state-of-the art (we do not forget that HTR will not be introduced immediately in reactor fleets, and we therefore allow for technical progress in MOX burnup).

-The isotopic composition of the Pu2 was calculated using the code KAFKA (réf. 1), for a fuel cooling time of 3 years.

Pu2	% (weight)
238	4.9
239	26.9
240	34.3
241	15.3
242	18.6

Table 2. Isotopic composition of second-generation plutonium.

With Pu1 and Pu2, we have two extreme plutonium isotopic compositions. It can be seen that this Pu2 is severely degraded as compared to Pu1, and has significantly less fissile isotopes. Subsequent core studies should tell us under which conditions HTGCRs can burn this second-generation plutonium. After this preliminary step, fuel cycle studies will then proceed on a sound basis and with verified hypotheses.

Ref. 1 : "Données de Base Réacteurs pour les Etudes de Prospaective", J. Guyot et al. CEA Tech. Note SIS/SPRC 95-1007 (Nov. 1995)

Ref. 2 : HTR-N Annual Report 2001