

# Advanced Reactor Source Terms for Safeguards Application - Tutorial

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# Problem Description

- Calculate total U and total Pu inventory in spent fuel typical of a pebble bed reactor (PBR) at 5 years after discharge and 40GWd/MTU burnup.
- Generate neutron and gamma spectra for spent fuel typical of a PBR using ORIGEN.
- Compare the results for PBR spent fuel with corresponding results for a typical PWR 17x17 spent fuel at 40GWd/MTU burnup.

# Learning Goals

- How to use existing or user-generated ORIGEN reactor libraries with the Origami GUI for fast depletion simulations.
- How to calculate isotopic inventories, neutron and gamma sources using an available ORIGEN reactor library.
- Estimate the difference in radiation sources between PBR and typical PWR LEU spent fuel.

# ORIGEN Reactor Libraries in SCALE

- Fuel/reactor specific ORIGEN libraries reside in the SCALE subdirectory `SCALE-6.2\data\arplibs\`
- The file `arpdata.txt` contains information on the libraries
  - Fuel type (name of the reactor library)
  - Number of values for each variable parameter
  - Parameter values
  - Burnup values for each library position
  - Filenames for parameter-dependent libraries
- The file `arpdata.txt` is located in `SCALE-6.2\data\`

# How to use arpdata.txt

- ORIGIN (and Origami) will look for reactor library information in **arpdata.txt** in the **SCALE-6.2.4/data** directory and for reactor library files in **SCALE-6.2.4/data/arplibs/**
- Unless... **arpdata.txt** and library files exist in the SCALE temporary directory!
- You can copy your **arpdata.txt** and library files to the SCALE temporary directory using a **shell** command at the beginning of your Origami (or ORIGIN) input file:

```
=shell
cp path/to/files/myarpdata.txt  ${TMPDIR}/arpdata.txt
cp path/to/files/libraryfile1    ${TMPDIR}
cp path/to/files/libraryfile2    ${TMPDIR} etc...
end
=origami ...
```

# arpdata.txt content example

!w17x17

7 1 16

0.5000 1.5000 2.0000 3.0000 4.0000 5.0000 6.0000

0.7230

'w17\_e05.f33' 'w17\_e15.f33' 'w17\_e20.f33' 'w17\_e30.f33'

'w17\_e40.f33' 'w17\_e50.f33' 'w17\_e60.f33'

0.00 1040.00 3000.00 5000.00 7500.00

10500.00 13500.00 16500.00 22500.00 28500.00

34500.00 40500.00 46500.00 55500.00 64500.00

70500.00

**library name**

**7 enrichments, 1 moderator density, 16 burnups**

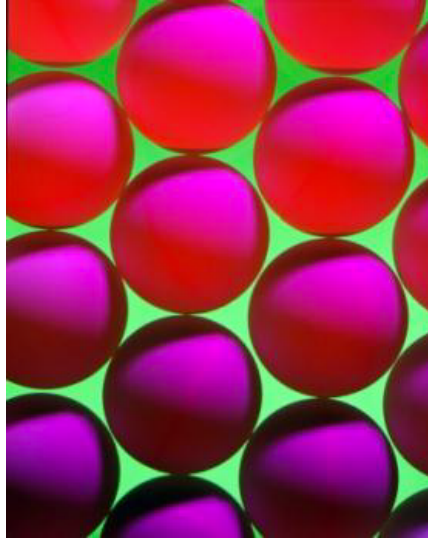
**enrichments, in wt% U-235**

**moderator density, in g/cm3**

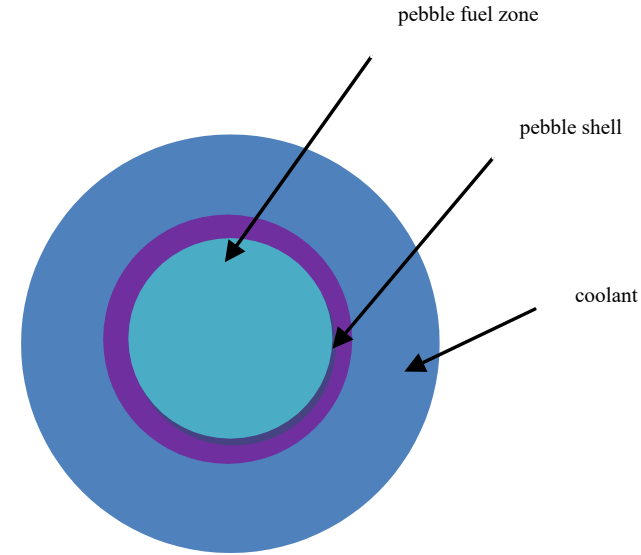
**library files names**

**burnup values in MWd/MTU**

# PBR Unit Cell Model for ORIGEN Library Generation



Pebble lattice



Simplified model

Ref for data: P.E. MacDonald et al., *NGNP Preliminary Point Design—Results of Initial Neutronics and Thermal-Hydraulic Assessment*, INEEL/EXT-03-00870 Rev. 1, Idaho National Engineering and Environmental Laboratory (2003).

# PBR Unit Cell Model Data

Table 1. Fuel and core data

Parameter	Value
Core diameter (m)	3.0
Core height (m)	9.4
Number of fuel pebbles in the core	360,000
Pebble discharge burnup (GWd/MTU)	80
Pebble residence time in core (d)	1,000
Heavy metal content (g/pebble)	7.0
Number of fuel particles per pebble	11,200
Fuel enrichment (wt % <sup>235</sup> U)	7.0
Pebble inner radius (cm)	2.5
Pebble outer radius (cm)	3.0

Table 2. Fuel particle data

Zone description	Material	Density (g/cm <sup>3</sup> )	Outer radius (mm)
fuel kernel	UC0.5O1.5	10.5	0.250
buffer	graphite	1.0	0.350
inner pyrolytic carbon	graphite	1.9	0.390
SiC	silicon carbide	3.2	0.425
inner pyrolytic carbon	graphite	1.9	0.465
matrix	graphite	1.2	N/A

Ref for data: P.E. MacDonald et al., *NGNP Preliminary Point Design—Results of Initial Neutronics and Thermal-Hydraulic Assessment*, INEEL/EXT-03-00870 Rev. 1, Idaho National Engineering and Environmental Laboratory (2003).



# Problem Input Data

- ORIGIN library and corresponding arpdata.txt file information provided for the simplified PBR unit cell
- For PWR, use ORIGIN library w17x17 in SCALE 6.2.4
- Initial mass of U – assume 1MTU for convenience
- Approach: use ORIGAMI for determining spent fuel composition at discharge + use ORIGIN to decay to 5 years for determining source terms
- Assumptions for irradiation history in ORIGAMI:
  - Initial mass - 1MTU
  - Burnup – 40GWd/MTU
  - Enrichment – 5wt% U235 for PWR, 7wt% U235 for PBR
  - Fuel – PWR (UO<sub>2</sub> 100%), PBR (~88.8% U, 9.0% O, 2.2% C, based on data in Table 2)
  - Use other default values in ORIGAMI for simplicity

# Let's work on this together!

