Specifications for the generic polynomial group constant model of Ants

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Summary

The GENPOLY-parametrization has been developed to be a flexible and easily extendable format for representing group constants required by the nodal code Ants. The GENPOLY-parametrization handles the dependence of group constants on burnup with tabulation, the dependence on momentary conditions with a polynomial fit and the dependence on historical conditions with a plutonium history fit. The parametrization offers special considerations for

- The treatment of short-lived fission poisons using a simple-chains approach.

- The evaluation of pin powers on the nodal code side via pin power reconstruction.

- The evaluation of some other, potentially localized, responses inside the nodes via a generic nodal response approach.

- The tracking of the production and removal of individual nuclides through the use of microdepletion.

This report describes the format of GENPOLY group constant library files in some detail and gives an overview on how the polynomial coefficients and plutonium k-coefficients are currently calculated in the parametrization process. Finally, a short description is given on how the tabulated nominal values, polynomial coefficients and plutonium k-coefficients can be used to evaluate the value of a group constant for a node at arbitrary momentary and historical conditions and burnup.

The GENPOLY-parametrization will likely evolve during the future development of the Serpent–Ants calculation chain and this report will fall out of date. Even so, this document should give a good introduction on the fundamentals and history of the GENPOLY-parametrization.

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Contents

1. Introduction

Nodal solvers used as the second step of the two-step reactor physics calculation chain use pre-calculated spatially homogenized and energetically condensed group constants to represent the neutron interaction properties of the materials present in the nodal problem. These group constants are typically based on a lattice level neutron transport calculation and are processed and collected into a *group constant library*. The group constants for a specific material depend on the material burnup, the momentary conditions and the historical conditions of the material. Thus, the group constant library should contain all the data required to *evaluate* the different group constants at any of these conditions.

The simplest reasonable *parametrization* for the group constant data is simply the listing of the data at different burnups as well as momentary and historical conditions and then using the data for the closest point. Multidimensional linear interpolation between the data points is a straightforward improvement and more complex fitting functions can be also used. The chosen parametrization affects which data needs to be included to the group constant library: For linear tabular interpolation, simply listing the data at the different points (and the points) should be enough, but for more complex fits also the fitting coefficients need to be included in the library.

This report describes the current specifications for the generic polynomial group constant library (GENPOLY) supported by VTT's Ants nodal neutronics code. The GENPOLY-parametrization is intended to provide flexibility for the development of application specific group constant parametrizations by allowing the user to specify the exact polynomial dependence used for parametrizing group constants with respect to the momentary conditions. The current rather verbose ASCII file-format makes the visual inspection of the parametrized group constants easy.

As the two-step Serpent–Ants calculation chain is still under active development, the GENPOLY-parametrization will eventually change and this specification will become out of date.

While the next section will give a short overview of the parametrization, the bulk of the report is made up by Section 3, which describes the content of GENPOLY-parametrization files. Section 4 goes into detail on how the fitting coefficients are actually evaluated during the parametrization process and how they can be used at the nodal code side to evaluate the values of group constants.

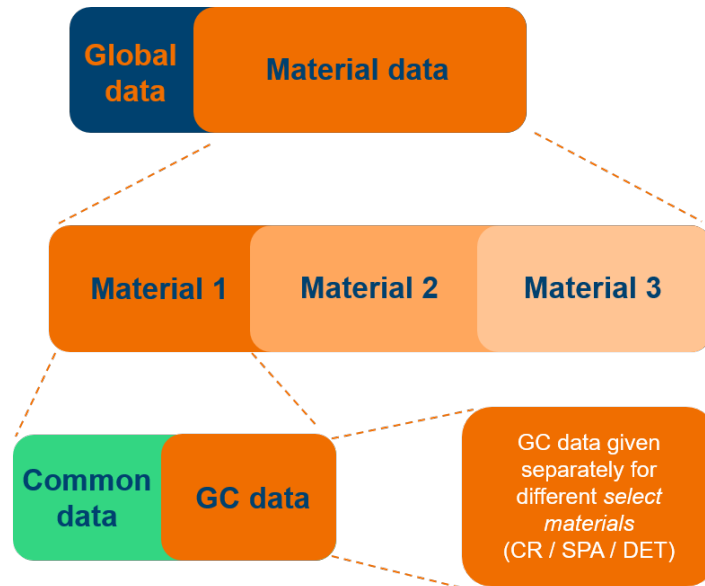## 2. Short overview of the GENPOLY-parametrization

Figure 1. Illustration of the division of a GENPOLY-library file into different data structures.

A GENPOLY-library file provides a set of material independent *global data* in the beginning of the file and the actual group constant data is given for *materials*. Each material has a block of material-specific *common data*, but the group constant data is further separated at the *select material* level based on the *select variables* indicating the (momentary) presence of control rod (CR), spacer grid (SPA) or detector (DET) in the material. This structure is illustrated in Fig. 1.

The group constants are parametrized separately for each select material level by the following process:

The values for each group constant at the nominal momentary conditions Σ_{nom} are given at a set of burnup points.

The effect of momentary values of *feedback variables* such as moderator density, fuel temperature, moderator boron content etc. on the group constant is taken in account via a polynomial parametrization of

$$\Delta\Sigma(fb) = \Sigma(fb) - \Sigma_{nom},$$

where $\Sigma(fb)$ is the value of the group constant at conditions (fb). The polynomial that is used to represent $\Delta\Sigma(fb)$ can contain an arbitrary number of terms of the feedback variables. At the moment, the fitting polynomial is material-dependent meaning that different materials can use different fitting polynomials, but different group constant for a single material use the same polynomial. The polynomial parametrization is described in more detail in Section 4.1.

Historical effects are taken in account via the plutonium history approach, in which a correction is made to the group constants based on three factors:

- Coefficients calculated in the parametrization phase based on group constants and ^{239}Pu atomic densities resulting from depleting the assembly in nominal and off-nominal conditions.

- The atomic density of ^{239}Pu for the assembly depleted with the nominal historical conditions, predicted by the same depletion chains approach as used in the nodal code.

- The current local atomic density of ^{239}Pu in the node as calculated by the nodal code.

The calculation of the plutonium k-coefficients is described in Section 4.2.

In addition to basic diffusion constants required for constructing the diffusion matrix, separate data may be included for

- Radial discontinuity factors.

- Delayed neutron parameters.

- Simplified chain modelling of fission poisons (^{135}Xe and ^{149}Sm).

- Plutonium history

- Reconstruction of pin powers.

- Evaluation of nodal responses (e.g. detector responses).

- Microdepletion.

The fission poison and plutonium history data might be reworked in the future to use the more generic microdepletion data approach.

3. Basic structure of the group constant library file

The group constant library can be coarsely divided into two parts, the global blocks in the beginning of the file defining material-independent common data and the material blocks defining data for the individual homogenized materials.

The following typesetting is used when the contents of the file are presented to identify between the "fixed text" (included in files as is), "parameter definitions" (representing a value that should exist in the file) etc.

```
fixed_text
PARAMETER_DEFINITION
REFERENCE_TO_EARLIER_PARAMETER_DEFINITION
INDEX_OF_GROUP_SURFACE_MATERIAL_ETC
control characters and markup for this specification (not included in files)
[... optional data ...]
```

Appendix A contains an example of a group constant library file, which can be contrasted to the descriptions in this section. However, the library file in the appendix only utilizes a subset of the capabilities of the parametrization.

3.1   Global blocks

3.1.1   Basic data block

Background: The basic data block is the first part of any GENPOLY-library file and starts with the fixed indicator `polynomial group constant library`. Otherwise it contains control-data and data-sizes that are required by Ants to allocate properly sized arrays for the data to be read into.

In the file:

```
polynomial group constant library

num_mat              NUM_MAT
num_group            NUM_GROUP
num_prec_group       NUM_PREC_GROUP
num_dir              NUM_DIR
num_fb_var           NUM_FB_VAR
num_select_var       NUM_SELECT_VAR
num_mdep_region      NUM_MDEP_REGION
version              VERSION
```

Parameters:

name	type	allowed values	description
NUM_MAT	integer	> 0	Number of material blocks in this file.
NUM_GROUP	integer	> 0	Number of energy groups.
NUM_PREC_GROUP	integer	> 0	Number of precursor groups
NUM_DIR	integer	> 0	Number of radial directions in each node.
NUM_FB_VAR	integer	11	Number of feedback variables for polynomial.
NUM_SELECT_VAR	integer	3	Number of possible select variables for materials.
NUM_MDEP_REGION	integer	≥ 0	Number of microdepletion regions globally.
VERSION	integer	1	GENPOLY version number for the library.

Comments: Currently, 11 feedback variables are supported and the polynomial representation of the feedback effects on the group constants are parametrized according to the deviations of these feedback variables from their nominal values. The currently supported feedback variables are

name	as variable	description
TFU	x_1	Fuel temperature (K)
TFUSQRT	x_2	Square root of fuel temperature ($K^{\frac{1}{2}}$)
DCO	x_3	Density of coolant (g/cm^3)
TCO	x_4	Temperature of coolant (K)
BOR	x_5	Boron content (ppm)
BORDENS	x_6	Boron density, BOR*DCO, ($ppm\,g/cm^3$)
XEN	x_7	^{135}Xe atomic density ($1/cm^3$)
SAM	x_8	^{149}Sm atomic density ($1/cm^3$)
BDCO	x_9	Density of "bypass" coolant (g/cm^3)
BTCO	x_{10}	Temperature of "bypass" coolant (K)
BORDENS2	x_{11}	Boron density, BOR*DCO, ($ppm\,g/cm^3$)

Having a second boron feedback variable in BORDENS2 allows for the polynomial to contain separate terms one depending on the deviation of boron from a nominal value and the other on the total boron density as is required in the evaluation of the boron fit of the MOD5 group constant model when using the c_{11} correction term (see e.g. Ref. [1]).

Currently, 3 momentary select variables are supported (CR, SPA, DET) and each of these select variables can take an arbitrary number of distinct values. Both the nominal group constants and the polynomial coefficients are evaluated separately for the separate select variables.

Each microdepletion region (NUM_MDEP_REGION) corresponds to a specific set mdep card in the Serpent input having its specified spatial domain (in the Serpent model) and forming its specified depletion matrix. Different burnup or decay chains for the same spatial domain (in the Serpent model) make up different microdepletion regions in the Ants model.

3.1.2   Poison block

Background: The poison block contains the "constant" data required for modelling the production and removal of the fission poisons ^{135}Xe and ^{149}Sm during the nodal calculation. As the decay constants listed here are normal nuclear data with uncertainties, their values are dependent on the nuclear data library used in the group constant generation calculation. The

information on the treatment of the branching of decay of ^{135}I is also dependent on the treatment in the group constant generating code.

In the file:

```
poison
lambda_I135          LAMBDA_I135
lambda_Xe135m        LAMBDA_XE135M
lambda_Xe135         LAMBDA_XE135
lambda_Pm149         LAMBDA_PM149
branch_decay_I135    NUM_PROD  NUM_PROD x ( PROD_NAME BRANCH_FRACTION )
```

Parameters:

name	type	allowed values	description
LAMBDA_I135	float	-	Decay constant of ^{135}I (1/s).
LAMBDA_XE135M	float	-	Decay constant of ^{135m}Xe (1/s).
LAMBDA_XE135	float	-	Decay constant of ^{135}Xe (1/s).
LAMBDA_PM149	float	-	Decay constant of ^{149}Pm (1/s).
NUM_PROD	integer	> 0	Number of decay products from ^{135}I.
PROD_NAME	string	XE135, XE135M	Name of the decay product
BRANCH_FRACTION	float	$0 \leq x \leq 1$	Fraction of decays leading to this product.

Comments: The separate treatment of the ^{135}Xe and ^{149}Sm chains could be moved to the more general microdepletion context at some point in the future, although this might be best to combine to a future implementation of generic microdepletion based correction to group constants, where the involved nuclides and chains could be indicated by the user.

3.1.3 Plutonium history block (optional)

Background: The plutonium history block is fully optional, but as the GENPOLY-parametrization does not contain any other type of historical parametrization it should most likely be included in most group constant libraries that contain burnup dependent data. Here, as in the poison-block, the "constant" data for the simplified chain representation of ^{239}Pu production is given.

In the file:

```
pu_history
lambda_U238          LAMBDA_U238
lambda_Np239         LAMBDA_NP239
lambda_Pu239         LAMBDA_PU239
```

Parameters:

name	type	allowed values	description
LAMBDA_U238	float	-	Decay constant of ^{238}U (1/s).
LAMBDA_NP239	float	-	Decay constant of ^{239}Np (1/s).
LAMBDA_PU239	float	-	Decay constant of ^{239}Pu (1/s).

Comments: The simplified chains treatment of ^{239}Pu atomic density is a special case of the more generic microdepletion treatment and may be reworked as a part of the more general microdepletion system in the future. This is highlighted by the fact that the ^{239}Pu-history is limited to uranium dioxide fuel and thorium and mixed oxide fuels require a more general heavy metal history treatment.

3.1.4 Mdep data block (optional)

Background: The mdep data block defines each of the microdepletion regions (see `NUM_MDEP_REGION` in Sec. 3.1.1) present for this material. It gives the information required to construct the depletion matrices for each region, providing information on the nuclides (ZAIs) included in each region, their decay channels, (neutron induced) reactions and the product nuclides of each decay and reaction. The microdepletion data is fully optional, but should naturally be included if `NUM_MDEP_REGION` is nonzero.

In the file:

```
mdep_table
NUM_MDEP_REGION x
(
  region                REG_IDX
  max_decay             MAX_CHAN_PER_ZAI
  max_decay_prod        MAX_PROD_PER_CHAN
  max_reaction          MAX_REA_PER_ZAI
  max_reaction_prod     MAX_PROD_PER_REA
  num_zai               NUM_ZAI
  num_decaying          NUM_DECAYING_ZAI
  num_reacting          NUM_REACTING_ZAI
  nnz                   NUM_NONZERO
  num_reaction          NUM_REACTION
  zai
  NUM_ZAI x ( ZAI )
  decay
  NUM_DECAYING_ZAI x (
    FROM_ZAI_IDX DECAY_CONSTANT DECAY_ENERGY NUM_CHANNEL NUM_CHANNEL x ( BRANCH_FRACTION )
    NUM_CHANNEL x ( NUM_DEC_PROD ) sum(NUM_DEC_PROD) x ( TO_ZAI_IDX )
  )
  reaction
  NUM_REACTING_ZAI x (
    FROM_ZAI_IDX NUM_REA
    NUM_REA x ( REACTION_IDX )
    NUM_REA x ( MT )
    NUM_REA x ( NUM_REA_PROD )
    sum(NUM_REA_PROD) x (
      TO_ZAI_IDX
    )
  )
)
```

Parameters:

name	type	allowed values	description
REG_IDX	integer	$1 \leq x \leq$ NUM_MDEP_REGION	Index of this region.
MAX_CHAN_PER_ZAI	integer	$0 \leq$	Maximum number of decay channels per nuclide.
MAX_PROD_PER_CHAN	integer	$0 \leq$	Maximum number of decay products per channel.
MAX_REA_PER_ZAI	integer	$0 \leq$	Maximum number of reactions per nuclide.
MAX_PROD_PER_REA	integer	$0 \leq$	Maximum number of products per reaction.
NUM_ZAI	integer	$0 <$	Number of distinct nuclides (ZAIs).
NUM_DECAYING_ZAI	integer	$0 \leq x \leq$ NUM_ZAI	Number of nuclides that have decay channels.
NUM_REACTING_ZAI	integer	$0 \leq x \leq$ NUM_ZAI	Number of nuclides that have neutron reactions.
NUM_NONZERO	integer	$0 \leq$	Number of nonzero elements in final depletion matrix.
NUM_REACTION	integer	$0 \leq$	Total number of reactions across all nuclides.
ZAI	integer	$10010 \leq$	ZAI identifier of nuclide.
FROM_ZAI_IDX	integer	$1 \leq x \leq$ NUM_ZAI	Index of decaying/reacting nuclide in ZAI-list.
DECAY_CONSTANT	float	$0 <$	Decay constant for nuclide (1/s).
DECAY_ENERGY	float	$0 <$	Energy release per decay (J)
NUM_CHANNEL	integer	$1 \leq x \leq$ MAX_CHAN_PER_ZAI	Number of decay channels for this nuclide.
BRANCH_FRACTION	float	$0 \leq x \leq 1.0$	Branching fraction for this channel.
NUM_DEC_PROD	integer	$0 \leq x \leq$ MAX_PROD_PER_CHAN	Number of product nuclides from this decay channel.
TO_ZAI_IDX	integer	$1 \leq x \leq$ NUM_ZAI	Index of decay/reaction product in ZAI-list.
NUM_REA	integer	$0 \leq x \leq$ MAX_REA_PER_ZAI	Number of reactions for this nuclide.
REACTION_IDX	integer	$1 \leq x \leq$ NUM_REACTION	Index of this individual reaction.
MT	integer	$16, 22, 102, \ldots$	The MT number of this reaction.
NUM_REA_PROD	integer	$0 \leq x \leq$ MAX_PROD_PER_REA	Number of product nuclides from this reaction.

Comments: Fission reactions still require additional implementation as the reaction needs to be linked to a fission yield distribution describing the fission product distribution. The fission yield distributions for different fissioning nuclides should then be added in the material block.

3.2 Material blocks

The global blocks are followed by NUM_MAT material blocks, each containing data specifically for a single homogenized material.

3.2.1 Material general information

Background: This block gives basic information pertaining to a certain material (e.g. an assembly type) listing the sizes of different data that will be included, but also some physical parameters such as the heavy metal content of the material.

In the file:

```
mat IDENTIFIER
num_pin              NUM_PIN
num_exp_nom          NUM_EXP_NOM
num_exp_coe          NUM_EXP_COE
num_coe              NUM_COE
num_region           NUM_REGION
```

```
num_nodal_response    NUM_NODAL_RESPONSE
mass_hm               MASS_HM
unheated_frac         UNHEATED_FRAC
is_quarter            IS_QUARTER
description           DESCRIPTION
```

Parameters:

name	type	allowed values	description
IDENTIFIER	string	-	Material identifier. Used in referring to this material in Ants input.
NUM_PIN	integer	$0 \leq$	Number of fuel pins in the assembly (refer to Section 3.2.4).
NUM_EXP_NOM	integer	$0 <$	Number of exposure (burnup) points for the nominal group constant data.
NUM_EXP_COE	integer	$0 \leq$	Number of exposure (burnup) points for the polynomial coefficients.
NUM_COE	integer	$0 \leq$	Number of polynomial coefficients (terms in polynomial).
NUM_REGION	integer	$0 < x \leq$ NUM_MDEP_REGION	Number of microdepletion regions in this material.
NUM_NODAL_RESPONSE	integer	$0 \leq$	Number of nodal response data that will be listed for this material.
MASS_HM	float	$0 <$	Heavy metal content of the material (g/cm).
UNHEATED_FRAC	float	$0 \leq x \leq 1$	Fraction of unheated coolant to use for TC0 and DC0 evaluation.
IS_QUARTER	integer	0, 1	Indicator on group constants having been generated in quarter assembly geometry.
DESCRIPTION	string	-	More free-form description of this material.

Comments: MASS_HM is used by Ants at the input node level, meaning that if input nodes correspond radially to full assemblies, the heavy metal content should be given for full assemblies.

If UNHEATED_FRAC is nonzero, the data used for evaluating the TC0 and DC0 feedbacks is taken as a fractional average from the coolant and bypass coolant data given to Ants[1]. The effect of unheated water regions can also be taken in account via separate parametrization against (TC0, DC0) and (BTC0, BDC0).

The IS_QUARTER flag affects the treatment of the material's discontinuity factors (DFs). If set to 1, the North and West DFs are interpreted as assembly-internal discontinuity factors whereas the South and East DFs are interpreted as inter-assembly discontinuity factors. If set to 0, all DFs are interpreted as inter-assembly discontinuity factors and assembly-internal DFs are set to 1.0 if subnodalization is used.

3.2.2   Select variable information

Background: These blocks give basic information of the included branch variations for control rod, spacer grid and instrumentation. All group constant data should be supplied separately for each combination of select variables.

---

[1]Implementation currently missing, but trivial if needed e.g. for MOD5 or MOD6 comparisons.

In the file:

```
num_select
CR  NUM_CR
SPA NUM_SPA
DET NUM_DET

select_description
NUM_CR x ( CR_DESC )
NUM_SPA x ( SPA_DESC )
NUM_DET x ( DET_DESC )
```

Parameters:

name	type	allowed values	description
NUM_CR	integer	$0 <$	Number of variations (excluding nominal).
NUM_SPA	integer	$0 <$	Number of variations (excluding nominal).
NUM_DET	integer	$0 <$	Number of variations (excluding nominal).
CR_DESC	string	1, 2, B4C, AIC, …	A more verbose description of the non-nominal select variable (not used for anything).
SPA_DESC	string	1, 2, ZRY, INC, …	A more verbose description of the non-nominal select variable (not used for anything).
DET_DESC	string	1, 2, SPND, AERO, …	A more verbose description of the non-nominal select variable (not used for anything).

Comments: Currently Ants supports references to a specific select material in the Ants input directly as

```
IDENTIFIER/CR_CRIDX/SPA_SPAIDX/DET_DETIDX
```

where `CRIDX`, `SPAIDX` and `DETIDX` are indices for the control rod select material etc. In the future, this may be extended so that the descriptions given in `select_description` can also be used in place of the indices. KrakenTools currently supports only integer descriptions, but the extension to string based descriptions should be trivial, switching from integer indexing to string-based dictionaries.

3.2.3 Feedback parametrization

Background: This part of the material block actually defines what kind of polynomial was used to parametrize the group constants and how that polynomial should be evaluated in the nodal calculation.

In the file:

```
fb_scale
TFU                NOM MIN MAX A1 A2
TFUSQRT            NOM MIN MAX A1 A2
DCO                NOM MIN MAX A1 A2
TCO                NOM MIN MAX A1 A2
BOR                NOM MIN MAX A1 A2
```

```
BORDENS             NOM MIN MAX A1 A2
XEN                 NOM MIN MAX A1 A2
SAM                 NOM MIN MAX A1 A2
BDCO                NOM MIN MAX A1 A2
BTCO                NOM MIN MAX A1 A2
BORDENS2            NOM MIN MAX A1 A2


fb_table
num_coe rows of
 P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11
```

Parameters:

name	type	allowed values	description
NOM	float	-	Value of the feedback variable in the nominal point.
MIN	float	-	Minimum value of the feedback variable across the variations.
MAX	float	-	Maximum value of the feedback variable across the variations.
A1	float	-	Scaling coefficient when calculating Δ for feedback variable, see Comments.
A2	float	-	Scaling coefficient when calculating Δ for feedback variable, see Comments.
P1	integer	$0 \leq$	Power of ΔTFU in this power product -term.
P2	integer	$0 \leq$	Power of ΔTFUSQRT in this power product -term.
P3	integer	$0 \leq$	Power of ΔDCO in this power product -term.
etc.	integer	$0 \leq$	etc.

Comments: The delta for each of the feedback variables is evaluated using the `A1` and `A2` information in the `fb_scale` block as

$$\Delta x_i = (x_i - A_1^i) \times A_2^i \tag{3.1}$$

where x is the value of the i:th feedback variable while A_1^i and A_2^i are the A coefficients listed at the i:th row of the `fb_scale` block.

When the polynomial representation of the feedback-effect on the group constant is evaluated, the `fb_table` describes each term of the polynomial, with different rows of the table representing different (power product) terms in the polynomial and the values on the row representing the powers of the different feedback variables in that term. To re-phrase, the row-index in the `fb_table` refers to a polynomial term while the column-index refers to a feedback variable (first column representing `TFU` and last one representing `BORDENS2`). Two examples of polynomials and their `fb_table` representations are given here:

$$\mathcal{P}(\Delta x_i) = c_1 \Delta\text{TFU} + c_2(\Delta\text{TFU})^2 + c_3 \Delta\text{DCO} + c_4(\Delta\text{DCO})^2$$
$$= c_1 \Delta x_1 + c_2(\Delta x_1)^2 + c_3 \Delta x_3 + c_4(\Delta x_3)^2$$

can be expressed as

```
fb_table
 1 0 0 0 0 0 0 0 0 0 0 0
 2 0 0 0 0 0 0 0 0 0 0 0
 0 0 1 0 0 0 0 0 0 0 0 0
 0 0 2 0 0 0 0 0 0 0 0 0
```

Similarly

$$\mathcal{P}(\Delta x_i) = c_1 (\Delta \text{TFU})(\Delta \text{DCO})^2 + c_2 (\Delta \text{TFU})(\Delta \text{DCO})(\Delta \text{BORDENS})$$
$$= c_1 (\Delta x_1)(\Delta x_3)^2 + c_2 (\Delta x_1)(\Delta x_3)(\Delta x_6)$$

can be expressed as

```
fb_table
 1 0 2 0 0 0 0 0 0 0 0 0
 1 0 1 0 0 1 0 0 0 0 0 0
```

3.2.4 Pin table

Background: This table gives basic geometry information for the pin-cells and the heavy metal content of each individual fuel pin. The number of pins should be specified as `NUM_PIN` in the material general block (Section 3.2.1).

In the file:

```
pin_table
x        NUM_PIN values for  PX
y        NUM_PIN values for  PY
wx       NUM_PIN values for  PWX
wy       NUM_PIN values for  PWY
mass_hm  NUM_PIN values for  PHM
```

Parameters:

name	type	allowed values	description
PX	float	-	Pin-cell center x-coordinate (cm relative to assembly center).
PY	float	-	Pin-cell center y-coordinate (cm relative to assembly center).
PWX	float	$0 <$	Pin-cell x-width (cm).
PWY	float	$0 <$	Pin-cell y-width (cm).
PHM	float	$0 <$	Pin heavy metal content (g/cm).

Comments: The geometry data in the pin table is used to specify the pin-cell integration areas for homogeneous flux used in the pin power reconstruction, while the heavy metal content is used in the future for calculating pin-burnups. In principle, guide tube positions etc. do not have to be included in the pin-information, but in practice it might be easier to include each (e.g. 17x17) positions in the lattice.

3.2.5 Exposure/burnup information and nominal atomic densities

Background: Here, information is given on which exposure (burnup) points the nominal and coefficient data is given for as well as the nominal history atomic densities required by the plutonium-history and microdepletion models.

In the file:

```
exp
 NUM_EXP_NOM x ( EXP_NOM )
 NUM_EXP_COE x ( EXP_COE )

[ optional, but should exist if using plutonium history for material
adens_table
 U238    NUM_EXP_NOM x ( ADENS_U238 )
 Np239   NUM_EXP_NOM x ( ADENS_NP239 )
 Pu239   NUM_EXP_NOM x ( ADENS_PU239 )
]

[ optional, but should exist if NUM_REGION is nonzero for material
mdep_adens
NUM_REGION x
(
  region REG_IDX
  NUM_ZAI x
  (
    zai_idx ZAI_IDX
    NUM_CR x NUM_SPA x NUM_DET x
    (
       CR_DESC SPA_DESC DET_DESC NUM_EXP_NOM x ( ADENS )
    )
  )
)
]
```

Parameters:

name	type	allowed values	description
EXP_NOM	float	$0 \leq$	Exposure (burnup) points for the nominal group constants (ascending order).
EXP_COE	float	$0 \leq$	Exposure (burnup) points for the polynomial coefficients (ascending order).
ADENS_U238	float	$0 \leq$	Nominal history atomic density of ^{238}U (10^{24}/cm^3).
ADENS_NP239	float	$0 \leq$	Nominal history atomic density of ^{239}Np (10^{24}/cm^3).
ADENS_PU239	float	$0 \leq$	Nominal history atomic density of ^{239}Pu (10^{24}/cm^3).
ADENS	float	$0 \leq$	Nominal history atomic density (10^{24}/cm^3) for nuclide ZAI_IDX in microdepletion region REG_IDX of select material defined by (CR_DESC SPA_DESC DET_DESC).

Comments:

3.2.6 Group constants

Background: The rest of the material block is made of the actual parametrization data written for the different group constants. The group constants that may be provided in this part of the file are listed in the following table.

name	dimensions	sizes	description
Sigma_a	group	NUM_GROUP	Absorption cross section (1/cm).
nuSigma_f	group	NUM_GROUP	Fission neutron production cross section (1/cm).
kappaSigma_f	group	NUM_GROUP	Fission energy production cross section (J/cm).
Sigma_f	group	NUM_GROUP	Fission cross section (1/cm).
D	group	NUM_GROUP	Diffusion coefficient (cm).
1/v	group	NUM_GROUP	Inverse velocity (s/cm).
chi	group	NUM_GROUP	Fission spectrum (unitless).
Sigma_s	group, to_group	NUM_GROUP, NUM_GROUP	Group-to-group scattering cross section (1/cm).
side_df	group, side	NUM_GROUP, NUM_SIDE	Discontinuity factor (unitless).
beta	prec_group	NUM_PREC_GROUP	Delayed neutron fraction (unitless).
lambda	prec_group	NUM_PREC_GROUP	Precursor group decay constant (1/s).
gamma_I135	group	NUM_GROUP	Fission yield (unitless).
gamma_Xe135	group	NUM_GROUP	Fission yield (unitless).
gamma_Xe135m	group	NUM_GROUP	Fission yield (unitless).
gamma_Pm149	group	NUM_GROUP	Fission yield (unitless).
gamma_Sm149	group	NUM_GROUP	Fission yield (unitless).
sigma_I135_a	group	NUM_GROUP	Microscopic absorption cross section (b).
sigma_Xe135_a	group	NUM_GROUP	Microscopic absorption cross section (b).
sigma_Xe135m_a	group	NUM_GROUP	Microscopic absorption cross section (b).
sigma_Pm149_a	group	NUM_GROUP	Microscopic absorption cross section (b).
sigma_Sm149_a	group	NUM_GROUP	Microscopic absorption cross section (b).
sigma_U238_c	group	NUM_GROUP	Microscopic capture cross section (b). Included only if material uses plutonium-history.
sigma_U238_a	group	NUM_GROUP	Microscopic absorption cross section (b). Included only if material uses plutonium-history.
sigma_Np239_a	group	NUM_GROUP	Microscopic absorption cross section (b). Included only if material uses plutonium-history.
sigma_Pu239_a	group	NUM_GROUP	Microscopic absorption cross section (b). Included only if material uses plutonium-history.
form_function	group, pin	NUM_GROUP, NUM_PIN	Pin power form function (unitless).
nodal_response	group, response	NUM_GROUP, NUM_NODAL_RESPONSE	Generic nodal response (unit depends on response, but treated as unitless).
sigma_mdep	region, reaction, group	NUM_REGION, NUM_REACTION, NUM_GROUP	Microscopic cross section (b).

In the file: All group constants are written in the file following the same basic approach. After giving the data name, the data is given repeated for each of the dimensions (groups, sides etc.) and in each of these for each of the select-variable combinations (CR, SPA, DET). The nominal

values are given first for each burnup point (collected on one line), after which the polynomial coefficients are given for each of the coef burnup points (one burnup point per line). If plutonium history is in use, the k-coefficients are given in a separate block, the structure of which mirrors that of the group constant itself.

```
Sigma_a
NUM_GROUP x
(
group GROUP_IDX
    NUM_CR x NUM_SPA x NUM_DET x
    (
      CR_DESC SPA_DESC DET_DESC NUM_EXP_NOM x ( NOM_VAL )
    )
    NUM_CR x NUM_SPA x NUM_DET x
    (
      NUM_EXP_COE x
      (
        CR_DESC SPA_DESC DET_DESC NUM_COE x ( COE_VAL )
      )
    )
)

[ optional, but should exist if using plutonium history for material
pu_k_Sigma_a
NUM_GROUP x
(
group GROUP_IDX
    NUM_CR x NUM_SPA x NUM_DET x
    (
      CR_DESC SPA_DESC DET_DESC NUM_EXP_NOM x ( NOM_VAL )
    )
    NUM_CR x NUM_SPA x NUM_DET x
    (
      NUM_EXP_COE x
      (
        CR_DESC SPA_DESC DET_DESC EXP_COE NUM_COE x ( COE_VAL )
      )
    )
)
]
```

Parameters:

name	type	allowed values	description
NOM_VAL	float	depends on group constant	The nominal value of the group constant for a specific select material at a specific burnup point.
COE_VAL	float	depends on group constant	The value of a specific polynomial coefficient for the group constant for a specific select material at a specific burnup point.

Comments: Here we give comment on how the group constants are currently defined and how they can be evaluated based on Serpent output.

Sigma_a: Macroscopic non-xenonated, reduced absorption cross section. Currently evaluated as RABSXS - XE_135_MACRO_ABS - XE_135M_MACRO_ABS.

nuSigma_f: Macroscopic fission neutron production cross section. Currently evaluated simply as NSF.

kappaSigma_f: Macroscopic fission energy production cross section. Currently evaluated as FISS*KAPPA*MEV_IN_JOULES.

Sigma_f: Macroscopic fission cross section. Currently evaluated simply as FISS.

D: Diffusion coefficient. Currently suggested to be calculated either with Cumulative Migration Method (CMM) or using transport correction for hydrogen in H_2O.

1/v: Inverse velocity. Currently evaluated simply as INVV.

chi: Fission spectrum. Currently evaluated simply as CHIT.

Sigma_s: Macroscopic group to group scattering production cross section. Currently evaluated simply as SP0.

side_df: Discontinuity factors for the node horizontal faces. Defined as Ants homogeneous surface flux at the face calculated for the homogenized node using the same boundary conditions as Serpent, divided by Serpent heterogeneous surface flux at the face. In the case of reflective boundary conditions in infinite-lattice group constant generation, the DF_SURF_DF in Serpent output can be directly used. In the case of nonzero net-boundary currents in Serpent group constant generation, a separate Ants single-node solution must be calculated to obtain the homogeneous surface flux.

beta: Delayed neutron group fractions. Currently evaluated simply as BETA_EFF.

lambda: Delayed neutron precursor group decay constants. Currently evaluated simply as LAMBDA.

gamma_I135: Iodine 135 fission yield. Currently evaluated simply as I135_YIELD.

gamma_Xe135: Xenon 135 fission yield. Currently evaluated simply as XE135_YIELD.

gamma_Xe135m: Xenon 135m fission yield. Currently evaluated simply as XE135M_YIELD.

gamma_Pm149: Promethium 149 fission yield. Currently evaluated simply as PM149_YIELD.

gamma_Sm149: Samarium 149 fission yield. Currently evaluated simply as SM149_YIELD.

sigma_I135_a: Iodine 135 microscopic absorption cross section. Currently evaluated simply as I135_MICRO_ABS.

sigma_Xe135_a: Xenon 135 microscopic absorption cross section. Currently evaluated simply as XE135_MICRO_ABS.

sigma_Xe135m_a: Xenon 135m microscopic absorption cross section. Currently evaluated simply as XE135M_MICRO_ABS.

sigma_Pm149_a: Promethium 149 microscopic absorption cross section. Currently evaluated simply as PM149_MICRO_ABS.

sigma_Sm149_a: Samarium 149 microscopic absorption cross section. Currently evaluated simply as SM149_MICRO_ABS.

sigma_U238_c: Uranium 238 microscopic capture cross section. Evaluated as microdepletion micro xs evaluation for uranium 238 MT 102.

sigma_U238_a: Uranium 238 microscopic absorption cross section. Summed up from microdepletion micro xs evaluation for uranium 238 MTs 16, 18 and 102.

sigma_Np239_a: Neptunium 239 microscopic absorption cross section. Summed up from microdepletion micro xs evaluation for Neptunium 239 MTs 16, 18 and 102.

sigma_Pu239_a: Plutonium 239 microscopic capture cross section. Summed up from microdepletion micro xs evaluation for Plutonium 239 MTs 16, 18 and 102.

form_function: The pin power form functions are currently evaluated as pin-cell heterogeneous power (due to flux in group g) per pin-cell homogeneous flux in group g multiplied by the system homogeneous macroscopic fission energy production cross section, i.e.

$$\mathsf{FF}_{g,\mathrm{pc}} = \frac{P_{g,\mathrm{pc}}^{\mathrm{het}}}{P_{g,\mathrm{pc}}^{\mathrm{hom}}} \tag{3.2}$$

where the subscript g refers to energy group and the subscript pc indicates that the power is calculated for the pin-cell. In theory this should be evaluated as

$$\mathsf{FF}_{g,\mathrm{pc}} = \frac{\int_{E_g^{\mathrm{low}}}^{E_g^{\mathrm{high}}} \int_{V_{\mathrm{pc}}} \phi^{\mathrm{het}}(\vec{r}, E) \kappa(\vec{r}, E) \Sigma_f(\vec{r}, E) \mathrm{d}V \mathrm{d}E}{\int_{V_{\mathrm{pc}}} \phi_g^{\mathrm{hom}} \mathrm{d}V (\kappa\Sigma_f)_g}, \tag{3.3}$$

where the homogeneous flux solution used in the denominator should use the same boundary conditions as the heterogeneous solution in the numerator. The homogenized fission energy production cross section here should be the same as the `kappaSigma_f` included in the group constant library.

Note: The current definition of pin power form functions cannot capture changes in pin power distribution coming from pin burnup distribution (and thus pin $\kappa\Sigma_f$) differing from that present in the group constant generation calculation. This may be an issue in nodes that have large internal flux (and thus burnup) gradients, e.g. at the core periphery. In the future, a form function of the form

$$\mathsf{FF}_{g,\mathrm{pc}} = \frac{\int_{E_g^{\mathrm{low}}}^{E_g^{\mathrm{high}}} \int_{V_{\mathrm{pc}}} \phi^{\mathrm{het}}(\vec{r}, E) \kappa(\vec{r}, E) \Sigma_f(\vec{r}, E) \mathrm{d}V \mathrm{d}E}{\int_{V_{\mathrm{pc}}} \phi_g^{\mathrm{hom}} \mathrm{d}V}, \tag{3.4}$$

or similar might be tested to be parametrized based on pin-wise burnup. One challenge of such approach is the fact that such form factors do not inherently preserve the consistency between the pin powers and the node total power.

nodal_response: The nodal responses are intended to tie the homogeneous flux in the homogenized region to some response such as detector signal. This can be described simply

as

$$NR_g = \frac{\int_{E_g^{\text{low}}}^{E_g^{\text{high}}} \int_{V_x} f(\vec{r}, E) \phi^{\text{het}}(\vec{r}, E) \mathrm{d}V \mathrm{d}E}{\int_V \phi_g^{\text{hom}} \mathrm{d}V},$$ (3.5)

where the numerator is integrated spatially over some chosen volume, which can be a sub-volume of the homogenized volume, f is a response function (e.g. the microscopic fission cross section of ^{235}U) and the homogeneous flux solution in the denominator uses the same boundary conditions as the heterogeneous solution in the numerator and is integrated over the whole homogenized volume.

Note: The integration of the homogeneous flux in the denominator could be limited to a specific smaller sub-volume of the node to obtain another kind of a response function (*local response*?), which may be implemented at some point.

sigma_mdep: Microdepletion microscopic cross section. Evaluated directly from .coe file's MDEP_<regionidx>_ZAI<zai>_MT<mt>.

4. Parametrization and evaluation

This section describes the polynomial fitting and plutonium-history fitting that are part of the group constant parametrization process and the way the fitting coefficients can be used to evaluate the value of the parametrized group constant at the nodal code side.

4.1 Polynomial fit

In a specific burnup point of a specific (select) material, the values for a specific group constant have been evaluated at the nominal conditions Σ_{nom} and in N_{var} momentarily varied conditions Σ_{var}^{j}. It is easy to evaluate the vector

$$\overline{\Delta\Sigma} = \begin{pmatrix} (\Delta\Sigma)^1 \\ (\Delta\Sigma)^2 \\ \vdots \\ (\Delta\Sigma)^{N_{\text{var}}} \end{pmatrix} = \begin{pmatrix} (\Sigma_{\text{var}}^1 - \Sigma_{\text{nom}}) \\ (\Sigma_{\text{var}}^2 - \Sigma_{\text{nom}}) \\ \vdots \\ (\Sigma_{\text{var}}^{N_{\text{var}}} - \Sigma_{\text{nom}}) \end{pmatrix}, \qquad \overline{\Delta\Sigma} \in \mathbb{R}^{N_{\text{var}}} \tag{4.1}$$

For each variation j, the delta in each feedback variable i can be evaluated according to Eqn. (3.1) to obtain $\Delta x_{i,j}$. The challenge now is to choose polynomial coefficients c_k so that the polynomial

$$\mathcal{P}(\Delta x_i) = \sum_k c_k \prod_i (\Delta x_i)^{p_{k,i}}$$

offers the best possible representation of $\Delta\Sigma$. Here, $p_{k,i}$ are the powers of the delta of fitting variable i included in term k of the polynomial. Usually the number of polynomial coefficients k may be the number of calculated momentary variations (N_{var}) in order to make the system exactly determined.

The polynomial may be written as a matrix product

$$\mathcal{P}(\Delta x_i) = \begin{pmatrix} \prod_i (\Delta x_i)^{p_{1,i}} & \prod_i (\Delta x_i)^{p_{2,i}} & \dots & \prod_i (\Delta x_i)^{p_{k,i}} \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_k \end{pmatrix}$$

and we can represent the polynomial evaluated at all N_{var} variation conditions with the vector

$$\overline{\mathcal{P}} = \begin{pmatrix} \mathcal{P}(\Delta x_{i,1}) \\ \mathcal{P}(\Delta x_{i,2}) \\ \vdots \\ \mathcal{P}(\Delta x_{i,N_{\text{var}}}) \end{pmatrix} = \overline{\overline{PP}}\,\overline{c} = \begin{pmatrix} \prod_i (\Delta x_{i,1})^{p_{1,i}} & \prod_i (\Delta x_{i,1})^{p_{2,i}} & \dots & \prod_i (\Delta x_{i,1})^{p_{k,i}} \\ \prod_i (\Delta x_{i,2})^{p_{1,i}} & \prod_i (\Delta x_{i,2})^{p_{2,i}} & \dots & \prod_i (\Delta x_{i,2})^{p_{k,i}} \\ \vdots & & \ddots & \vdots \\ \prod_i (\Delta x_{i,N_{\text{var}}})^{p_{1,i}} & \prod_i (\Delta x_{i,N_{\text{var}}})^{p_{2,i}} & \dots & \prod_i (\Delta x_{i,N_{\text{var}}})^{p_{k,i}} \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_k \end{pmatrix}$$

The problem can then be represent as finding the solution $\overline{c}$ to the matrix equation

$$\overline{\overline{PP}}\,\overline{c} = \overline{\Delta\Sigma} \tag{4.2}$$

$$\begin{pmatrix} \prod_i(\Delta x_{i,1})^{p_{1,i}} & \prod_i(\Delta x_{i,1})^{p_{2,i}} & ... & \prod_i(\Delta x_{i,1})^{p_{k,i}} \\ \prod_i(\Delta x_{i,2})^{p_{1,i}} & \prod_i(\Delta x_{i,2})^{p_{2,i}} & ... & \prod_i(\Delta x_{i,2})^{p_{k,i}} \\ \vdots & & \ddots & \vdots \\ \prod_i(\Delta x_{i,N_{var}})^{p_{1,i}} & \prod_i(\Delta x_{i,N_{var}})^{p_{2,i}} & ... & \prod_i(\Delta x_{i,N_{var}})^{p_{k,i}} \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_k \end{pmatrix} = \begin{pmatrix} (\Sigma_{var}^1 - \Sigma_{nom}) \\ (\Sigma_{var}^2 - \Sigma_{nom}) \\ \vdots \\ (\Sigma_{var}^{N_{var}} - \Sigma_{nom}) \end{pmatrix}. \tag{4.3}$$

Here $\overline{\overline{PP}} \in \mathbb{R}^{N_{var} \times k}$, $\overline{c} \in \mathbb{R}^k$ and $\overline{\Delta\Sigma} \in \mathbb{R}^{N_{var}}$. As noted previously, if k is equal to N_{var} the system is exactly determined and a unique solution can be found if $\overline{\overline{PP}}$ is of full rank, i.e. if the terms of the polynomial and the calculated variations are unique. If N_{var} is larger than k the system is overdetermined, i.e. the number of polynomial terms is too small to guarantee a full reproduction of the result in the variation points. In such cases a linear least squares fit can be used to obtain a good fit for $\overline{c}$. Finally, if N_{var} is smaller than k the system is underdetermined and there is an infinite number of $\vec{c}$ that can reproduce the result in the variation points.

The matrix $\overline{\overline{PP}}$ and the vector $\overline{\Delta\Sigma}$ are easy to form in the parametrization after which the matrix equation is currently solved using `numpy.linalg.lstsq`. This guarantees reasonable results both in exactly determined and overdetermined systems, but underdetermined parametrizations should generally not be used without modifying the system to include additional boundary conditions.

4.2 Plutonium coefficients

The plutonium k coefficients offer a parametrization of the effect of ^{239}Pu atomic density (and by this proxy the effect of the historical conditions) on a group constant. The plutonium history parametrization used in the GENPOLY-parametrizationis based on that used in DYN3D which is described in Chapter 4 of Ref. [2]. The idea in the plutonium coefficients is to evaluate them as

$$k = \frac{\Sigma^{offhis}/\Sigma^{nomhis} - 1}{\sqrt{N^{offhis}/N^{nomhis} - 1}} \tag{4.4}$$

where Σ^{offhis} and Σ^{nomhis} are the group constant evaluated at the same burnup and (branch) conditions but based on different historical conditions, here denoted as off-nominal and nominal historical conditions (or more precisely the fuel compositions resulting from those). N^{offhis} and N^{nomhis} are the homogenized atomic densities (or total atomic content) of ^{239}Pu.

If the same branch calculations have been repeated for the off-nominal and nominal histories, the numerator is easy to evaluate and the evaluation of the denominator requires only the atomic densities of ^{239}Pu, which, while available from the Serpent calculation, should be evaluated for the burnup points using the same approach that will be used in the nodal code. This means that the ^{239}Pu atomic densities are currently recalculated during the parametrization process based on the simple-chains model used in Ants to solve the ^{238}U $\rightarrow$ ^{239}Np $\rightarrow$ ^{239}Pu system.

Once nominal and off-nominal group constants and atomic densities are available for each burnup and branch point, the burnup and branch dependent values for k can be calculated for

the group constant. As k for a specific group constant has a dependence on the momentary conditions, the k for each group constant is further fitted using the same polynomial representation as all other group constants.

The k coefficient can then be used to evaluate the value of Σ after depletion at some other historical conditions his by assuming that Eqn. (4.4) holds regardless of the actual off-nominal history, i.e.

$$k = \frac{\Sigma^{his}/\Sigma^{nomhis} - 1}{\sqrt{N^{his}/N^{nomhis}} - 1}$$

$$\left(\sqrt{N^{his}/N^{nomhis}} - 1 \right) k = \Sigma^{his}/\Sigma^{nomhis} - 1$$

$$\left(\sqrt{N^{his}/N^{nomhis}} - 1 \right) k\Sigma^{nomhis} = \Sigma^{his} - \Sigma^{nomhis}$$

$$\Sigma^{his} = \left(1 + \left(\sqrt{N^{his}/N^{nomhis}} - 1 \right) k \right) \Sigma^{nomhis} \tag{4.5}$$

where k is the value calculated and parametrized during group constant parametrization and N^{his} is the atomic density of ^{239}Pu evaluated by the nodal code for the node in question based on the actual historical conditions present in the nodal calculation.

4.3 Evaluation of parametrized group constants

The following process can be used, when the value of a group constant Σ needs to be evaluated in the nodal code for a specific material at a specific burnup (bu) with specific historical conditions ^{his} at specific momentary conditions (fb) as represented by the feedback variables.

1. First figure out which select material to use.

2. Then interpolate/extrapolate nominal value and polynomial coefficients from burnup tabulation

$$\Sigma_{nom}(bu)$$

$$c_{\Sigma,i}(bu)$$

3. Then evaluate the momentary feedback effect

$$\Sigma_{fb}(bu) = \Sigma_{nom}(bu) + \mathcal{P}_{\Sigma}(fb) \tag{4.6}$$

4. Then, evaluate plutonium k for current burnup and feedback conditions:

    (a) Interpolate/extrapolate nominal value and polynomial coefficients from burnup tabulation

$$k_{nom}(bu)$$

$$c_{k,i}(bu)$$

    (b) Evaluate feedback effect for k

$$k_{fb}(bu) = k_{nom}(bu) + \mathcal{P}_{k}(fb) \tag{4.7}$$

5. Then, based on Eq. (4.5), using the current atomic density of ^{239}Pu in the node N^{his}, evaluate the final, history corrected value for the group constant

$$\Sigma_{fb}^{his}(bu) = \left(1 + \left(\sqrt{N^{his}/N^{nomhis}} - 1\right) k_{fb}(bu)\right) \Sigma_{fb}(bu). \tag{4.8}$$

5. Summary

The GENPOLY-parametrization has been developed to be a flexible and easily extendable format for representing group constants required by the nodal neutronicscode Ants. The GEN-POLY-parametrization handles the dependence of group constants on burnup with tabulation, the dependence on momentary conditions with a polynomial fit and the dependence on historical conditions with a plutonium history fit. The parametrization offers special considerations for

- The treatment of short-lived fission poisons using a simple-chains approach.

- The evaluation of pin powers on the nodal code side via pin power reconstruction.

- The evaluation of some other, potentially localized, responses inside the nodes via a generic nodal response approach.

- The tracking of the production and removal of individual nuclides through the use of microdepletion.

This report described the format of GENPOLY group constant library files in some detail and gave an overview of how the polynomial coefficients and plutonium k-coefficients are currently calculated in the parametrization process. Finally, a short description was given on how the tabulated nominal values, polynomial coefficients and plutonium k-coefficients can be used to evaluate the value of a group constant for a node at arbitrary momentary and historical conditions and burnup.

The GENPOLY-parametrization will likely evolve during the future development of the Serpent–Ants calculation chain and this report will fall out of date. Even so, this document should give a good introduction on the fundamentals of the GENPOLY-parametrization.

References

[1] E. Kaloinen, "CRFIT, a code for creation of input file of two-group diffusion parameters and fitting coefficients for HEXBU-3D/MOD5", VTT Technical Research Centre of Finland, Tech. Rep., 1996.

[2] Y. Bilodid, "Spectral history modeling in the reactor dynamics code DYN3D", PhD thesis, Technical University of Dresden, 2014.

A. Example of a GENPOLY group constant library file

This appendix contains a rather simple group constant library file according to the GENPOLY-parametrization. The library contains a single material (FUEL1) with two select materials (un-rodded and rodded). Both the nominal branch and the (momentary) variation branches have been calculated at three burnup points. The polynomial fit uses five terms, first and second order terms for delta-TFUSQRT, first and second order terms for DCO and a first order term for TCO.

No plutonium history has been included here and the library itself should only be considered as an illustration of the file structure.

This file is currently used as the reference result of the KrakenTools regression test `32_gc_poly_dhreactor`.

file contents:

```
polynomial group constant library
! Ants polynomial group constant file
! Serpent files:

num_mat             1
num_group           2
num_prec_group      6
num_dir             4
num_fb_var          11
num_select_var      3
num_mdep_region     0
version             1

poison
lambda_I135         2.930610e-05
lambda_Xe135m       7.555560e-04
lambda_Xe135        2.106570e-05
lambda_Pm149        3.627370e-06
branch_decay_I135   2 Xe135m 0.000000e+00 Xe135 1.000000e+00

mat FUEL1
num_pin             0
num_exp_nom         3
num_exp_coe         3
num_coe             5
num_region          0
mass_hm             1133.5
unheated_frac       0.0
is_quarter          0
description         "Fuel assembly 1"

num_select
CR  1
SPA 0
DET 0

select_description
CR  1

fb_scale
TFU             5.00000000E+02 3.00000000E+02 7.00000000E+02 5.00000000E+02 5.00000000E-03
```

```
TFUSQRT          2.23606798E+01 1.73205081E+01 2.64575131E+01 2.23606798E+01 1.98405939E-01
DCO              9.70774625E-01 8.17729844E-01 9.98206093E-01 9.70774625E-01 6.53403528E+00
TCO              3.55000000E+02 3.55000000E+02 4.10000000E+02 3.55000000E+02 1.81818182E-02
BOR              0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
BORDENS          0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
XEN              0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
SAM              0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
BDCO             0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
BTCO             0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
BORDENS2         0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00


fb_table
 0 1 0 0 0 0 0 0 0 0 0
 0 2 0 0 0 0 0 0 0 0 0
 0 0 1 0 0 0 0 0 0 0 0
 0 0 2 0 0 0 0 0 0 0 0
 0 0 0 1 0 0 0 0 0 0 0


exp
 0.0 0.1 0.5
 0.0 0.1 0.5


Sigma_a
group 1
 0  0  0   1.0713E-02   1.0696E-02   1.0716E-02
 1  0  0   1.4597E-02   1.4587E-02   1.4599E-02
 0  0  0   0.000000   2.1663E-04   4.1034E-05   2.9125E-04   1.1195E-04   4.7800E-05
 0  0  0   0.100000   2.0351E-04   3.8411E-05   3.3006E-04   1.7556E-04   4.9798E-05
 0  0  0   0.500000   1.7704E-04  -3.9358E-05   1.1141E-04  -1.2039E-04  -8.3003E-06
 1  0  0   0.000000   1.7023E-04   3.2435E-05   2.6380E-04  -3.9989E-05   2.7099E-05
 1  0  0   0.100000   1.5448E-04   6.0283E-05   2.6117E-04  -2.5321E-05   4.2499E-05
 1  0  0   0.500000   1.6769E-04  -3.8607E-05   1.3897E-04  -1.6842E-04  -9.9007E-06
group 2
 0  0  0   1.2699E-01   1.2676E-01   1.2707E-01
 1  0  0   1.6426E-01   1.6436E-01   1.6405E-01
 0  0  0   0.000000  -1.8104E-04   1.3218E-04   1.7286E-03   2.0096E-04  -3.7863E-03
 0  0  0   0.100000  -3.0289E-05   4.4563E-04   2.2440E-03   8.7644E-04  -3.7071E-03
 0  0  0   0.500000  -1.4435E-04  -4.2765E-04   1.6790E-03  -1.7828E-04  -4.0124E-03
 1  0  0   0.000000  -2.0927E-05   8.6893E-05  -4.4801E-04  -1.5685E-03  -3.5582E-03
 1  0  0   0.100000  -3.1886E-04   3.7936E-05  -3.5683E-04  -1.1711E-03  -3.6417E-03
 1  0  0   0.500000  -1.5733E-04   3.8214E-04   1.8174E-04  -7.8483E-04  -2.8470E-03


nuSigma_f
group 1
 0  0  0   6.6869E-03   6.6805E-03   6.6800E-03
 1  0  0   6.6820E-03   6.6825E-03   6.6401E-03
 0  0  0   0.000000   1.8539E-05   2.2569E-05   1.5973E-04   6.7852E-05   3.6050E-05
 0  0  0   0.100000   3.2559E-06   7.9059E-06   2.4135E-04   1.6998E-04   3.4640E-05
 0  0  0   0.500000  -4.1001E-06  -3.8101E-06   1.0516E-04  -2.4414E-06   6.7700E-06
 1  0  0   0.000000  -8.6017E-06  -7.7617E-06   1.0546E-04  -5.6126E-05   5.1000E-07
 1  0  0   0.100000  -1.7317E-05  -7.2867E-06   6.4658E-07  -1.4710E-04   4.1800E-06
 1  0  0   0.500000  -8.2476E-06   1.3582E-05   2.0148E-04   8.3657E-05   1.5700E-06
group 2
 0  0  0   1.5469E-01   1.5430E-01   1.5463E-01
 1  0  0   1.5872E-01   1.5885E-01   1.5858E-01
 0  0  0   0.000000  -4.9835E-04   1.1665E-04   2.5276E-03  -1.8835E-04  -5.7860E-03
 0  0  0   0.100000  -2.7884E-04   4.6716E-04   3.4632E-03   7.8622E-04  -5.6280E-03
 0  0  0   0.500000  -3.4477E-04  -2.9477E-04   3.5629E-03   4.4791E-04  -6.0210E-03
 1  0  0   0.000000  -7.2872E-04   2.0028E-04   4.6261E-03   3.3708E-04  -5.5860E-03
 1  0  0   0.100000  -4.5605E-04  -1.2305E-04   2.0258E-03  -2.4622E-03  -5.7340E-03
 1  0  0   0.500000  -5.8067E-04   6.5233E-04   4.4479E-03   3.0392E-04  -4.8730E-03
```

```
kappaSigma_f
group 1
 0  0  0   8.5485E-14  8.5402E-14  8.5308E-14
 1  0  0   8.5465E-14  8.5423E-14  8.4851E-14
 0  0  0   0.000000  2.3829E-16  3.0180E-16  2.0617E-15  9.8883E-16  4.7161E-16
 0  0  0   0.100000  3.2351E-17  9.8808E-17  2.9331E-15  2.1092E-15  4.4325E-16
 0  0  0   0.500000 -5.2161E-17 -4.1297E-17  1.4401E-15  1.5137E-16  1.1509E-16
 1  0  0   0.000000 -1.2430E-16 -1.1451E-16  1.2269E-15 -7.4292E-16 -1.5097E-17
 1  0  0   0.100000 -2.2434E-16 -6.6479E-17  1.9700E-16 -1.5966E-15  7.5952E-17
 1  0  0   0.500000 -9.2510E-17  1.2958E-16  2.3932E-15  9.5078E-16  3.5377E-17
group 2
 0  0  0   2.0573E-12  2.0515E-12  2.0525E-12
 1  0  0   2.1109E-12  2.1120E-12  2.1046E-12
 0  0  0   0.000000 -6.6322E-15  1.5474E-15  3.3626E-14 -2.4987E-15 -7.6951E-14
 0  0  0   0.100000 -3.7099E-15  6.2073E-15  4.6034E-14  1.0400E-14 -7.4859E-14
 0  0  0   0.500000 -4.6020E-15 -3.9115E-15  4.7461E-14  5.9523E-15 -8.0082E-14
 1  0  0   0.000000 -9.6899E-15  2.6605E-15  6.1491E-14  4.4417E-15 -7.4294E-14
 1  0  0   0.100000 -6.0642E-15 -1.6436E-15  2.6940E-14 -3.2777E-14 -7.6269E-14
 1  0  0   0.500000 -7.7351E-15  8.6623E-15  5.9265E-14  4.0616E-15 -6.4836E-14


Sigma_f
group 1
 0  0  0   2.6204E-03  2.6179E-03  2.6145E-03
 1  0  0   2.6203E-03  2.6189E-03  2.6011E-03
 0  0  0   0.000000  7.3195E-06  9.3695E-06  6.3298E-05  3.0958E-05  1.4560E-05
 0  0  0   0.100000  9.3351E-07  2.9835E-06  8.9176E-05  6.4316E-05  1.3600E-05
 0  0  0   0.500000 -1.6158E-06 -1.2058E-06  4.4073E-05  4.9931E-06  3.6300E-06
 1  0  0   0.000000 -3.8806E-06 -3.5806E-06  3.7127E-05 -2.2863E-05 -4.5000E-07
 1  0  0   0.100000 -6.9270E-06 -1.9970E-06  5.9822E-06 -4.8628E-05  2.3800E-06
 1  0  0   0.500000 -2.8391E-06  3.8409E-06  7.2765E-05  2.8875E-05  1.1100E-06
group 2
 0  0  0   6.3483E-02  6.3301E-02  6.3312E-02
 1  0  0   6.5138E-02  6.5167E-02  6.4916E-02
 0  0  0   0.000000 -2.0465E-04  4.7749E-05  1.0376E-03 -7.7103E-05 -2.3745E-03
 0  0  0   0.100000 -1.1447E-04  1.9153E-04  1.4204E-03  3.2090E-04 -2.3101E-03
 0  0  0   0.500000 -1.4195E-04 -1.2065E-04  1.4641E-03  1.8282E-04 -2.4711E-03
 1  0  0   0.000000 -2.9900E-04  8.2096E-05  1.8975E-03  1.3706E-04 -2.2925E-03
 1  0  0   0.100000 -1.8711E-04 -5.0714E-05  8.3125E-04 -1.0114E-03 -2.3533E-03
 1  0  0   0.500000 -2.3873E-04  2.6737E-04  1.8297E-03  1.2575E-04 -2.0008E-03


D
group 1
 0  0  0   1.2390E+00  1.2415E+00  1.2421E+00
 1  0  0   1.2273E+00  1.2328E+00  1.2304E+00
 0  0  0   0.000000  2.1358E-03  3.3358E-03 -1.1120E-01  1.5911E-02  2.5600E-03
 0  0  0   0.100000 -1.3962E-03 -3.7462E-03 -1.0897E-01  1.2215E-02  1.0600E-03
 0  0  0   0.500000  2.0102E-03 -2.1098E-03 -1.1020E-01  1.0038E-02 -1.3000E-03
 1  0  0   0.000000  3.0032E-03  4.4632E-03 -1.0024E-01  1.5469E-02  6.2000E-03
 1  0  0   0.100000  2.1322E-03 -2.0178E-03 -1.1010E-01 -4.8249E-03 -3.3000E-04
 1  0  0   0.500000  7.5963E-04  6.2396E-03 -9.7671E-02  1.5139E-02  1.8000E-03
group 2
 0  0  0   2.8657E-01  2.8199E-01  2.8549E-01
 1  0  0   2.8618E-01  2.9155E-01  2.8586E-01
 0  0  0   0.000000  6.2602E-06 -3.6447E-03 -6.4393E-02 -3.1200E-02  7.5400E-04
 0  0  0   0.100000  1.1659E-03  3.6269E-03 -1.9626E-02  2.3334E-02  7.3930E-03
 0  0  0   0.500000 -1.7826E-03 -5.5336E-03 -3.6532E-02  5.8198E-03  3.7990E-03
 1  0  0   0.000000  2.0408E-03  7.2228E-03 -3.5186E-02  7.5565E-03  7.1670E-03
 1  0  0   0.100000 -2.4159E-04  6.5441E-04 -6.2032E-02 -2.2084E-02  6.6090E-03
 1  0  0   0.500000  5.9537E-05  9.0125E-03 -3.9160E-02  4.1364E-03  6.3830E-03


1/v
group 1
```

```
0  0  0    5.7905E-08   5.8016E-08   5.7929E-08
1  0  0    5.5234E-08   5.5143E-08   5.5278E-08
0  0  0    0.000000 -2.5950E-10 -7.0444E-13  8.4670E-10 -2.0596E-11  9.9300E-11
0  0  0    0.100000 -3.0423E-10 -1.2413E-10  1.2424E-10 -8.1146E-10  4.8200E-11
0  0  0    0.500000 -2.9002E-10  2.5784E-11  9.6554E-10 -3.3058E-11  1.4460E-10
1  0  0    0.000000 -2.7583E-10 -2.2203E-10  1.1631E-09 -2.0770E-10  8.1200E-11
1  0  0    0.100000 -2.5688E-10  1.3652E-10  1.1787E-09 -1.2996E-10  2.4890E-10
1  0  0    0.500000 -2.6151E-10 -9.0712E-11  1.0050E-09 -3.9631E-10  2.2500E-11
group 2
0  0  0    2.9339E-06   2.9391E-06   2.9341E-06
1  0  0    2.8092E-06   2.8076E-06   2.8057E-06
0  0  0    0.000000 -2.6563E-09  3.3437E-09  8.0434E-08  8.8140E-09 -1.1806E-07
0  0  0    0.100000 -6.9820E-09 -7.8020E-09  4.5063E-08 -3.3837E-08 -1.2221E-07
0  0  0    0.500000 -3.8094E-09  5.1406E-09  7.5594E-08  2.8237E-09 -1.1748E-07
1  0  0    0.000000 -8.2471E-09 -3.6271E-09  7.1765E-08 -9.7448E-09 -1.0393E-07
1  0  0    0.100000 -4.3685E-09 -5.2846E-10  7.8725E-08 -4.3749E-09 -1.0278E-07
1  0  0    0.500000 -3.5008E-09  2.8992E-09  8.4395E-08  1.9653E-09 -1.0091E-07


chi
group 1
0  0  0    1.0000E+00   1.0000E+00   1.0000E+00
1  0  0    1.0000E+00   1.0000E+00   1.0000E+00
0  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0  0  0    0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0  0  0    0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
group 2
0  0  0    0.0000E+00   0.0000E+00   0.0000E+00
1  0  0    0.0000E+00   0.0000E+00   0.0000E+00
0  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0  0  0    0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
0  0  0    0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
1  0  0    0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00


Sigma_s
group 1 to_group 1
0  0  0    6.4543E-01   6.4543E-01   6.4506E-01
1  0  0    6.3743E-01   6.3705E-01   6.3778E-01
0  0  0    0.000000  5.2316E-05  1.2332E-04  7.6639E-02  6.0466E-04  4.4900E-04
0  0  0    0.100000  5.6400E-05  1.3040E-04  7.4007E-02 -2.2060E-03  2.8800E-04
0  0  0    0.500000  9.0719E-05  9.2719E-05  7.6796E-02  7.8757E-04  7.8400E-04
1  0  0    0.000000  4.1348E-05 -2.6652E-05  7.1770E-02 -3.7187E-04  2.7000E-04
1  0  0    0.100000  3.8100E-04  8.9800E-04  7.4309E-02  2.5512E-03  1.0910E-03
1  0  0    0.500000  4.0446E-05 -6.4155E-04  7.0027E-02 -2.6645E-03 -1.2900E-04
group 1 to_group 2
0  0  0    2.4469E-02   2.4490E-02   2.4450E-02
1  0  0    2.1693E-02   2.1635E-02   2.1635E-02
0  0  0    0.000000 -1.2048E-04 -3.6581E-05  4.2393E-03 -7.6013E-05  9.2000E-05
0  0  0    0.100000 -1.1561E-04 -2.8805E-05  3.9972E-03 -3.1927E-04  2.2900E-05
0  0  0    0.500000 -1.1678E-04 -2.6843E-06  4.1878E-03 -1.0604E-04  7.3300E-05
1  0  0    0.000000 -1.2248E-04 -7.4682E-05  4.0087E-03 -7.4927E-05  2.1200E-05
1  0  0    0.100000 -6.2786E-05  5.7114E-05  4.2368E-03  2.0559E-04  1.1940E-04
1  0  0    0.500000 -1.0095E-04  5.2451E-05  4.2586E-03  2.1763E-04  9.9100E-05
group 2 to_group 1
0  0  0    7.0014E-04   7.0054E-04   7.2766E-04
1  0  0    8.8152E-04   9.3423E-04   8.8067E-04
0  0  0    0.000000  5.8410E-05  1.1887E-05 -4.2590E-05 -6.2043E-05  1.7543E-04
0  0  0    0.100000  5.7892E-05  1.1273E-05  3.3701E-05  4.1724E-05  1.1814E-04
```

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 0  0  0    0.500000   7.2170E-05 -2.1188E-05 -1.1305E-04 -1.2187E-04  1.4173E-04
 1  0  0    0.000000   9.8602E-05  1.8897E-05 -9.3331E-06 -6.1681E-06  2.5437E-04
 1  0  0    0.100000   7.5354E-05 -3.3893E-05 -1.5237E-04 -1.8293E-04  1.3061E-04
 1  0  0    0.500000   1.1528E-04  5.7084E-05  4.6059E-05  7.7831E-05  1.8632E-04
group 2 to_group 2
 0  0  0    1.8982E+00  1.9008E+00  1.8989E+00
 1  0  0    1.7970E+00  1.7939E+00  1.7949E+00
 0  0  0    0.000000  -5.3787E-05  2.3062E-03  3.0802E-01  1.2797E-03 -3.9640E-02
 0  0  0    0.100000  -2.1541E-03 -4.5241E-03  2.9229E-01 -1.7721E-02 -4.3090E-02
 0  0  0    0.500000  -3.9371E-04  2.3763E-03  3.1335E-01  6.4090E-03 -4.0390E-02
 1  0  0    0.000000  -3.5866E-03 -4.9866E-03  2.8409E-01 -6.5215E-03 -3.4900E-02
 1  0  0    0.100000  -1.3113E-03  1.6587E-03  3.0263E-01  1.4859E-02 -2.7740E-02
 1  0  0    0.500000  -2.5029E-03 -5.2295E-04  3.0730E-01  1.8361E-02 -3.2520E-02


side_df
group 1 dir E
 0  0  0    9.8927E-01  9.8988E-01  9.8848E-01
 1  0  0    1.0490E+00  1.0487E+00  1.0454E+00
 0  0  0    0.000000   2.7863E-03  4.4529E-04 -3.0898E-03  4.1652E-03  3.8590E-03
 0  0  0    0.100000   1.2952E-03  6.0120E-04 -1.1059E-02 -1.0826E-02  1.4490E-03
 0  0  0    0.500000   1.5738E-03 -1.8712E-03  1.1389E-02  1.7299E-02 -2.1600E-04
 1  0  0    0.000000   8.9602E-04 -1.8440E-03 -1.4311E-02 -2.8481E-02  1.0800E-03
 1  0  0    0.100000  -3.5316E-04 -3.2132E-03  3.4933E-05 -2.6851E-03 -3.3000E-03
 1  0  0    0.500000  -1.9118E-03  2.4820E-04  6.3361E-03  4.4609E-04 -1.7100E-03
group 1 dir N
 0  0  0    9.8927E-01  9.8988E-01  9.8848E-01
 1  0  0    1.0490E+00  1.0487E+00  1.0454E+00
 0  0  0    0.000000   2.7870E-03  4.4597E-04 -3.0898E-03  4.1652E-03  3.8590E-03
 0  0  0    0.100000   1.2959E-03  6.0188E-04 -1.1059E-02 -1.0826E-02  1.4490E-03
 0  0  0    0.500000   1.5738E-03 -1.8712E-03  1.1389E-02  1.7299E-02 -2.1600E-04
 1  0  0    0.000000   8.9602E-04 -1.8440E-03 -1.4311E-02 -2.8481E-02  1.0800E-03
 1  0  0    0.100000  -3.4867E-04 -3.2187E-03  3.4933E-05 -2.6851E-03 -3.3000E-03
 1  0  0    0.500000  -1.9118E-03  2.4820E-04  6.3361E-03  4.4609E-04 -1.7100E-03
group 1 dir W
 0  0  0    9.8927E-01  9.8988E-01  9.8848E-01
 1  0  0    1.0490E+00  1.0487E+00  1.0454E+00
 0  0  0    0.000000   2.7863E-03  4.4529E-04 -3.0898E-03  4.1652E-03  3.8590E-03
 0  0  0    0.100000   1.2952E-03  6.0120E-04 -1.1059E-02 -1.0826E-02  1.4490E-03
 0  0  0    0.500000   1.5738E-03 -1.8712E-03  1.1389E-02  1.7299E-02 -2.1600E-04
 1  0  0    0.000000   8.9602E-04 -1.8440E-03 -1.4311E-02 -2.8481E-02  1.0800E-03
 1  0  0    0.100000  -3.5316E-04 -3.2132E-03  3.4933E-05 -2.6851E-03 -3.3000E-03
 1  0  0    0.500000  -1.9118E-03  2.4820E-04  6.3361E-03  4.4609E-04 -1.7100E-03
group 1 dir S
 0  0  0    9.8927E-01  9.8988E-01  9.8848E-01
 1  0  0    1.0490E+00  1.0487E+00  1.0454E+00
 0  0  0    0.000000   2.7870E-03  4.4597E-04 -3.0898E-03  4.1652E-03  3.8590E-03
 0  0  0    0.100000   1.2959E-03  6.0188E-04 -1.1059E-02 -1.0826E-02  1.4490E-03
 0  0  0    0.500000   1.5738E-03 -1.8712E-03  1.1389E-02  1.7299E-02 -2.1600E-04
 1  0  0    0.000000   8.9602E-04 -1.8440E-03 -1.4311E-02 -2.8481E-02  1.0800E-03
 1  0  0    0.100000  -3.4867E-04 -3.2187E-03  3.4933E-05 -2.6851E-03 -3.3000E-03
 1  0  0    0.500000  -1.9118E-03  2.4820E-04  6.3361E-03  4.4609E-04 -1.7100E-03
group 2 dir E
 0  0  0    1.0072E+00  1.0088E+00  1.0039E+00
 1  0  0    1.4248E+00  1.4168E+00  1.4087E+00
 0  0  0    0.000000   9.8307E-04  2.9831E-03  5.1572E-02  5.7162E-02  1.6600E-03
 0  0  0    0.100000   8.7350E-03  8.4150E-03  5.5086E-02  5.7166E-02 -1.4800E-03
 0  0  0    0.500000   4.0922E-03  9.1322E-03  3.2177E-02  4.2107E-02  5.5700E-03
 1  0  0    0.000000   6.6128E-04 -2.5087E-03  2.6534E-02  2.3044E-03 -7.0800E-03
 1  0  0    0.100000   1.5411E-04 -4.2459E-03  1.0897E-05 -1.1889E-02 -1.0120E-02
 1  0  0    0.500000  -6.7841E-03  1.8366E-02  8.5575E-02  6.6665E-02 -8.4000E-04
group 2 dir N
 0  0  0    1.0072E+00  1.0088E+00  1.0039E+00
```

```
 1   0   0    1.4248E+00   1.4168E+00   1.4087E+00
 0   0   0    0.000000  9.7629E-04   2.9763E-03   5.1572E-02   5.7162E-02   1.6600E-03
 0   0   0    0.100000  8.7395E-03   8.4095E-03   5.5086E-02   5.7166E-02  -1.4800E-03
 0   0   0    0.500000  4.0922E-03   9.1322E-03   3.2177E-02   4.2107E-02   5.5700E-03
 1   0   0    0.000000  6.6577E-04  -2.5142E-03   2.6534E-02   2.3044E-03  -7.0800E-03
 1   0   0    0.100000  1.5860E-04  -4.2514E-03   1.0897E-05  -1.1889E-02  -1.0120E-02
 1   0   0    0.500000 -6.7841E-03   1.8366E-02   8.5575E-02   6.6665E-02  -8.4000E-04
group 2 dir W
 0   0   0    1.0072E+00   1.0088E+00   1.0039E+00
 1   0   0    1.4248E+00   1.4168E+00   1.4087E+00
 0   0   0    0.000000  9.8307E-04   2.9831E-03   5.1572E-02   5.7162E-02   1.6600E-03
 0   0   0    0.100000  8.7350E-03   8.4150E-03   5.5086E-02   5.7166E-02  -1.4800E-03
 0   0   0    0.500000  4.0922E-03   9.1322E-03   3.2177E-02   4.2107E-02   5.5700E-03
 1   0   0    0.000000  6.6128E-04  -2.5087E-03   2.6534E-02   2.3044E-03  -7.0800E-03
 1   0   0    0.100000  1.5411E-04  -4.2459E-03   1.0897E-05  -1.1889E-02  -1.0120E-02
 1   0   0    0.500000 -6.7841E-03   1.8366E-02   8.5575E-02   6.6665E-02  -8.4000E-04
group 2 dir S
 0   0   0    1.0072E+00   1.0088E+00   1.0039E+00
 1   0   0    1.4248E+00   1.4168E+00   1.4087E+00
 0   0   0    0.000000  9.7629E-04   2.9763E-03   5.1572E-02   5.7162E-02   1.6600E-03
 0   0   0    0.100000  8.7395E-03   8.4095E-03   5.5086E-02   5.7166E-02  -1.4800E-03
 0   0   0    0.500000  4.0922E-03   9.1322E-03   3.2177E-02   4.2107E-02   5.5700E-03
 1   0   0    0.000000  6.6577E-04  -2.5142E-03   2.6534E-02   2.3044E-03  -7.0800E-03
 1   0   0    0.100000  1.5860E-04  -4.2514E-03   1.0897E-05  -1.1889E-02  -1.0120E-02
 1   0   0    0.500000 -6.7841E-03   1.8366E-02   8.5575E-02   6.6665E-02  -8.4000E-04


beta
prec_group 1
 0   0   0    2.3828E-04   2.3742E-04   1.8723E-04
 1   0   0    2.0598E-04   2.2788E-04   2.1327E-04
 0   0   0    0.000000 -2.6745E-06  -6.9572E-05  -2.0928E-04  -2.0111E-04   4.5241E-05
 0   0   0    0.100000 -1.2192E-05  -1.9598E-05   2.0400E-05  -2.4761E-05  -1.7140E-05
 0   0   0    0.500000  2.2756E-05   5.7217E-05   1.1394E-04   1.6668E-04   1.1847E-04
 1   0   0    0.000000  1.0570E-05   4.3714E-05  -1.8283E-05   1.5192E-05   2.1756E-05
 1   0   0    0.100000 -7.1272E-05   5.2151E-05   1.3960E-04   6.3961E-05  -5.7100E-05
 1   0   0    0.500000 -1.4470E-05  -2.7597E-05   7.1341E-05   1.0117E-05  -5.7990E-06
prec_group 2
 0   0   0    1.2058E-03   1.0547E-03   1.1843E-03
 1   0   0    1.1603E-03   1.0761E-03   1.2205E-03
 0   0   0    0.000000  8.0883E-05  -3.8367E-06  -2.9846E-04  -3.2169E-04   1.3813E-04
 0   0   0    0.100000  1.7397E-05   1.6690E-04   2.3283E-04   4.3539E-04   1.2038E-04
 0   0   0    0.500000 -8.9381E-05  -3.5701E-05  -4.9222E-04  -4.4588E-04  -2.1110E-05
 1   0   0    0.000000 -1.9686E-05   1.3654E-05  -5.0334E-04  -5.7253E-04   2.9180E-05
 1   0   0    0.100000  4.2381E-05   7.3121E-05   5.0034E-04   6.5801E-04   7.5040E-05
 1   0   0    0.500000 -6.5806E-05  -8.2776E-05   9.4717E-05   6.1417E-05  -1.5150E-05
prec_group 3
 0   0   0    1.1964E-03   1.0806E-03   1.2440E-03
 1   0   0    1.1312E-03   1.2264E-03   1.0844E-03
 0   0   0    0.000000  4.7891E-05  -5.2879E-05  -4.9854E-04  -5.7284E-04  -1.1192E-04
 0   0   0    0.100000 -3.0155E-05   1.1819E-04   3.9980E-04   4.8434E-04   1.4095E-04
 0   0   0    0.500000 -2.1401E-05  -1.1729E-04  -1.6946E-04  -2.2866E-04  -2.2565E-04
 1   0   0    0.000000 -4.1447E-05   1.1327E-04  -2.4018E-05  -3.6578E-05  -1.3390E-05
 1   0   0    0.100000 -9.8908E-05  -1.5324E-04  -2.6813E-04  -3.2097E-04  -5.9350E-05
 1   0   0    0.500000 -4.0764E-05   6.1396E-05   7.2182E-04   7.3966E-04   2.3740E-05
prec_group 4
 0   0   0    2.7942E-03   2.6908E-03   2.6871E-03
 1   0   0    2.5657E-03   2.7673E-03   2.5880E-03
 0   0   0    0.000000 -9.8153E-05  -1.4835E-04  -6.9034E-04  -8.6457E-04  -1.4080E-04
 0   0   0    0.100000  2.4524E-05  -2.0853E-04  -1.7600E-04  -2.2670E-04   1.0230E-05
 0   0   0    0.500000 -7.3240E-05  -2.1613E-04  -4.1231E-05  -1.5034E-04   4.8170E-05
 1   0   0    0.000000 -5.5139E-05   1.8250E-04  -4.3788E-04  -3.3195E-04   7.3800E-06
 1   0   0    0.100000  1.0050E-04  -3.5925E-04   8.8614E-06  -5.4109E-05  -2.6028E-04
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 1  0  0    0.500000 -6.9725E-05  4.1175E-05  7.0322E-05  2.4483E-04  8.0450E-05
prec_group 5
 0  0  0    1.1768E-03  1.0953E-03  1.2414E-03
 1  0  0    1.1547E-03  1.2563E-03  1.2128E-03
 0  0  0    0.000000 -6.1608E-05  6.1172E-05 -3.1788E-04 -2.4353E-04 -9.8700E-06
 0  0  0    0.100000  6.2515E-05  9.9735E-05  7.2933E-04  8.2912E-04  2.8280E-05
 0  0  0    0.500000 -8.2851E-05 -1.9197E-04  2.6124E-04  2.4860E-04 -8.9450E-05
 1  0  0    0.000000  9.3086E-05  1.4330E-04  2.8676E-04  3.5088E-04 -5.0850E-05
 1  0  0    0.100000 -3.3551E-05 -1.5406E-04 -1.7601E-04 -4.6131E-05 -2.9100E-05
 1  0  0    0.500000 -6.1617E-06  5.2608E-05  4.9320E-05 -3.1750E-05 -1.1037E-04
prec_group 6
 0  0  0    5.1952E-04  4.7818E-04  4.6417E-04
 1  0  0    5.2333E-04  4.6479E-04  5.1680E-04
 0  0  0    0.000000 -2.9467E-07 -4.2415E-05  6.7288E-05  9.6956E-06  2.5774E-05
 0  0  0    0.100000 -5.3640E-05  8.0778E-07  3.7844E-05 -2.5931E-05  4.5183E-05
 0  0  0    0.500000  3.6929E-05  2.5751E-05 -4.9378E-05 -1.2216E-04 -1.3816E-05
 1  0  0    0.000000 -3.7285E-07 -5.1468E-05  3.4996E-05  3.2105E-05 -1.0141E-04
 1  0  0    0.100000 -2.2306E-05  9.2244E-05  2.7587E-04  3.2249E-04  7.3930E-06
 1  0  0    0.500000  4.7308E-05 -2.6141E-05 -5.2537E-05 -8.1937E-05  9.0693E-05


lambda
prec_group 1
 0  0  0    1.3351E-02  1.3352E-02  1.3346E-02
 1  0  0    1.3363E-02  1.3357E-02  1.3348E-02
 0  0  0    0.000000 -3.7773E-06 -3.6773E-06  1.4602E-05  8.8019E-06  1.0000E-06
 0  0  0    0.100000  9.5336E-06  8.3359E-07 -2.8795E-05 -2.2995E-05 -6.3000E-06
 0  0  0    0.500000  8.8805E-06  1.2080E-05  4.6428E-05  4.9128E-05  4.8000E-06
 1  0  0    0.000000 -1.8066E-07 -1.1281E-05 -4.9369E-05 -4.5169E-05 -7.0000E-07
 1  0  0    0.100000 -1.5994E-05 -4.9940E-06 -4.8452E-05 -4.0952E-05  2.0000E-07
 1  0  0    0.500000  1.0446E-05  2.0446E-05  4.0386E-05  4.5486E-05  6.8000E-06
prec_group 2
 0  0  0    3.2630E-02  3.2634E-02  3.2610E-02
 1  0  0    3.2583E-02  3.2536E-02  3.2592E-02
 0  0  0    0.000000 -7.3076E-07 -2.4308E-06 -1.8471E-04 -1.9591E-04 -1.9100E-05
 0  0  0    0.100000 -1.4799E-05 -2.7199E-05 -2.8446E-04 -3.2106E-04 -4.4100E-05
 0  0  0    0.500000  5.4693E-06  3.2169E-05  5.8496E-05 -4.3104E-05 -9.6000E-06
 1  0  0    0.000000  2.5931E-05 -2.8269E-05  4.9472E-05  1.3472E-05 -1.4700E-05
 1  0  0    0.100000 -5.3075E-06  5.2693E-05  1.1515E-04  1.6685E-04  3.8300E-05
 1  0  0    0.500000  4.1312E-05 -3.5688E-05 -1.1192E-04 -1.4442E-04 -1.5200E-05
prec_group 3
 0  0  0    1.2102E-01  1.2093E-01  1.2085E-01
 1  0  0    1.2107E-01  1.2115E-01  1.2103E-01
 0  0  0    0.000000  3.2369E-05  9.3369E-05  1.6588E-04  1.3288E-04  7.2000E-05
 0  0  0    0.100000  3.8260E-05  2.1326E-04  3.2818E-04  4.1018E-04  9.3000E-05
 0  0  0    0.500000  1.0363E-04  2.2063E-04  7.0382E-04  8.6682E-04  1.0100E-04
 1  0  0    0.000000 -3.7203E-05  4.8797E-05 -4.2199E-05  7.9801E-05  1.4000E-05
 1  0  0    0.100000 -2.4334E-05 -3.3385E-07 -3.3470E-04 -3.4270E-04 -1.3100E-04
 1  0  0    0.500000  1.3439E-05 -1.9561E-05  1.0061E-04  1.5461E-04  6.6000E-05
prec_group 4
 0  0  0    3.0527E-01  3.0585E-01  3.0543E-01
 1  0  0    3.0617E-01  3.0561E-01  3.0615E-01
 0  0  0    0.000000  4.8863E-06  3.1789E-04 -1.1531E-03 -8.1913E-04  3.1900E-04
 0  0  0    0.100000 -9.5648E-06 -4.1656E-04 -1.7996E-03 -2.2236E-03 -1.2800E-04
 0  0  0    0.500000  1.7511E-04  1.8111E-04  2.9225E-03  3.4295E-03  1.3400E-04
 1  0  0    0.000000 -3.0705E-04 -2.1405E-04 -1.0026E-03 -8.4961E-04 -8.3000E-05
 1  0  0    0.100000  2.0249E-04  7.1349E-04  1.6709E-03  3.2219E-03  7.3700E-04
 1  0  0    0.500000  2.8997E-04  3.3797E-04 -6.8915E-04 -3.2615E-04  2.0900E-04
prec_group 5
 0  0  0    8.5871E-01  8.5927E-01  8.6108E-01
 1  0  0    8.6258E-01  8.6176E-01  8.6161E-01
 0  0  0    0.000000  7.0739E-05  1.9547E-03 -4.6959E-04  2.4954E-03  1.4660E-03
 0  0  0    0.100000 -1.7411E-04 -4.9111E-04  9.2032E-03  1.2962E-02  2.9550E-03
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 0  0  0    0.500000 -2.2141E-05 -7.1141E-05  2.1511E-03  3.2821E-03 -1.8690E-03
 1  0  0    0.000000  5.0133E-04  4.0033E-04  1.5832E-02  1.8936E-02  1.3020E-03
 1  0  0    0.100000  2.6064E-04  1.5016E-03  5.8038E-03  8.7388E-03  2.3140E-03
 1  0  0    0.500000  4.8898E-04  2.9250E-03 -6.4929E-03 -5.1119E-03  2.5190E-03
prec_group 6
 0  0  0    2.8963E+00  2.8859E+00  2.8834E+00
 1  0  0    2.8984E+00  2.8955E+00  2.8934E+00
 0  0  0    0.000000 -9.8155E-03 -8.9547E-04 -7.5565E-02 -7.6755E-02 -1.6960E-02
 0  0  0    0.100000 -1.3022E-03  3.9178E-03 -3.8789E-02 -2.6069E-02 -1.1640E-02
 0  0  0    0.500000  6.6659E-03  7.0859E-03 -1.1301E-02  7.9853E-04 -6.9000E-04
 1  0  0    0.000000  4.1785E-03  9.8585E-03  3.4797E-02  3.2467E-02 -2.6500E-03
 1  0  0    0.100000  9.9968E-03  4.5168E-03  1.2381E-02  3.0531E-02  2.4000E-04
 1  0  0    0.500000 -1.1414E-03  8.0486E-03  3.0731E-02  4.2391E-02  2.2450E-02


gamma_I135
group 1
 0  0  0    6.4750E-02  6.4743E-02  6.4774E-02
 1  0  0    6.4692E-02  6.4705E-02  6.4714E-02
 0  0  0    0.000000 -2.1729E-06 -1.3673E-05 -1.3225E-05 -7.5625E-05 -1.1600E-05
 0  0  0    0.100000  6.2325E-06  3.5325E-06  8.0737E-05  3.5137E-05 -2.3000E-06
 0  0  0    0.500000  1.5051E-06 -6.6949E-06  5.8460E-06 -4.1954E-05 -1.1200E-05
 1  0  0    0.000000  8.0503E-06  7.3503E-06  5.4197E-05  8.8970E-06 -7.0000E-07
 1  0  0    0.100000  4.7770E-06 -5.4230E-06  5.2532E-06 -3.8647E-05 -5.8000E-06
 1  0  0    0.500000 -3.2587E-07  1.4174E-05  6.6808E-05  2.8808E-05 -2.9000E-06
group 2
 0  0  0    6.2819E-02  6.2824E-02  6.2853E-02
 1  0  0    6.2819E-02  6.2825E-02  6.2855E-02
 0  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0    0.100000  0.0000E+00  0.0000E+00 -3.0399E-08  1.6960E-07  3.0000E-07
 0  0  0    0.500000  1.5754E-07 -4.2461E-08 -1.1590E-06  2.4097E-07  1.4000E-06
 1  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0    0.100000  4.4838E-08 -5.5162E-08 -5.0352E-07 -3.0352E-07  2.0000E-07
 1  0  0    0.500000  2.0238E-07 -9.7623E-08 -2.1661E-06 -3.6606E-07  1.5000E-06


gamma_Xe135
group 1
 0  0  0    1.8926E-03  1.9017E-03  1.9270E-03
 1  0  0    1.9127E-03  1.9153E-03  1.9490E-03
 0  0  0    0.000000  7.6726E-07  4.7773E-06  4.6379E-06  2.6418E-05  4.0600E-06
 0  0  0    0.100000 -2.1972E-06 -1.2472E-06 -2.8118E-05 -1.2148E-05  8.0000E-07
 0  0  0    0.500000 -7.2188E-07  2.5681E-06 -4.3038E-07  1.6720E-05  4.2900E-06
 1  0  0    0.000000 -2.8132E-06 -2.5932E-06 -1.8912E-05 -3.1218E-06  2.4000E-07
 1  0  0    0.100000 -1.6912E-06  1.8688E-06 -2.1042E-06  1.3296E-05  1.9800E-06
 1  0  0    0.500000 -7.0814E-08 -5.2708E-06 -2.6056E-05 -1.2446E-05  7.5000E-07
group 2
 0  0  0    2.5663E-03  2.5832E-03  2.6733E-03
 1  0  0    2.5663E-03  2.5843E-03  2.6802E-03
 0  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0    0.100000  7.2226E-08  3.2226E-08 -4.4214E-07  2.8786E-07  7.5000E-07
 0  0  0    0.500000  5.3879E-07  7.8787E-08 -3.5578E-06  8.6217E-07  4.5700E-06
 1  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0    0.100000  7.6710E-08  2.6710E-08 -5.5500E-07  2.9500E-07  7.1000E-07
 1  0  0    0.500000  6.1659E-07 -1.8341E-07 -5.6342E-06 -4.2064E-09  4.6200E-06


gamma_Xe135m
group 1
 0  0  0    0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0    0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0    0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0    0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0    0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
```

```
 1  0  0    0.100000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.500000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
group 2
 0  0  0    0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.0000E+00   0.0000E+00   0.0000E+00
 0  0  0    0.000000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0  0  0    0.100000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0  0  0    0.500000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.000000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.100000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.500000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00


gamma_Pm149
group 1
 0  0  0    1.2414E-02   1.2408E-02   1.2431E-02
 1  0  0    1.2367E-02   1.2376E-02   1.2381E-02
 0  0  0    0.000000  -1.8482E-06  -1.1348E-05  -1.1082E-05  -6.2682E-05  -9.7000E-06
 0  0  0    0.100000   5.1940E-06   2.9940E-06   6.6747E-05   2.9147E-05  -1.8000E-06
 0  0  0    0.500000   1.2166E-06  -5.5834E-06   4.5996E-06  -3.5000E-05  -9.3000E-06
 1  0  0    0.000000   6.6713E-06   6.1713E-06   4.4953E-05   7.5533E-06  -6.0000E-07
 1  0  0    0.100000   3.9700E-06  -4.4300E-06   4.5712E-06  -3.1729E-05  -4.7000E-06
 1  0  0    0.500000  -1.7805E-07   1.1722E-05   5.5411E-05   2.3911E-05  -2.4000E-06
group 2
 0  0  0    1.0816E-02   1.0819E-02   1.0834E-02
 1  0  0    1.0816E-02   1.0819E-02   1.0835E-02
 0  0  0    0.000000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0  0  0    0.100000   0.0000E+00   0.0000E+00  -1.5199E-08   8.4801E-08   1.0000E-07
 0  0  0    0.500000   6.7864E-08   6.7864E-08  -5.9471E-07   2.0529E-07   8.0000E-07
 1  0  0    0.000000   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1  0  0    0.100000   3.2267E-24   1.1575E-23  -1.5199E-08   8.4801E-08   1.0000E-07
 1  0  0    0.500000   1.1270E-07   1.2702E-08  -1.0830E-06  -1.8303E-07   8.0000E-07


gamma_Sm149
group 1
 0  0  0    1.3288E-12   1.9467E-12   5.2222E-12
 1  0  0    1.3405E-12   1.9638E-12   5.3289E-12
 0  0  0    0.000000   2.9499E-16   2.7550E-15   1.3501E-15   1.5190E-14   2.1800E-15
 0  0  0    0.100000  -2.3659E-15  -1.1759E-15  -1.7956E-14  -9.8563E-16   2.2700E-15
 0  0  0    0.500000  -1.8176E-14   2.3224E-14   1.5055E-13   2.0470E-13   3.9060E-14
 1  0  0    0.000000  -1.6467E-15  -1.6067E-15  -1.2661E-14  -1.8906E-15   1.3000E-16
 1  0  0    0.100000  -4.3660E-15  -4.8604E-16  -1.6633E-14   1.2866E-15  -1.3600E-15
 1  0  0    0.500000  -1.4932E-14  -3.2742E-14  -2.5773E-13  -2.1776E-13  -2.2080E-14
group 2
 0  0  0    1.7102E-12   3.4131E-12   1.2508E-11
 1  0  0    1.7101E-12   3.5253E-12   1.3203E-11
 0  0  0    0.000000   4.4838E-18  -5.5162E-18   1.5199E-18  -8.4801E-18   2.1195E-33
 0  0  0    0.100000   7.4724E-15   3.1424E-15  -4.3615E-14   2.9805E-14   7.5230E-14
 0  0  0    0.500000   5.4263E-14   8.1628E-15  -3.5741E-13   8.9087E-14   4.6180E-13
 1  0  0    0.000000   3.7563E-34   1.3475E-33   0.0000E+00   0.0000E+00   1.0000E-17
 1  0  0    0.100000   7.9736E-15   2.2836E-15  -5.8735E-14   2.7315E-14   7.1750E-14
 1  0  0    0.500000   6.2131E-14  -1.8469E-14  -5.6990E-13  -1.6036E-15   4.6650E-13


sigma_I135_a
group 1
 0  0  0    9.2143E-01   9.2386E-01   9.2676E-01
 1  0  0    8.9848E-01   8.9585E-01   9.0023E-01
 0  0  0    0.000000  -3.9196E-03   2.8954E-03   1.5521E-02   5.8547E-03   3.3290E-03
 0  0  0    0.100000  -5.6450E-03  -2.0970E-03   1.3800E-02   1.5996E-05   2.2600E-03
 0  0  0    0.500000  -3.9557E-03  -9.2272E-04   1.0683E-02  -7.9327E-03   2.6920E-03
 1  0  0    0.000000  -5.3709E-03  -8.4719E-03   2.1089E-02  -5.1651E-03   2.4070E-03
 1  0  0    0.100000  -4.6515E-03   2.1415E-03   1.9458E-02  -7.0221E-03   4.2110E-03
 1  0  0    0.500000  -5.4151E-03  -2.7901E-03   1.0185E-02  -1.3680E-02  -3.5220E-03
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group 2
 0  0  0   4.2401E+01  4.2316E+01  4.2434E+01
 1  0  0   4.3136E+01  4.3219E+01  4.3147E+01
 0  0  0   0.000000 -1.0998E-01  1.9519E-02  5.5221E-01 -9.8891E-02 -1.3152E+00
 0  0  0   0.100000 -5.0005E-02  1.5929E-01  9.7582E-01  3.5472E-01 -1.2530E+00
 0  0  0   0.500000 -8.1874E-02 -8.3774E-02  8.8129E-01  9.7694E-02 -1.4029E+00
 1  0  0   0.000000 -1.7050E-01  7.4299E-02  1.2357E+00  2.0590E-01 -1.2382E+00
 1  0  0   0.100000 -1.0690E-01 -4.2396E-02  3.8178E-01 -7.1682E-01 -1.2928E+00
 1  0  0   0.500000 -1.3247E-01  1.5163E-01  1.1096E+00  5.9697E-02 -1.0926E+00

sigma_Xe135_a
group 1
 0  0  0   1.2252E+02  1.2187E+02  1.2418E+02
 1  0  0   1.1476E+02  1.1426E+02  1.1439E+02
 0  0  0   0.000000 -2.0174E-01  3.6626E-01  5.6140E+00  2.5450E+00 -5.8000E-02
 0  0  0   0.100000 -1.3284E-01  5.2516E-01  3.5954E+00  1.3564E+00  1.3700E+00
 0  0  0   0.500000 -5.4470E-01 -1.6017E+00 -1.2189E+00 -5.5569E+00  2.4500E-01
 1  0  0   0.000000 -6.0329E-01 -1.6613E+00  4.1882E+00 -1.5468E+00  1.1410E+00
 1  0  0   0.100000 -5.3239E-01  1.0606E+00  6.2481E+00  9.9912E-01  9.1000E-01
 1  0  0   0.500000 -5.4849E-01  5.8851E-01  6.8465E+00  2.0805E+00  5.8600E-01
group 2
 0  0  0   1.6742E+06  1.6671E+06  1.6742E+06
 1  0  0   1.6787E+06  1.6826E+06  1.6792E+06
 0  0  0   0.000000 -4.1239E+03  8.9610E+02  3.3828E+04 -7.2618E+03 -4.4900E+04
 0  0  0   0.100000 -1.2445E+03  1.0976E+04  6.5737E+04  2.8867E+04 -3.8940E+04
 0  0  0   0.500000 -4.3038E+03 -4.0438E+03  3.9020E+04 -7.5902E+03 -4.9950E+04
 1  0  0   0.000000 -7.5321E+03  2.1679E+03  6.1398E+04  1.5828E+02 -4.2330E+04
 1  0  0   0.100000 -5.4983E+03 -3.5883E+03  2.4308E+04 -3.8812E+04 -4.6250E+04
 1  0  0   0.500000 -5.6056E+03  6.1244E+03  5.7284E+04 -5.5258E+03 -4.0740E+04

sigma_Xe135m_a
group 1
 0  0  0   0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
group 2
 0  0  0   0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0  0  0   0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.000000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.100000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 1  0  0   0.500000  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00

sigma_Pm149_a
group 1
 0  0  0   4.4280E+01  4.7661E+01  4.6981E+01
 1  0  0   4.4001E+01  4.6715E+01  4.6331E+01
 0  0  0   0.000000 -1.1699E-01  2.0115E-02  4.0720E-01  4.0901E-02  3.2820E-01
 0  0  0   0.100000 -1.3937E-01 -1.0447E+00 -4.0060E+00 -5.0481E+00 -2.2767E+00
 0  0  0   0.500000 -5.4419E-01 -1.7219E-01  2.4708E+00  1.4922E+00 -3.2190E-01
 1  0  0   0.000000 -2.3774E-01 -1.2434E-01  1.3822E+00  5.4650E-01  2.4340E-01
 1  0  0   0.100000 -4.7931E-01 -2.1841E-01  1.6711E+00  1.4240E-01 -4.4120E-01
 1  0  0   0.500000 -9.5076E-01 -3.0056E-01  1.3676E+00  7.0261E-01  9.6060E-01
group 2
 0  0  0   7.4028E+02  7.4113E+02  7.4339E+02
```

```
 1  0  0   7.6192E+02  7.5740E+02  7.5573E+02
 0  0  0   0.000000 -1.8914E+00  3.8959E-01  9.9522E+00 -1.3638E+00 -2.2832E+01
 0  0  0   0.100000 -8.4595E-01  2.7510E+00  1.6933E+01  6.0983E+00 -2.1881E+01
 0  0  0   0.500000 -1.4384E+00 -1.4664E+00  1.5414E+01  1.7215E+00 -2.4519E+01
 1  0  0   0.000000 -3.0331E+00  1.0479E+00  2.0888E+01  2.4317E+00 -2.1922E+01
 1  0  0   0.100000 -1.8629E+00 -6.8987E-01  6.6128E+00 -1.2552E+01 -2.2594E+01
 1  0  0   0.500000 -2.2945E+00  2.6655E+00  1.9392E+01  1.0348E+00 -1.9062E+01


sigma_Sm149_a
group 1
 0  0  0   1.0266E+02  1.0136E+02  1.0302E+02
 1  0  0   9.9333E+01  9.8062E+01  9.8557E+01
 0  0  0   0.000000 -1.9079E-01 -2.1479E-01 -8.3355E-01 -3.5982E+00 -1.6800E-01
 0  0  0   0.100000 -1.6631E-03  1.1523E+00  6.3644E+00  5.3304E+00  9.5400E-01
 0  0  0   0.500000 -4.3031E-01 -8.3431E-01 -5.7723E+00 -9.5992E+00 -4.0100E-01
 1  0  0   0.000000  2.8306E-01 -2.4060E+00 -4.0301E+00 -8.2376E+00 -4.4040E-01
 1  0  0   0.100000 -5.9252E-01  5.4676E-02 -3.4155E+00 -5.4412E+00  5.1200E-01
 1  0  0   0.500000 -1.0985E-01 -4.5545E-01  4.1440E+00  3.3437E-01 -7.3360E-01
group 2
 0  0  0   4.5287E+04  4.5138E+04  4.5283E+04
 1  0  0   4.6126E+04  4.5958E+04  4.6097E+04
 0  0  0   0.000000  5.1716E+01  1.9016E+01  6.1906E+02 -1.5434E+02  3.2010E+02
 0  0  0   0.100000  1.4004E+02  4.0514E+02  1.9192E+03  1.3666E+03  5.7940E+02
 0  0  0   0.500000  3.3831E+01 -1.2517E+02  2.5604E+02 -6.4406E+02  1.6450E+02
 1  0  0   0.000000 -3.3186E+01  2.8114E+01  1.4125E+03  1.2857E+02  3.1170E+02
 1  0  0   0.100000 -3.1673E+01 -1.2737E+02 -1.0649E+02 -1.4105E+03  1.9400E+02
 1  0  0   0.500000 -8.2678E+00  7.2832E+01  1.0134E+03 -4.2485E+02  2.4390E+02
```