Linked list specifications for DONJON

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CONTENTS

1. INTRODUCTION

DONJON is a computer code intended to compute the neutron flux in a nuclear reactor and to simulate operating reactor. DONJON[1] is built around the GAN generalized driver[2] and share the same modular approach as DRAGON[3].

This driver allows the code to be a module collection. Modules communicate with each other through data structures. These structures can be sequential `ASCII` files, `XSM` files or dynamical structures called linked lists.

A linked list is a hierarchical structure composed of nodes representing records and directories. At each directory level, all nodes are chained to form a list and each directory is linked with its first daughter and its mother.

As modules are created for specific use, linked lists they use must have a fixed structure. This document describes the specifications of these linked lists.

Each specification begins with a "signature" which is a character*12 identification for the type of specification (e.g., `L_GEOM`, `L_MACROLIB`, etc.). The signature is always named `'SIGNATURE'` and is written in an integer array (dimension=3) containing a twelve digit character expression such as `'L_GEOM'`, `'L_MACROLIB'`, etc. A leading star ($\star$) designates an optional record or directory.

Some specifications also contain links to the parent linked list or XSM file in the form of a character*12 variable containing the user-defined name of the parent. The link is named `'LINK.GEOM'`, `'LINK.MACRO'`, `'LINK.TRACK'`, etc., depending on the signature of the parent.

2. L_GEOM specification

The L_GEOM specification is used to store a geometry with its boundary conditions.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_GEOM'.
'STATE '	Record containing the state vector of the geometry. • STATE(1) : type of geometry: =1 homogeneous; =2 Cartesian 1-D; =3 tube 1-D; =4 sphere 1-D; =5 Cartesian 2-D; =6 tube 2-D; =7 Cartesian 3-D; =8 hexagonal 2-D; =9 hexagonal 3-D. • STATE(2) : the number of tubes for type 3, 4 and 6 geometries (before mesh-splitting). • STATE(3) : the number of $X-$directed mesh intervals or the number of hexagons (including the virtual hexagons) in the $X-Y$ plane for type 2, 5, 7, 8 and 9 geometries (before mesh-splitting). • STATE(4) : the number of $Y-$directed mesh intervals for type 5 and 7 geometries (before mesh-splitting). • STATE(5) : the number of $Z-$directed mesh intervals for type 6, 7 and 9 geometries (before mesh-splitting). • STATE(6) : the number of regions (before mesh-splitting). • STATE(7) : the maximum number of material mixtures (i.e., MAX(MIX(I))). • STATE(8) : Number of radii in the cylindrical correction for type 5 or 7 geometries. =0 for no cylindrical correction. • STATE(11) : =1 if mesh-splitting is present and =0 otherwise. • STATE(9), STATE(10), STATE(12) and STATE(13) are set to zero. Dimension: 13
'MIX '	Record containing the material mixture indices per region. MIX(I) is set to zero in virtual regions I (i.e., in regions outside the calculation domain). Dimension: STATE(6)
⋆ 'RADIUS '	Record containing the radius for type 3, 4 and 6 geometries (before mesh-splitting). MESHR(1)=0.0 Dimension: STATE(2)+1

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Records

⋆ 'MESHX ' Record containing the $X-$directed mesh position for type 2, 5 and 7 geometries (before mesh-splitting). Dimension: STATE(3)+1

⋆ 'MESHY ' Record containing the $Y-$directed mesh position for type 5 and 7 geometries (before mesh-splitting). Dimension: STATE(4)+1

⋆ 'MESHZ ' Record containing the $Z-$directed mesh position for type 6, 7 and 9 geometries (before mesh-splitting). Dimension: STATE(5)+1

⋆ 'SIDE ' Side of a hexagon for type 8 and 9 geometries. Dimension: 1

⋆ 'XRO ' Record containing the coordinate of the Z axis from which the cylindrical correction is applied to Cartesian geometries. This data is provided if and only if NCODE record contains a type 8 (CYLI) boundary conditions in the $X-Y$ plane. Dimension: STATE(8)

⋆ 'RRO ' Record containing the radius of the real cylindrical boundary. This data is provided if and only if NCODE record contains a type 8 (CYLI) boundary conditions in the $X-Y$ plane. Dimension: STATE(8)

⋆ 'ANG ' Record containing the angle (in radian) of the cylindrical notch. $ang(\text{ir}) = \frac{\pi}{2}$ by default (i.e. the correction is applied at every angle). This data is provided if and only if NCODE record contains a type 8 (CYLI) boundary conditions in the $X-Y$ plane. Dimension: STATE(8)

⋆ 'SPLITR ' Record containing the radius mesh splitting integers for type 3, 4 and 6 geometries. A negative value permits a splitting into equal sub-volumes; a positive value permits a splitting into equal sub-radius spacings. Dimension: STATE(2)

⋆ 'SPLITX ' Record containing the $X-$directed mesh splitting integers for type 2, 5 and 7 geometries. Dimension: STATE(3)

⋆ 'SPLITY ' Record containing the $Y-$directed mesh splitting integers for type 5 and 7 geometries. Dimension: STATE(4)

⋆ 'SPLITZ ' Record containing the $Z-$directed mesh splitting integers for type 6, 7 and 9 geometries. Dimension: STATE(5)

⋆ 'IHEX ' Type of hexagonal symmetry for type 8 and 9 geometries. =1 S30; =2 SA60; =3 SB60; =4 S90; =5 R120; =6 R180; =7 SA180; =8 SB180; =9 COMPLETE. Dimension: 1

'NCODE ' Record containing the types of boundary conditions on each surface. =0 side not used; =1 VOID; =2 REFL; =3 DIAG; =4 TRAN; =5 SYME; =6 ALBE; =7 ZERO; =8 CYLI. Dimension: 6

'ZCODE ' Record containing the albedo value (real number) on each surface. Dimension: 6

'ICODE ' Record containing the albedo index on each surface. ZCODE(I) is used if ICODE(I)=0. Dimension: 6

3. L_INDEX specification

The L_INDEX specification is used to store material mixture indices. It is created from a L_GEOM file.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_INDEX'.
'SIZE '	Record containing the specific parameters. • SIZE(1) : Initial maximum number of material mixtures. • SIZE(2) : Extended maximum number of material mixtures. Dimension: 2
'MIX '	Record containing the material mixture indices per region and for device types. MIX(I) is set to zero in virtual regions I (i.e., in regions outside the calculation domain). The material mixture indices for fuel regions are negative while for reflector and devices they are positive. Dimension: STATE(6) + STATUS(2)∗2

4. L_MACROLIB specification

The L_MACROLIB specification is used to store mixture-dependent nuclear properties, including diffusion coefficients, reciprocal velocities and macroscopic cross sections. The L_MACROLIB specification can be extended to store the effective multiplication factor, mixture volumes and mixture-dependent integrated fluxes. In general, an extended L_MACROLIB is obtained by accessing informations stored in an L_COMPO linked list provided by DRAGON calculations.[3]

The scattering cross sections are stored as shown in Fig. 1.

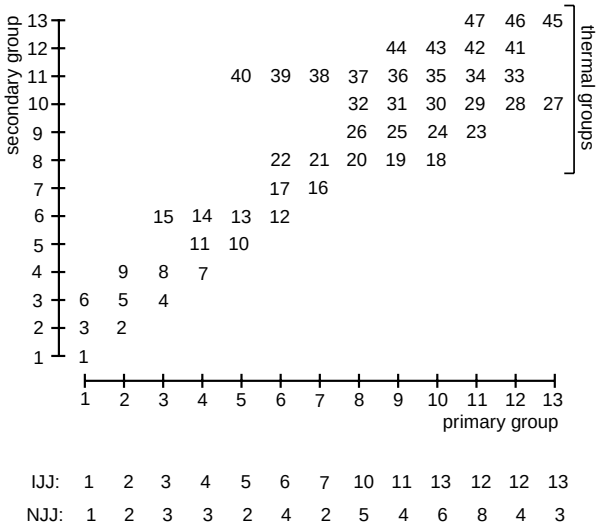

Figure 1: Numbering of scattering elements in 'SCAT' matrices.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_MACROLIB'.
'IDATAXS '	Record containing the macroscopic library parameters: IDATAXS(1) is the number of energy groups; IDATAXS(2) is the number of material mixtures for which data was either initialized to zero or read; IDATAXS(3) is the order of anisotropy of the scattering cross sections (IDATAXS(3)=1 for isotropic scattering in the laboratory system). IDATAXS(4) is equal to 1 to indicate the presence of a unique fissile isotope. IDATAXS(5) and IDATAXS(6) are not used. IDATAXS(7) is the number of precursor groups for delayed neutrons. Dimension: 7
⋆ 'ALBEDO '	Surface ordered physical albedos. The albedos are assumed to be energy independent. Dimension: NALBD.
⋆ 'VOLUME '	Mixture ordered volumes. This information is given in an extended MACROLIB only. Dimension: IDATAXS(2).
⋆ 'K-EFFECTIVE '	Effective multiplication factor correspond to the MACROLIB. This information is given in an extended MACROLIB only. Dimension: 1.

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Records

⋆ 'ENERGY'	$E(g)$: Group energy limits in EV. Group g is defined as $E(g) < E \leq E(g-1)$. Dimension: IDATAXS(1)+ 1

Directories

'GROUP'//*HGROUP*	Group sub-directory containing mixture-ordered macroscopic cross sections or diffusion coefficients. *HGROUP* is a seven digit character expression composed using "WRITE(HGROUP,'(I3,1H/,I3)') jg,ngroup" where *jg* is a three digit suffix with a value corresponding to the energy group under consideration and where *ngroup* is a three digit suffix with a value equal to IDATAXS(1).
⋆ 'STEP'//*HSTEP*	Perturbation sub-directory containing embedded 'GROUP'//*HGROUP* directories. *HSTEP* is an eight digit character expression composed using "WRITE(HSTEP,'(I8)') istep" where *istep* is the index associated with the perturbation set of cross sections and diffusion coefficients.

'GROUP'//*HGROUP*

Records

'DIFFX '	Mixture ordered $X-$directed diffusion coefficients. Blocks DIFFY and DIFFZ are taken equal to DIFFX in cases where they are not explicitly given in L_COMPO linked lists. Dimension: IDATAXS(2).
⋆ 'DIFFY '	Mixture ordered $Y-$directed diffusion coefficients. Dimension: IDATAXS(2).
⋆ 'DIFFZ '	Mixture ordered $Z-$directed diffusion coefficients. Dimension: IDATAXS(2).
'TOTAL '	Mixture ordered macroscopic total cross sections. Dimension: IDATAXS(2).
'SCAT 0 '	$\Sigma_{\text{scat0}}(jg \leftarrow g, matnum)$: Array containing macroscopic scattering cross sections for an isotropic collision in the laboratory system. Index g is varied first. Dimension: L_{scat0} with $$L_{\text{scat0}} = \sum_{m=1}^{M} N_{\text{scat0}}(jg, m)$$ where M=IDATAXS(2).
'NJJ 0 '	$N_{\text{scat0}}(jg, matnum)$: Mixture ordered number of primary energy contributions for each secondary energy of the Σ_{scat0} matrix. Dimension: IDATAXS(2).
'IJJ 0 '	$I_{\text{scat0}}(jg, matnum)$: Lowest thermal primary energy contributions for each secondary energy of the Σ_{scat0} matrix. $I_{\text{scat0}}(jg, matnum) = jg$ if there is no up-scattering. Dimension: IDATAXS(2).
'IPOS 0 '	Position in the SCAT 0 array of the first cross section value corresponding to each mixture. Dimension: IDATAXS(2).

'GROUP'//*HGROUP*

Records

	‘SIGW 0 ’	$\Sigma_{\text{scat0}}(jg \leftarrow jg, matnum)$: Array containing macroscopic within group scattering cross sections for an isotropic collision in the laboratory system. Dimension: IDATAXS(2).
⋆	‘SCAT 1 ’	$\Sigma_{\text{scat1}}(jg \leftarrow g)$: Array containing macroscopic scattering cross sections for a linearly anisotropic collision in the laboratory system. Index g is varied first. This optional information is used for reactor calculations based on transport theory (P_n or S_n type of calculations) and is given if and only if IDATAXS(3)≥ 2. The $2l+1=3$ factor is *not* included in the numerator. Dimension: L_{scat1} with $$L_{\text{scat1}} = \sum_{m=1}^{M} N_{\text{scat1}}(jg, m)$$ where M=IDATAXS(2).
⋆	‘NJJ 1 ’	$N_{\text{scat1}}(jg, matnum)$: Mixture ordered number of primary energy contributions for each secondary energy of the Σ_{scat1} matrix. Dimension: IDATAXS(2).
⋆	‘IJJ 1 ’	$I_{\text{scat1}}(jg, matnum)$: Lowest thermal primary energy contributions for each secondary energy of the Σ_{scat1} matrix. $I_{\text{scat1}}(jg, matnum) = jg$ if there is no up-scattering. Dimension: IDATAXS(2).
⋆	‘IPOS 1 ’	Position in the SCAT 1 array of the first cross section value corresponding to each mixture. Dimension: IDATAXS(2).
⋆	‘SIGW 1 ’	$\Sigma_{\text{scat1}}(jg \leftarrow jg, matnum)$: Array containing macroscopic within group scattering cross sections for a linearly anisotropic collision in the laboratory system. Dimension: IDATAXS(2).
⋆	‘NFTOT ’	Mixture ordered macroscopic fission cross sections. Dimension: IDATAXS(2).
⋆	‘NUSIGF ’	Mixture ordered $\nu(jg, matnum) \times \Sigma_{\text{f}}(jg, matnum)$ where $\nu(jg, matnum)$ is the number of neutrons per fission and $\Sigma_{\text{f}}(jg, matnum)$ is the macroscopic fission cross section. Dimension: IDATAXS(2).
⋆	‘H-FACTORS ’	Mixture ordered macroscopic H-factors (i.e. product of the macroscopic fission cross section times the energy recovered by fission). Dimension: IDATAXS(2).
⋆	‘CHI ’	Mixture ordered fission spectrum. Dimension: IDATAXS(2).
⋆	‘CHDL’//HPREC	Mixture ordered delayed neutron fission spectrum. HPREC is a three character expression composed using “WRITE(HPREC,’(I3)’) i” where i indexes the precursor group. Dimension: IDATAXS(2).
⋆	‘OVERV ’	Average reciprocal velocities ($1/v_g$ in s cm^{-1}). Dimension: IDATAXS(2).
⋆	‘FIXE ’	Mixture ordered fixed neutron sources. Dimension: IDATAXS(2).
⋆	‘FLUX-INTG ’	Mixture ordered integrated fluxes. This information is given in an extended MACROLIB only. Dimension: IDATAXS(2).

5. L_TABLE specification

The L_TABLE specification is used to store burnup-dependent nuclear properties, including diffusion coefficients, reciprocal velocities and macroscopic cross sections. For each nuclear property, first derivative with respect to burnup can be also stored for further interpolation.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_TABLE'.

Directories

nam_fuel	Material table sub-directory containing burnup-dependent fuel properties fo a specific type (Ex: Depleted, Natural, DUPIC ...)

nam_fuel

Records

'IDIM '	Record containing the macroscopic library parameters: IDIM(1) is the number of energy groups; IDIM(2) is the number of burnup or irradiation steps; IDIM(3) is the order of anisotropy of the scattering cross sections (IDIM(3)=1 for isotropic scattering in the laboratory system). IDIM(4) is the number of coefficients for each property (If = 2, derivatives are included, if = 1 no). Dimension: 4
'VOLUME '	Cell volume from L_COMPO informations. Dimension: 1.
'ENERGY'	$E(g)$: Group energy limits in EV. Group g is defined as $E(g) < E \leq E(g-1)$. Dimension: IDIM(1)+ 1
⋆ 'BURNUP '	Record containing the values of the burnup in MW day/tonne of heavy initial elements corresponding to each burnup step. Dimension: IDIM(2).
⋆ 'N/KB '	Record containing the values of the neutron exposure in neutron/kb corresponding to each burnup step. Dimension: IDIM(2).

nam_fuel

Records

'DIFFX '	Burnup ordered $X-$directed diffusion coefficients and derivatives with respect to burnup. Blocks DIFFY and DIFFZ are taken equal to DIFFX. Dimension: DIFFX(IDIM(2),IDIM(1),IDIM(4)).
'DIFFY '	Burnup ordered $Y-$directed diffusion coefficients and derivatives with respect to burnup. Dimension: DIFFY (IDIM(2),IDIM(1),IDIM(4)).
'DIFFZ '	Burnup ordered $Z-$directed diffusion coefficients and derivatives with respect to burnup. Dimension: DIFFZ (IDIM(2),IDIM(1),IDIM(4)).
'TOTAL '	Burnup ordered macroscopic total cross sections and derivatives with respect to burnup. Dimension: TOTAL (IDIM(2),IDIM(1),IDIM(4)).
'SCAT '	Array containing burnup ordered macroscopic scattering cross sections and derivatives with respect to burnup. Dimension: SCAT (IDIM(2),IDIM(3),IDIM(1),IDIM(1),IDIM(4)).
'NFTOT '	Burnup ordered macroscopic fission cross sections and derivatives with respect to burnup. Dimension: NFTOT (IDIM(2),IDIM(1),IDIM(4)).
'NUSIGF '	Burnup ordered $\nu(jg, matnum) \times \Sigma_{\mathrm{f}}(jg, matnum)$ where $\nu(jg, matnum)$ is the number of neutrons per fission and $\Sigma_{\mathrm{f}}(jg, matnum)$ is the macroscopic fission cross section and derivatives with respect to burnup. Dimension: NUSIGF (IDIM(2),IDIM(1),IDIM(4)).
'H-FACTORS '	Burnup ordered macroscopic H-factors (i.e. product of the macroscopic fission cross section times the energy recovered by fission) and derivatives with respect to burnup. Dimension: H-FACTORS (IDIM(2),IDIM(1),IDIM(4)).
'CHI '	Mixture ordered fission spectrum and derivatives with respect to burnup. Dimension: CHI (IDIM(2),IDIM(1),IDIM(4)).
'OVERV '	Average reciprocal velocities ($1/v_g$ in s cm^{-1}) and derivatives with respect to burnup. Dimension: OVERV (IDIM(2),IDIM(1),IDIM(4)).
'FLUX-INTG '	Mixture ordered integrated fluxes and derivatives with respect to burnup. Dimension: FLUX-INTG(IDIM(2),IDIM(1),IDIM(4)).

6. L_COMPO specification

The COMPO interface format defines a logical organization for efficiently storing the nuclear data to be used in a reactor code. The COMPO specification is intended to store *all* the nuclear data, produced in a single run of a lattice code (Powderpuff, WIMS, DRAGON, etc.), that is useful in reactor calculations including fuel management and space-time kinetics. The COMPO format is similar to the format used by the code CRONOS 2.1 to input nuclear data of a pressurized water reactor.[4] A few improvements have been made to the original specifications to make it suitable for both PWR and CANDU reactors.

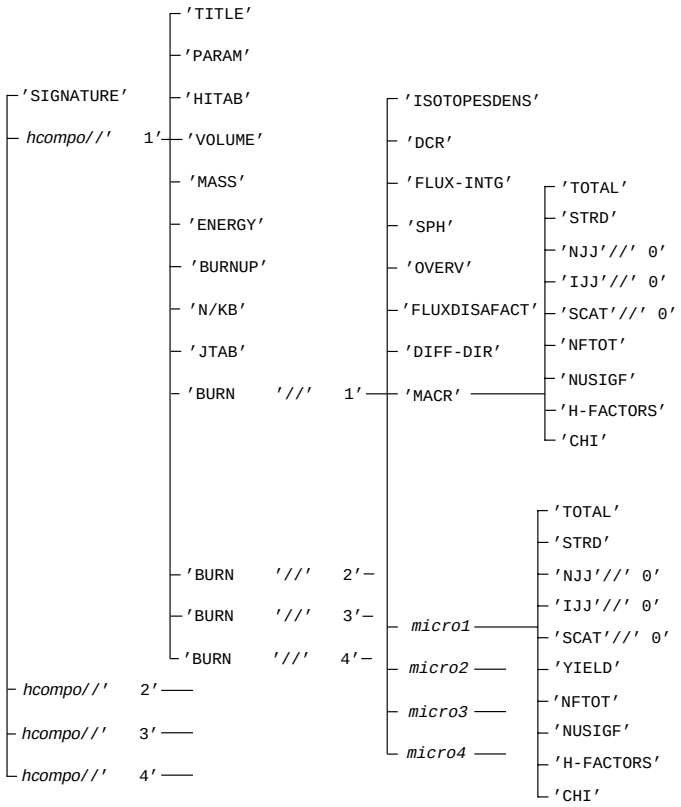

Figure 2: Hierarchical structure of a L_COMPO specification.

A COMPO is specified to contain a set of material mixture sub-directories located on the root directory (i.e., each sub-directory contains a homogeneous material), as shown in Fig. Figure 2. A typical lattice calculation for a CANDU reactor generally produce a single material mixture sub-directory, since the cross sections are homogenized over the entire cell. Each material mixture sub-directory contains burnup-independant data and a set of burnup sub-directories. Finally, each burnup sub-directory contains a "MACR" sub-directory for describing macroscopic cross sections and a set of isotopic sub-directories for describing extracted isotopes. Isotopic sub-directories are useful to store microscopic cross-section data for isotopes, such as the xenon or boron, that need to be described in the reactor calculation. Any macroscopic cross section $\Sigma_{\mathrm{x}}(g)$ for reaction x is given by:

$$\Sigma_{\mathrm{x}}(g) = \Sigma_{\mathrm{x}}^{\mathrm{MACR}}(g) + \sum_i N_i \; \sigma_{\mathrm{x},i}(g) \tag{1}$$

where $\Sigma_{\mathrm{x}}^{\mathrm{MACR}}(g)$ is a macroscopic cross section as written on the "MACR" sub-directory, N_i is the number density for an extracted isotope and $\sigma_{\mathrm{x},i}(g)$ is its microscopic cross section as written on the isotopic sub-directory.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_COMPO'.

Directories

hcompo//hiord	Material mixture sub-directory containing a homogeneous material. *hcompo* is an ASCII name with a maximum of 8 characters and *hiord* is a four digit suffix with value ' 1', ' 2', ' 3', etc., indicating the material mixture index.

hcompo//hiord

Records

'TITLE '	Character*72 identification field for the material mixture.
'PARAM '	Record containing four integer numbers: PARAM(1) is the number of energy groups; PARAM(2) is the number of isotopic sub-directories (1 plus the number of extracted isotopes); PARAM(3) is the number of Legendre orders for scattering cross sections (generally equal to 1 in diffusion theory) and PARAM(4) is the number of burnup steps.
'HITAB '	Record containing the character*12 names of the isotopic sub-directories. HITAB(1) is always equal to 'MACR' and is the name of the isotopic sub-directory containing the residual macroscopic cross sections. Dimension: PARAM(2).
'VOLUME '	Volume associated to the material mixture. Dimension: 1.
'MASS '	Record containing W, a single real number equal to the initial mass of heavy elements. This number is defined in such a way that $$\frac{1}{W}\sum_g F(g)\left[H^{\mathrm{MACR}}(g)+\sum_i N_i h_i(g)\right]=P$$ where i is an extracted isotope index, N_i is the number density for this isotope, g is an energy group index, $H^{\mathrm{MACR}}(g)$ is the residual H-factor, $h_i(g)$ is an isotopic H-factor, $F(g)$ is the integrated neutron flux and P is the power in MW/tonne of heavy initial elements.
'ENERGY'	$E(g)$: Group energy limits in EV. Group g is defined as $E(g) < E \leq E(g-1)$. Dimension: $G+1$ where $G =$PARAM(1) is the number of energy groups.

hcompo//hiord

Records

`'BURNUP '`	Record containing the values of the burnup in MW day/tonne of heavy initial elements corresponding to each burnup step. Dimension: `PARAM(4)`.
`'N/KB '`	Record containing the values of the neutron exposure in neutron/kb corresponding to each burnup step. Dimension: `PARAM(4)`.
`'JTAB '`	Record containing the type of data stored in each isotopic sub-directory. `JTAB(i)` is equal to 1 for a fissionable isotope (i.e., an isotope with fission cross sections); equal to 2 for a fission product (i.e., an isotope with production yields and radioactive decay) and equal to zero otherwise. Dimension: `PARAM(2)`.

Directories

`'BURN '`*//hiord*	Burnup sub-directory containing data at a specific burnup step. *hiord* is a four digit suffix with value `' 1'`, `' 2'`, `' 3'`, etc., indicating the burnup step index.

`'BURN '`*//hiord*

Records

`'ISOTOPESDENS'`	Record containing N_i, the number densities (in 10^{24} particles per cm^3) associated with each isotopic sub-directory. N_1 is always equal to 1.0, since the first isotopic sub-directory contains macroscopic cross sections. Dimension: `PARAM(2)`.
`'DCR '`	Radioactive decay constant in s^{-1} for each isotopic sub-directory. `DCR(i)` is always equal to 0.0 for isotopic sub-directories with a `JTAB(i)` value other than 2. Dimension: `PARAM(2)`.
`'FLUX-INTG '`	$F(g)$: Integrated neutron flux in each group. The integrated flux is defined in such a way that a reaction rate $R_{\rm x}(g)$ in the lattice code is defined by the relation $$R_{\rm x}(g) = \left[\Sigma_{\rm x}^{\rm MACR}(g) + \sum_i N_i\ \sigma_{{\rm x},i}(g)\right] F(g)$$ Dimension: `PARAM(1)`.
⋆ `'SPH '`	SPH factors in each group. By default, these factors are set equal to 1.0. In cases where these factors are not 1.0, all the cross sections and integrated fluxes stored on the COMPO file are SPH-corrected. Dimension: `PARAM(1)`.
`'OVERV '`	Average reciprocal velocities in each group ($1/v_g$ in s cm^{-1}). Dimension: `PARAM(1)`.

'BURN '//*hiord*

Records

'FLUXDISAFACT' Flux disadvantage factor in each group, defined as the average flux in the fuel divided by the average flux in the cell. Dimension: PARAM(1).

⋆ 'DIFF-DIR ' Streaming directional factors $f_{\rm x}(g)$, $f_{\rm y}(g)$ and $f_{\rm z}(g)$ used to multiply the diffusions coefficients. By default, these factors are set equal to 1.0. For example, an X-oriented diffusion coefficient is given by the formula

$$D_{\rm x}(g) = \frac{f_{\rm x}(g)}{3\left[\Sigma_{\rm strd}^{\rm MACR}(g) + \sum_i N_i\ \sigma_{{\rm strd},i}(g)\right]}$$

Dimension: (PARAM(1),3).

Directories

'MACR' Isotopic sub-directory containing the macroscopic cross sections. This data *should* not include the contributions of the extracted isotopes contained in the other isotopic sub-directories.

⋆ *micro* Isotopic sub-directory containing the microscopic cross sections of an extracted isotope. When *micro* directories are present, their contribution is substracted from the 'MACR' directory, so that a macroscopic cross section $\Sigma_{\rm x}(g)$ for reaction x is given by Eq. (1).

'MACR'

Records

'TOTAL ' Macroscopic total cross section. The transport correction may be included if PARAM(3)=1. Dimension: PARAM(1).

'STRD ' $\Sigma_{\rm strd}^{\rm MACR}(g)$: Macroscopic strd cross section used to compute a diffusion coefficient. A strd cross section is defined in such a way that a diffusion coefficient can be computed from the formula

$$D(g) = \frac{1}{3\Sigma_{\rm strd}^{\rm MACR}(g)}$$

in cases where no extracted isotopes are present. Dimension: PARAM(1).

'MACR'

Records

'SCAT 0 ' $\Sigma^{\mathrm{MACR}}_{\mathrm{scat0}}(h \leftarrow g)$: Matrix containing macroscopic diffusion cross sections for an isotropic collision in the laboratory system. The transport correction may be included if PARAM(3)=1. Dimension: L_{scat0} with

$$L^{\mathrm{MACR}}_{\mathrm{scat0}} = \sum_{g=1}^{G} N^{\mathrm{MACR}}_{\mathrm{scat0}}(g)$$

where G=PARAM(1)

'NJJ 0 ' $N^{\mathrm{MACR}}_{\mathrm{scat0}}(g)$: Number of primary energy group contributions for each secondary energy group of the $\Sigma^{\mathrm{MACR}}_{\mathrm{scat0}}$ matrix. Dimension: PARAM(1).

'IJJ 0 ' $I^{\mathrm{MACR}}_{\mathrm{scat0}}(g)$: Most thermal primary energy group contributions for each secondary energy group of the $\Sigma^{\mathrm{MACR}}_{\mathrm{scat0}}$ matrix. $I^{\mathrm{MACR}}_{\mathrm{scat0}}(g) = g$ if there is no up-scattering. Dimension: PARAM(1).

⋆ 'SCAT 1 ' $\Sigma^{\mathrm{MACR}}_{\mathrm{scat1}}(h \leftarrow g)$: Matrix containing macroscopic diffusion cross sections for a linearly anisotropic collision in the laboratory system. This optional information is used for reactor calculations based on transport theory (P_n or S_n type of calculations) and is given if and only if PARAM(3)$\geq$ 2. The $2l+1 = 3$ factor is *not* included in the numerator. Dimension: $L^{\mathrm{MACR}}_{\mathrm{scat1}}$ with

$$L^{\mathrm{MACR}}_{\mathrm{scat1}} = \sum_{g=1}^{G} N^{\mathrm{MACR}}_{\mathrm{scat1}}(g)$$

⋆ 'NJJ 1 ' $N^{\mathrm{MACR}}_{\mathrm{scat1}}(g)$: Number of primary energy group contributions for each secondary energy group of the $\Sigma^{\mathrm{MACR}}_{\mathrm{scat1}}$ matrix. Dimension: PARAM(1).

⋆ 'IJJ 1 ' $I^{\mathrm{MACR}}_{\mathrm{scat1}}(g)$: Most thermal primary energy group contributions for each secondary energy group of the Σ_{scat1} matrix. $I^{\mathrm{MACR}}_{\mathrm{scat1}}(g) = g$ if there is no up-scattering. Dimension: PARAM(1).

⋆ 'NFTOT ' $\Sigma^{\mathrm{MACR}}_{\mathrm{f}}(g)$: Macroscopic fission cross section. This information is given if and only if JTAB(i)=1. Dimension: PARAM(1).

⋆ 'NUSIGF ' $\nu(g)\Sigma^{\mathrm{MACR}}_{\mathrm{f}}(g)$ where $\nu(g)$ is the number of neutrons per fission and $\Sigma^{\mathrm{MACR}}_{\mathrm{f}}(g)$ is the macroscopic fission cross section. This information is given if and only if JTAB(i)=1. Dimension: PARAM(1).

⋆ 'H-FACTORS ' $H^{\mathrm{MACR}}(g)$: Macroscopic H-factor (i.e. product of the macroscopic fission cross-section times the energy recovered by fission). This information is given if and only if JTAB(i)=1. Dimension: PARAM(1).

⋆ 'CHI ' $\chi^{\mathrm{MACR}}(g)$: Fission spectrum. This information is given if and only if JTAB(i)=1. Dimension: PARAM(1).

micro

Records

`'TOTAL '` Microscopic total cross section. The transport correction may be included if `PARAM(3)`=1. Dimension: `PARAM(1)`.

`'STRD '` $\sigma_{\text{strd},i}(g)$: Microscopic strd cross section used to compute a diffusion coefficient. A microscopic strd cross section is defined in such a way that a diffusion coefficient can be computed from the formula

$$D(g) = \frac{1}{3\left[\Sigma_{\text{strd}}^{\text{MACR}}(g) + \sum_i N_i\ \sigma_{\text{strd},i}(g)\right]}$$

in cases where extracted isotopes are present. Dimension: `PARAM(1)`.

`'SCAT 0 '` $\sigma_{\text{scat0}}(h \leftarrow g)$: Matrix containing microscopic diffusion cross sections for an isotropic collision in the laboratory system. The transport correction may be included if `PARAM(3)`=1. Dimension: L_{scat0} with

$$L_{\text{scat0}} = \sum_{g=1}^{G} N_{\text{scat0}}(g)$$

where G=`PARAM(1)`

`'NJJ 0 '` $N_{\text{scat0}}(g)$: Number of primary energy group contributions for each secondary energy group of the σ_{scat0} matrix. Dimension: `PARAM(1)`.

`'IJJ 0 '` $I_{\text{scat0}}(g)$: Most thermal primary energy group contributions for each secondary energy group of the σ_{scat0} matrix. $I_{\text{scat0}}(g) = g$ if there is no up-scattering. Dimension: `PARAM(1)`.

⋆ `'SCAT 1 '` $\sigma_{\text{scat1}}(h \leftarrow g)$: Matrix containing microscopic diffusion cross sections for a linearly anisotropic collision in the laboratory system. This optional information is used for reactor calculations based on transport theory (P_n or S_n type of calculations) and is given if and only if PARAM(3)$\geq$ 2. The $2l + 1 = 3$ factor is *not* included in the numerator. Dimension: L_{scat1} with

$$L_{\text{scat1}} = \sum_{g=1}^{G} N_{\text{scat1}}(g)$$

⋆ `'NJJ 1 '` $N_{\text{scat1}}(g)$: Number of primary energy group contributions for each secondary energy group of the σ_{scat1} matrix. Dimension: `PARAM(1)`.

⋆ `'IJJ 1 '` $I_{\text{scat1}}(g)$: Most thermal primary energy group contributions for each secondary energy group of the σ_{scat1} matrix. $I_{\text{scat1}}(g) = g$ if there is no up-scattering. Dimension: `PARAM(1)`.

micro

Records

⋆ ‘YIELD ’	$Y(g)$: Yield for the production of the extracted isotope by fission. This information is given if and only if `JTAB(i)`=2. Dimension: `PARAM(1)`.
⋆ ‘NFTOT ’	$\sigma_{\mathrm{f}}(g)$: Microscopic fission cross section. This information is given if and only if `JTAB(i)`=1. Dimension: `PARAM(1)`.
⋆ ‘NUSIGF ’	$\nu(g)\sigma_{\mathrm{f}}(g)$ where $\nu(g)$ is the number of neutrons per fission and $\sigma_{\mathrm{f}}(g)$ is the microscopic fission cross section. This information is given if and only if `JTAB(i)`=1. Dimension: `PARAM(1)`.
⋆ ‘H-FACTORS ’	$h(g)$: Microscopic H-factor (i.e. product of the microscopic fission cross section times the energy recovered by fission for the extracted isotope). This information is given if and only if `JTAB(i)`=1. Dimension: `PARAM(1)`.
⋆ ‘CHI ’	$\chi(g)$: Fission spectrum. This information is given if and only if `JTAB(i)`=1. Dimension: `PARAM(1)`.

7. L_DEVICE specification

The L_DEVICE specification is used to store device information. 3-D hexagonal devices can be composed of descriptors along z-axis only.

'/ '

Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_DEVICE'.
'STATUS '	Record containing the specific parameters. • STATUS(1) : Total number of devices. (number of directories name_sequen) • STATUS(2) : Total number of device descriptors. (number of directories name_descript) Dimension: 2
'HEX '	Logical, $= T$ for hexagonal device definition, $= F$ otherwise.

Directories

name_type	Directory containing the devices of type name_type.

name_type

Directories

name_family	Directory containing the devices of family name_family.

name_family

Directories

name_sequen	Directory containing the specifications of the device name_sequen.

name_sequen .

Records

⋆ ‘NHEX ’	Record containing the number of affected hexagons. Dimension: nhex.
‘POSITION_MAX’	Record containing the maximum coordinates of the device name_sequen. Dimension: 6. Type: Real.
‘MOVEMENT_DIR’	Record containing the movement direction of the device name_sequen. Dimension: 1. Type: Character*1.
‘SPEED ’	Record containing the speed of the device name_sequen. Dimension: 1. Type: Real.
‘PARAMETERS ’	Record containing the parameters of the device name_sequen. Values are currently not used. Dimension: 2. Type: Real.

Directories

name_descript	Directory containing the descriptor name_descript definition of the device name_sequen.

name_descript .

Records

‘POSITION ’	Record containing the current coordinates of the device description name_descript. Dimension: 6. Type: Real.
‘MIX_NUMBER ’	Record containing the material mixture indices of the device description name_descript. Dimension: 2. Type: Integer.

8. L_PROCEDE specification

The L_PROCEDE specification is used to store some controller informations in order to have a link between the object L_DEVICE and the user in order to place controllers at their correct positions in the core. All the names specified in the object L_PROCEDE must be the same as those specified in the object L_DEVICE.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_PROCEDE'.

Directories

name_lzc	Directory containing the liquid zone controllers of family name_lzc.
name_rod	Directory containing the rods of family name_adj.

name_lzc

Directories

name_seqlzc	Directory containing the specifications of the liquid zone controller name_seqlzc.

name_rod .

Directories

name_seqrod	Directory containing the specifications of the rod name_seqrod.

name_seqlzc .

Records

	‘NAMFUL ’	Record containing the description name of full liquid zone controller part name_seqlzc. Dimension: 1. Type: Character*12.
	‘NAMEMP ’	Record containing the description name of empty liquid zone controller part name_seqlzc. Dimension: 1. Type: Character*12.
⋆	‘BIAS ’	Record containing the valve bias of the liquid zone controller name_seqlzc in % of full filling. This information is required for demanded valve lift calculation. Dimension: 1. Type: Real.
⋆	‘YFULL ’	Record containing the coordinate of full filling of the liquid zone controller. This information is not required if the full filling coordinates is the maximum coordinates along the moving axis. Dimension: 1. Type: Real.
	‘NIV ’	Record containing the level in % of full filling of the liquid zone controller name_seqlzc. Dimension: 1. Type: Real.
⋆	‘NUMBER ’	Record containing the zone number associated to the liquid zone controller name_seqlzc. This information is required for the regulation system. Dimension: 1. Type: Integer.
⋆	‘TIME ’	Record containing the filling times of the liquid zone controller name_seqlzc. This information is required for demanded valve lift calculation. Dimension: 2. Type: Real.
⋆	‘YVZ ’	Record containing the total demanded valve lift of the liquid zone controller name_seqlzc in % of full filling. Dimension: 1. Type: Real.
⋆	‘ZFLOW ’	Record containing the total demanded valve lift filtered and the previous one not filtered of the liquid zone controller name_seqlzc in % of full filling. This information is required for demanded valve lift calculation. Dimension: 2. Type: Real.

`name_seqrod` .

Records

	`'POS '`	Record containing the position in % of insertion or extraction. Dimension: 1. Type: Real.
⋆	`'NUMBER '`	Record containing the number associated with the rod `name_seqrod`. This information is required for the regulation system. Dimension: 1. Type: Integer.
⋆	`'NBANC '`	Record containing the bank number associated with the rod `name_sequen`. This information is required for the regulation system. Dimension: 1. Type: Integer.
⋆	`'TIME '`	Record containing the maximum time of insertion or extraction. This information is required for speed calculation. Dimension: 1. Type: Real.
⋆	`'VITBC '`	Record containing the speed in cm/s. Dimension: 1. Type: Real.

Directories

`name_descript`	Directory containing the descriptor `name_descript` informations of the rod `name_sequen`.

`name_descript` .

Records

	`'NPOS '`	Record containing the order index of the rod part `name_descript` in the entire physical rod. This means that in the movement direction, each rod part is numbered in the increasing order of its coordinates. Dimension: 1. Type: Integer.

9. L_MAP specification

The L_MAP specification is used to store fuel bundles map and information.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_MAP'.
'RES-DATA '	Record containing the dimension data. • RDATA(1) : number of bundles per channel. • RDATA(2) : number of channels in the core. • RDATA(3) : number of combustion zones. • RDATA(4) : number of energy groups. • RDATA(5) : fuel property model. = 1, for homogeneous model; = 2, for time-average model per combustion zone; = 3, for time-average model; = 4, for instantaneous model; = 5, for instantaneous model per combustion zone. • RDATA(6) : number of bundle shift. Dimension: 6
'INDEX '	Record containing the material mixture numbers for fuel. Dimension: RDATA(2),RDATA(1).
'ZONE '	Record containing the combustion zone number of each channel. Dimension: RDATA(2).
'BURN-ZONE '	Record containing the average exit burnup per combustion zones. Dimension: RDATA(3).
'CONTR-ZONE '	Record containing the smallest control zone number of each channel. Each channel belongs to its smallest control zone number for a half and to its smallest control zone number plus the maximal zone number for its other half. Dimension: RDATA(2).
'CPPF-ZONE '	Record containing CPPF interest flag per channel. Dimension: RDATA(2).
'XNAME '	Record containing the horizontal numbering of the channels. Dimension: STATE(3) corresponding to the embedded geometry description.
'YNAME '	Record containing the vertical numbering of the channels. Dimension: STATE(4) corresponding to the embedded geometry description.

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Records

'BURN-DEB '	Record containing the initial or instantaneous burnup per bundle for 2, 3, 4 and 5 fuel models. Dimension: RDATA(2),RDATA(1).
'BURN-END '	Record containing the final burnup per bundle for 2 and 3 fuel models. Dimension: RDATA(2),RDATA(1).
⋆ 'BURN-POOL '	Record containing the final burnup per bundle for 2 and 3 fuel models. Dimension: RDATA(2),RDATA(1).
⋆ 'REFUEL-SCH '	Record containing the refueling scheme of each channel. Dimension: RDATA(2).
'EPSF-AX '	Record containing the convergence error on axial flux shape calculation. Dimension: 1.
'FLUX-AV '	Record containing the integrated fluxes over the bundles. Dimension: RDATA(2),RDATA(1),RDATA(4).
'FLUX-AX '	Record containing the axial flux shapes over bundles. Dimension: RDATA(2),RDATA(1),RDATA(4).
'VOLUME '	Record containing the bundle volumes. Dimension: RDATA(2),RDATA(1).
'POWER-BUN '	Record containing the bundle powers in kW. Dimension: RDATA(2),RDATA(1).
'POWER-SURV '	Record containing the control zone powers in fraction of full power. Dimension: MAX(CONTR-ZONE) $*$ 2.
⋆ 'PSHIFT//hsft'	Record containing the power of the bundles shifted the $isft$th time. $hsft$ is a two digit character expression composed using "**WRITE(HSFT,'(I2)') isft**". Dimension: RDATA(2),RDATA(1).
⋆ 'BSHIFT//hsft'	Record containing the burnup of the bundles shifted the $isft$th time. $hsft$ is a two digit character expression composed using "**WRITE(HSFT,'(I2)') isft**". Dimension: RDATA(2),RDATA(1).
⋆ 'ISHIFT '	Record containing the number of bundle shifts during refuelling. The maximum value of the vector is RDATA(6). Dimension: RDATA(2),RDATA(1).

Directories

'GEO:RES '	Directory containing the embedded geometry description of the fuel map.(cf. L_GEOM specification)

10. L_DETECT specification

The L_DETECT specification is used to store detector positions and responses.

'/ '

Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_DETECT'.
'HEX '	Logical, $= T$ for hexagonal detector definition, $= F$ otherwise.
'DET-PARAM '	Record containing the detector parameters: • DET-PARAM(1) : Number of energy groups. • DET-PARAM(2) : Total number of detectors. Dimension: 2. Type: Integer.

Directories

name_type	Detector type sub-directory contains informations for each detector of this type.

name_type

Records

'INFORMATIONS'	Record containing specific parameters. • INFORMATIONS(1) : Number of detectors of type name_type. • INFORMATIONS(2) : 2+ number of delayed responses. Dimension: 2. Type: Integer.
⋆ 'INV-CONST '	Record containing the inverse time constant of the delayed detector responses. Dimension: INFORMATIONS(2)−2.
⋆ 'FRACTION '	Record containing the delayed and prompt fractions of the detector responses. Dimension: INFORMATIONS(2)−1.
'SPECTRAL '	Record containing the energy spectrum of the detector. Dimension: INFORMATIONS(2)−2.

Directories

name_detect	Detector information sub-directory

name_detect

Records

⋆	‘NHEX ’	Record containing the number of affected hexagons. Dimension: nhex.
	‘POSITION ’	Record containing the coordinates of the detector.Dimension: 6.
	‘RESPON ’	Record containing the responses of the detector. Dimension: INFORMATIONS(2).

11. L_BIVAC specification

The L_BIVAC specification is a tracking specification, which means that the general entries 'GPARAM', 'MATCOD', 'VOLUME' and 'KEYFLX' are present in addition to BIVAC-specific information.

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Records

	'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_BIVAC'.
	'GPARAM '	Record containing general parameters for a BIVAC tracking. • GPARAM(1) : exact number of finite elements, including the virtual elements (i.e., finite elements located outside the calculation domain). • GPARAM(2) : exact number of unknowns per energy group in the flux array. • GPARAM(3) : =0 if neutron leakage through external boundary is present; =1 otherwise. • GPARAM(4) : maximum number of material mixtures present in the tracking. Dimension: 4
⋆	'TITLE '	Character*72 identification field for the title.
	'MATCOD '	Record containing the element-ordered mixture numbers. MATCOD(I) is set to zero in virtual elements. Dimension: GPARAM(1).
	'VOLUME '	Record containing the element-ordered volumes. Dimension: GPARAM(1).
	'KEYFLX '	Record containing the element-ordered indices pointing to an averaged flux in the flux array. Dimension: GPARAM(1).
	'BPARAM '	Record containing specific parameters for a BIVAC tracking. • BPARAM(1) : Type of geometry: =2 Cartesian 1-D geometry; =3 Tube 1-D geometry; =5 Cartesian 2-D geometry; =6 Tube 2-D geometry; =8 Hexagonal 2-D geometry. • BPARAM(2) : Type of hexagonal symmetry for type 8 geometries: =1 S30; =2 SA60; =3 SB60; =4 S90; =5 R120; =6 R180; =7 SA180; =8 SB180; =9 COMPLETE. • BPARAM(3) : If < 0 Order -BPARAM(3) primal finite elements; If > 0 Order BPARAM(3) mixed dual finite elements.

'/ '

Records

- BPARAM(4) : Type of integration: =1 Analytical integration; =2 Gauss-Lobatto quadrature (collocation method); =3 Gauss-Legendre quadrature (superconvergent approximation).
- BPARAM(5) : Type of hexagonal mesh-splitting for type 8 geometries: =1 full hexagons, =2 for splitting each hexagon into 6 triangles, =3 for splitting each hexagon into 24 triangles, etc.
- BPARAM(6) : Order of the finite element matrices per energy groups. Generally equal to GPARAM(2) except in cases where averaged fluxes are appended to the unknown vector. BPARAM(6) $\leq$ GPARAM(2).
- BPARAM(7) : Number of elements along the X axis.
- BPARAM(8) : Number of elements along the Y axis.

Dimension: 8

'XX ' Element-ordered X-directed mesh spacings after mesh-splitting for type 2 and 5 geometries. Element-ordered radius after mesh-splitting for type 3 and 6 geometries. Dimension: GPARAM(1)

'YY ' Element-ordered Y-directed mesh spacings after mesh-splitting for type 5 and 6 geometries. Dimension: GPARAM(1)

'DD ' Element-ordered position used with type 3 and 6 geometries. Dimension: GPARAM(1)

⋆ 'SIDE ' Side of a hexagon for type 8 geometries. Dimension: 1.

'KN ' Element-ordered unknown list. Dimension: GPARAM(1)$\times N$ where N is the number of unknowns per element.

'QFR ' Element-ordered boundary conditions (real numbers). Dimension: GPARAM(1) $\times 6$ if BPARAM(1) $= 8$ and GPARAM(1) $\times 4$ otherwise.

'BFR ' Element-ordered external surface fractions (real numbers). Dimension: GPARAM(1) $\times 6$ if BPARAM(1) $= 8$ and GPARAM(1) $\times 4$ otherwise.

'MU ' Indices used with compressed diagonal storage mode matrices. Dimension: BPARAM(6).

'NCODE ' Record containing the types of boundary conditions on each surface. =0 side not used; =1 VOID; =2 REFL; =4 TRAN; =5 SYME; =7 ZERO. NCODE(5) and NCODE(6) are not used. Dimension: 6

'ZCODE ' Record containing the albedo value (real number) on each surface. ZCODE(5) and ZCODE(6) are not used. Dimension: 6

Directories

'BIVCOL ' Directory containing the unit matrices (mass, stiffness, nodal coupling, etc.) for a finite element discretization.

'BIVCOL '

Records

'T '	Cartesian linear product vector. Dimension: LC
'TS '	Cylindrical linear product vector. Dimension: LC
'R '	Cartesian mass matrix. Dimension: LC×LC
'RS '	Cylindrical mass matrix. Dimension: LC×LC
'Q '	Cartesian stiffness matrix. Dimension: LC×LC
'QS '	Cylindrical stiffness matrix. Dimension: LC×LC
'V '	Nodal coupling matrix. Dimension: LC×(LC-1)
'E '	Polynomial coefficients. Dimension: LC×LC
'RH '	Hexagonal mass matrix. Dimension: 6×6
'QH '	Hexagonal stiffness matrix. Dimension: 6×6
'RT '	Triangular mass matrix. Dimension: 3×3
'QT '	Triangular stiffness matrix. Dimension: 3×3

12. L_TRIVAC specification

The L_TRIVAC specification is a tracking specification, which means that the general entries 'GPARAM', 'MATCOD', 'VOLUME' and 'KEYFLX' are present in addition to TRIVAC-specific information.

'/ '

Records

'SIGNATURE ' Character*12 signature of the linked list or XSM file. Always equal to 'L_TRIVAC'.

'GPARAM ' Record containing general parameters for a TRIVAC tracking.

- GPARAM(1) : exact number of finite elements, including the virtual elements (i.e., finite elements located outside the calculation domain).
- GPARAM(2) : exact number of unknowns per energy group in the flux array.
- GPARAM(3) : =0 if neutron leakage through external boundary is present; =1 otherwise.
- GPARAM(4) : maximum number of material mixtures present in the tracking.

Dimension: 4

⋆ 'TITLE ' Character*72 identification field for the title.

'MATCOD ' Record containing the element-ordered mixture numbers. MATCOD(I) is set to zero in virtual elements. Dimension: GPARAM(1).

'VOLUME ' Record containing the element-ordered volumes. Dimension: GPARAM(1).

'KEYFLX ' Record containing the element-ordered indices pointing to an averaged flux in the flux array. Dimension: GPARAM(1).

'TPARAM ' Record containing specific parameters for a TRIVAC tracking.

- TPARAM(1) : Type of geometry: =2 Cartesian 1-D geometry; =3 Tube 1-D geometry; =5 Cartesian 2-D geometry; =6 Tube 2-D geometry; =7 Cartesian 3-D geometry; =8 Hexagonal 2-D geometry; =9 Hexagonal 3-D geometry.
- TPARAM(2) : Type of hexagonal symmetry for type 8 geometries: =1 S30; =2 SA60; =3 SB60; =4 S90; =5 R120; =6 R180; =7 SA180; =8 SB180; =9 COMPLETE.
- TPARAM(3) : =0 No diagonal symmetry; =1 Diagonal symmetry is present (for type 5 or 7 geometries only).

'/ '

Records

- `TPARAM(4)` : If < 0 Order `-TPARAM(4)` primal finite elements; If > 0 Order `TPARAM(4)` mixed dual finite elements.
- `TPARAM(5)` : Type of integration: =1 Analytical integration; =2 Gauss-Lobatto quadrature (collocation method); =3 Gauss-Legendre quadrature (superconvergent approximation).
- `TPARAM(6)` : Type of discretization algorithm: =1 Variational collocation method (primal finite elements with Gauss-Lobatto quadrature); =2 Dual finite element approximation; =3 Nodal collocation method with full tensorial products (dual finite elements with Gauss-Lobatto quadrature and a numerically optimized solution algorithm); =4 Nodal collocation method with serendipity approximation.
- `TPARAM(7)` : Type of hexagonal mesh-splitting for type 8 geometries: =1 full hexagons, =2 for splitting each hexagon into 6 triangles, =3 for splitting each hexagon into 24 triangles, etc.
- `TPARAM(8)` : Order of the finite element matrices per energy groups. Generally equal to `GPARAM(2)` except in cases where averaged fluxes are appended to the unknown vector. `TPARAM(8)` $\leq$ `GPARAM(2)`.
- `TPARAM(9)` : Number of elements along the X axis.
- `TPARAM(10)` : Number of elements along the Y axis.
- `TPARAM(11)` : Number of elements along the Z axis.
- `TPARAM(12)` : Number of elements in a vector register. Equal to zero for operations in scalar mode.
- `TPARAM(13)` : Print parameter for supervectorial operations.
- `TPARAM(14)` : Maximum bandwidth in supervector matrices. =2 for tridiagonal systems.
- `TPARAM(15)` : Number of supervector groups of linear systems for $W-$matrices.
- `TPARAM(16)` : Number of supervector groups of linear systems for $X-$matrices.
- `TPARAM(17)` : Number of supervector groups of linear systems for $Y-$matrices.
- `TPARAM(18)` : Number of supervector groups of linear systems for $Z-$matrices.
- `TPARAM(19)` : Number of radii in the cylindrical correction for type 5 or 7 geometries. =0 for no cylindrical correction.

Dimension: 19

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Records

	'XX '	Element-ordered X-directed mesh spacings after mesh-splitting for type 2, 5 and 7 geometries. Element-ordered radius after mesh-splitting for type 3 and 6 geometries. Dimension: GPARAM(1)
	'YY '	Element-ordered Y-directed mesh spacings after mesh-splitting for type 5, 6 and 7 geometries. Dimension: GPARAM(1)
	'ZZ '	Element-ordered Z-directed mesh spacings after mesh-splitting for type 7 and 9 geometries. Dimension: GPARAM(1)
	'DD '	Element-ordered position used with type 3 and 6 geometries. Dimension: GPARAM(1)
⋆	'SIDE '	Side of a hexagon for type 8 and 9 geometries. Dimension: 1.
	'KN '	Element-ordered unknown list. Dimension: GPARAM(1)$\times N$ where N is the number of unknowns per element.
	'QFR '	Element-ordered boundary condition (real numbers). Dimension: GPARAM(1)$\times$6.
	'NCODE '	Record containing the types of boundary conditions on each surface. =0 side not used; =1 VOID; =2 REFL; =4 TRAN; =5 SYME; =7 ZERO; =8 CYLI. Dimension: 6
	'ZCODE '	Record containing the albedo value (real number) on each surface. Dimension: 6
⋆	'MUW '	Indices used with $W-$directed compressed diagonal storage mode matrices. Dimension: TPARAM(8).
⋆	'MUX '	Indices used with $X-$directed compressed diagonal storage mode matrices. This array is not present if TPARAM(3)=1. Dimension: TPARAM(8).
⋆	'MUY '	Indices used with $Y-$directed compressed diagonal storage mode matrices. Dimension: TPARAM(8).
⋆	'MUZ '	Indices used with $Z-$directed compressed diagonal storage mode matrices. Dimension: TPARAM(8).
⋆	'IPW '	$W-$directed ADI permutation matrix. Dimension: TPARAM(8).
	'IPX '	$X-$directed ADI permutation matrix. Dimension: TPARAM(8).
⋆	'IPY '	$Y-$directed ADI permutation matrix. Dimension: TPARAM(8).
⋆	'IPZ '	$Z-$directed ADI permutation matrix. Dimension: TPARAM(8).

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Records

⋆ 'LL4VW '	Order of a reordered $W-$matrix, including supervectorial fill-in. Multiple of TPARAM(12). Dimension: 1.
⋆ 'LL4VX '	Order of a reordered $X-$matrix, including supervectorial fill-in. Multiple of TPARAM(12). Dimension: 1.
⋆ 'LL4VY '	Order of a reordered $Y-$matrix, including supervectorial fill-in. Multiple of TPARAM(12). Dimension: 1.
⋆ 'LL4VZ '	Order of a reordered $Z-$matrix, including supervectorial fill-in. Multiple of TPARAM(12). Dimension: 1.
⋆ 'NBLW '	Number of linear systems per supervector group for $W-$matrices. Dimension: TPARAM(15).
⋆ 'NBLX '	Number of linear systems per supervector group for $X-$matrices. Dimension: TPARAM(16).
⋆ 'NBLY '	Number of linear systems per supervector group for $Y-$matrices. Dimension: TPARAM(17).
⋆ 'NBLZ '	Number of linear systems per supervector group for $Z-$matrices. Dimension: TPARAM(18).
⋆ 'LBLW '	Number of unknowns per supervector group for $W-$matrices. Dimension: TPARAM(15).
⋆ 'LBLX '	Number of unknowns per supervector group for $X-$matrices. Dimension: TPARAM(16).
⋆ 'LBLY '	Number of unknowns per supervector group for $Y-$matrices. Dimension: TPARAM(17).
⋆ 'LBLZ '	Number of unknowns per supervector group for $Z-$matrices. Dimension: TPARAM(18).
⋆ 'MUVW '	Indices used with $W-$directed compressed diagonal storage mode matrices in supervector mode. Dimension: TPARAM(8).
⋆ 'MUVX '	Indices used with $X-$directed compressed diagonal storage mode matrices in supervector mode. This array is not present if TPARAM(3)=1. Dimension: TPARAM(8).
⋆ 'MUVY '	Indices used with $Y-$directed compressed diagonal storage mode matrices in supervector mode. Dimension: TPARAM(8).
⋆ 'MUVZ '	Indices used with $Z-$directed compressed diagonal storage mode matrices in supervector mode. Dimension: TPARAM(8).

'/ '

Records

⋆ 'IPVW ' $W-$directed ADI permutation matrix in supervector mode. Dimension: TPARAM(8).

⋆ 'IPVX ' $X-$directed ADI permutation matrix in supervector mode. This array is not present if TPARAM(3)=1. Dimension: TPARAM(8).

⋆ 'IPVY ' $Y-$directed ADI permutation matrix in supervector mode. Dimension: TPARAM(8).

⋆ 'IPVZ ' $Z-$directed ADI permutation matrix in supervector mode. Dimension: TPARAM(8).

⋆ 'RRO ' Radii of the cylindrical boundaries in the cylindrical correction for type 5 or 7 geometries. Dimension: TPARAM(19).

⋆ 'XRO ' Coordinates on principal axis in the cylindrical correction for type 5 or 7 geometries. Dimension: TPARAM(19).

⋆ 'ANG ' Angles for applying the cylindrical correction for type 5 or 7 geometries. Dimension: TPARAM(19).

Directories

⋆ 'BIVCOL ' Directory containing the unit matrices (mass, stiffness, nodal coupling, etc.) for a finite element discretization. This directory is present if and only if TPARAM(6)$\leq$2.

13. L_SYSTEM specification

The L_SYSTEM specification is used to store a set of system matrices (or a set of perturbations on system matrices) obtained after discretization of the algebraic operators contained in the neutron transport or diffusion equation. A complete set of matrices can be written on the root directory or on a STEP directory named TEXT12, embodying an index ISTEP, using

```
WRITE(TEXT12,'(4HSTEP,I8)') ISTEP
```

The discretized neutron transport or diffusion equation is assumed to be given in a form similar to the matrix system represented in Fig. Figure 3:

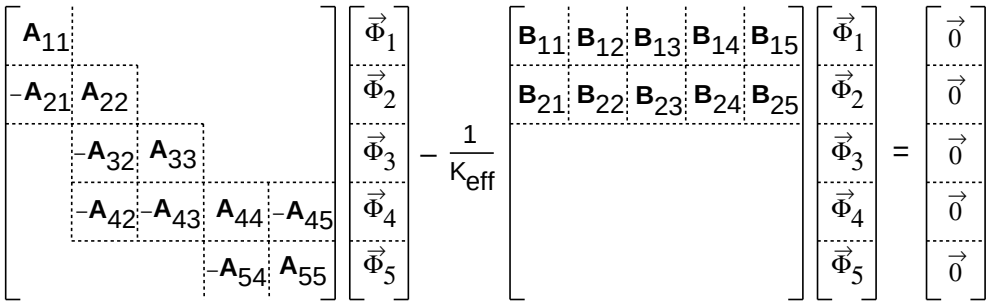

Figure 3: Example of a 5 energy group matrix eigenvalue problem

Each system matrix is stored on a block named TEXT7, embodying the primary group index IGR and the secondary group index JGR, using

```
WRITE(TEXT7,'(1HA,2I3)') JGR,IGR
```

or

```
WRITE(TEXT7,'(1HB,2I3)') JGR,IGR
```

'/ '

Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_SYSTEM'.
'SYS-PARAM '	Record containing the matrix dimension: SYS-PARAM(1) is the number of energy groups; SYS-PARAM(2) is MU(BPARAM(6)) with BIVACA or TPARAM(8) with TRIVAA (i.e., diagonal matrix); SYS-PARAM(3) is the number of precursor groups for delayed neutrons; SYS-PARAM(4) is MUW(TPARAM(8)) with TRIVAA or 0 with BIVACA; SYS-PARAM(5) is MUX(TPARAM(8)) with TRIVAA or 0 with BIVACA; SYS-PARAM(6) is MUY(TPARAM(8)) with TRIVAA or 0 with BIVACA; SYS-PARAM(7) is MUZ(TPARAM(8)) with TRIVAA or 0 with BIVACA. Dimension: 7.

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Records

⋆ 'A'//*HGROUP* A-type system matrix. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') jgr,igr" where *jgr* and *igr* are the secondary and primary group indices respectively. jgr≠igr with TRIVAA. Many blocks with different values of *jgr* and *igr* can be given. Dimension: SYS-PARAM(2).

⋆ 'B'//*HGROUP* B-type system matrix. Many blocks with different values of *jgr* and *igr* can be given. Dimension: SYS-PARAM(2).

⋆ 'WA'//*HGROUP* W-oriented component of an A-type system matrix used in an ADI splitting in hexagonal geometry. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(4).

⋆ 'XA'//*HGROUP* X-oriented component of an A-type system matrix used in an ADI splitting. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(5).

⋆ 'YA'//*HGROUP* Y-oriented component of an A-type system matrix used in an ADI splitting in 2-D geometry. *HGROUP* is a six digit character expression composed using ' 'WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(6).

⋆ 'ZA'//*HGROUP* Z-oriented component of an A-type system matrix used in an ADI splitting in 3-D geometry. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(7).

⋆ 'WIA'//*HGROUP* $L - D - L^T$ factors of the W-oriented component of an A-type system matrix used in an ADI splitting in hexagonal geometry. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(4).

⋆ 'XIA'//*HGROUP* $L - D - L^T$ factors of the X-oriented component of an A-type system matrix used in an ADI splitting. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(5).

⋆ 'YIA'//*HGROUP* $L - D - L^T$ factors of the Y-oriented component of an A-type system matrix used in an ADI splitting in 2-D geometry. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(6).

⋆ 'ZIA'//*HGROUP* $L - D - L^T$ factors of the Z-oriented component of an A-type system matrix used in an ADI splitting in 3-D geometry. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(2I3)') igr,igr". Many blocks with different values of *igr* can be given. Dimension: SYS-PARAM(7).

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Records

⋆ 'IA'//*HGROUP*	$L-D-L^T$ factors of an A-type system matrix in cases where no ADI splitting is performed. *HGROUP* is a six digit character expression composed using "`WRITE(HGROUP,'(2I3)') igr,igr`" . Many blocks with different values of *igr* can be given. Dimension: `SYS-PARAM(2)`.
⋆ 'RM'	Unit system matrix, i.e., a system matrix corresponding to cross sections all set to 1.0. This matrix is useful in IQS cases where the neutron velocity is constant in each group. *This block is always located on the root directory.* Dimension: `SYS-PARAM(2)`.
⋆ 'V'//*HGROUP*	System matrix corresponding to the reciprocal neutron velocities in the group `igr`. *HGROUP* is a six digit character expression composed using "`WRITE(HGROUP,'(2I3)') igr,igr`". This matrix is useful in IQS cases where the neutron velocity is mixture-dependent in group `igr`. Many blocks with different values of *igr* can be given. Dimension: `SYS-PARAM(2)`.
⋆ 'B'//*PGROUP*	Additional B-type system matrix. *PGROUP* is a nine digit character expression composed using "`WRITE(PGROUP,'(3I3)') i,jgr,igr`" where *i* indices the precursor group. This matrix is useful in IQS cases when the fission spectrum is different from the delayed neutron spectrum. Dimension: `SYS-PARAM(2)`.

Directories

⋆ 'STEP'//*HSTEP*	Sub-directory containing perturbations of A- and/or B-type system matrices. *HSTEP* is an eight digit character expression composed using "`WRITE(HSTEP,'(I8)') istep`" where *istep* is the index associated with the perturbation set of cross sections and diffusion coefficients.

14. L_FLUX specification

The L_FLUX specification is used to store a solution of the matrix system. The solution consists of the effective multiplication factor K_{eff} with a set of group-dependent unknown vectors representing the neutron fluxes. Optionally, group-dependent unknown vectors representing the adjoint fluxes, harmonics or perturbation to the fluxes can also be stored.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_FLUX'.
'FLU-PARAM '	Record containing the flux parameters: FLU-PARAM(1) is the number of energy groups; FLU-PARAM(2) is the exact number of unknowns per energy group; FLU-PARAM(3) = 1 direct fluxes, = 0 adjoint fluxes; FLU-PARAM(4) is the number of harmonics or GPT fluxes, = 0 otherwise ; FLU-PARAM(5) = 0 eigenvalue diffusion equation solution, = 1 GPT calculation. Dimension: 5.
'K-EFFECTIVE '	Effective multiplication factor. Dimension: 1 or FLU-PARAM(4) in cases where many harmonics of the flux were computed.
'FLUX'//*HGROUP*	Group-dependent unknown vectors representing the neutron flux in group *igr*. *HGROUP* is a three digit character expression composed using "WRITE(HGROUP,'(I3)') igr". The averaged flux in region J is recovered using FLUX(KEYFLX(J)) where the KEYFLX information is recovered from a L_BIVAC or L_TRIVAC specification. In cases where many harmonics of the flux were computed (i.e., the MONI keyword was used), *HGROUP* is a six character expression composed using "WRITE(HGROUP,'(2I3)') igr,imod" where *imod* is the harmonic index, with $1 \leq imod \leq$ FLU-PARAM(4). Dimension: FLU-PARAM(2).
⋆ 'AFLUX'//*HGROUP*	Group-dependent unknown vectors representing the adjoint flux in group *igr*. *HGROUP* is a three digit character expression composed using "WRITE(HGROUP,'(I3)') igr". In cases where many harmonics of the flux were computed (i.e., the MONI keyword was used), *HGROUP* is a six character expression composed using "WRITE(HGROUP,'(2I3)') igr,imod" where *imod* is the harmonic index, with $1 \leq imod \leq$ FLU-PARAM(4). Dimension: FLU-PARAM(2).

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Records

⋆ 'DFLUX'//*HGROUP* Group-dependent unknown vectors representing a perturbed flux or the solution of a direct GPT problem in group *igr*. *HGROUP* is a three digit character expression composed using "`WRITE(HGROUP,'(I3)') igr`". In cases where many GPT problems were solved, *HGROUP* is a six character expression composed using "`WRITE(HGROUP,'(2I3)') igr,imod`" where *imod* is the problem index, with $1 \leq imod \leq$ `FLU-PARAM(4)`. Dimension: `FLU-PARAM(2)`.

⋆ 'DAFLUX'//*HGROUP* Group-dependent unknown vectors representing a perturbation to the adjoint flux or the solution of an adjoint GPT problem (i.e., a generalized adjoint) in group *igr*. *HGROUP* is a three digit character expression composed using "`WRITE(HGROUP,'(I3)') igr`". In cases where many GPT problems were solved, *HGROUP* is a six character expression composed using "`WRITE(HGROUP,'(2I3)') igr,imod`" where *imod* is the problem index, with $1 \leq imod \leq$ `FLU-PARAM(4)`. Dimension: `FLU-PARAM(2)`.

15. L_IQS specification

The L_IQS specification is used to store a space-time solution of the improved quasistatic (IQS) method. The solution consists of a set of extended MACROLIBS stored into STEP directories:

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_IQS'.
'IQS-PARAM '	Record containing the kinetics flux parameters: IQS-PARAM(1) is the number of energy groups; IQS-PARAM(2) is the exact number of unknowns per energy group; IQS-PARAM(3) is the number of precursor groups for delayed neutrons. Dimension: 3.
'BETA '	Record containing the delayed neutron fraction associated with each percursor group. Dimension: IQS-PARAM(3).
'DECAY '	Record containing the delayed neutron decay rates associated with each percursor group. Dimension: IQS-PARAM(3).
'AFLUX'//*HGROUP*	Group-dependent unknown vectors representing the adjoint flux in group *igr*. *HGROUP* is a three digit character expression composed using "WRITE(HGROUP,'(I3)') igr". Dimension: IQS-PARAM(2).
'SHAPE'//*HGROUP*	Group-dependent unknown vectors representing the shape function at end-of-transient in group *igr*. *HGROUP* is a three digit character expression composed using "WRITE(HGROUP,'(I3)') igr". Dimension: IQS-PARAM(2).
'AMPGA '	Vector representing the group-dependent amplitudes of the fluxes at end-of-transient. Dimension: IQS-PARAM(1).
'FLUX'//*HGROUP*	Group-dependent unknown vectors representing the flux in group *igr*. *HGROUP* is a three digit character expression composed using "WRITE(HGROUP,'(I3)') igr". Dimension: IQS-PARAM(2).
'TMACRO'	Time (in seconds) at end-of-transient.
'POWER'	Power (in Watts) at end-of-transient.

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Records	
'PREC'//*HPREC*	Energy and delayed group-dependent unknown vectors representing the concentration of delayed group *idg* precursor at end-of-transient in energy group *igr*. *HPREC* is a three digit character expression composed using "`WRITE(HPREC,'(I3,I3)') igr,idg`". Dimension: `IQS-PARAM(2)`.

Directories	
⋆ 'STEP'//*HSTEP*	Sub-directory containing an extended MACROLIB at a particular macro time step of the IQS method. *HSTEP* is an eight digit character expression composed using "`WRITE(HSTEP,'(I8)') istep`" where *istep* is the index associated with the macro time step.

16. L_GPT specification

The L_GPT specification is used to store an eigenvalue perturbation vector and group-dependent unknown vectors representing a source term. The sources can be direct or adjoint.

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Records

'SIGNATURE '	Character*12 signature of the linked list or XSM file. Always equal to 'L_GPT'.
'PARAM '	Record containing the source parameters: PARAM(1) is the number of energy groups; PARAM(2) is the exact number of unknowns per energy group; PARAM(3) is the number of sources, number of different configurations. Dimension: 3.
'DELTA-KEFF '	Effective multiplication factor variation vector. Dimension: 14 or 380.
'DSOUR'//*HGROUP*	Group-dependent unknown vectors representing the direct source term *isrc* in group *igr*. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(I3)') igr, isrc". Dimension: PARAM(2).
'ASOUR'//*HGROUP*	Group-dependent unknown vectors representing the adjoint source term *isrc* in group *igr*. *HGROUP* is a six digit character expression composed using "WRITE(HGROUP,'(I3)') igr, isrc". Dimension: PARAM(2).

17. REFERENCES

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