3. STARTING THE PROGRAM

This chapter describes the code input and output data and the SKETCH-N postprocessing module.

3.1 Parameters in the include file "parameters.fh"

The include file "parameters.fh" contains the basic description of the reactor model dimensions and parameters. It is included into the file "sketch.fh" to define the array dimensions. If you change the problem you need to recompile the source code.

The variables defined in the file "parameters.fh" are separated into several groups: parameters describing the reactor geometry, parameters describing the reactor core, parameters describing the macro cross sections, parameters describing the control rods, parameters used by internal thermal-hydraulics model and parameters used for calculations with an external thermal-hydraulics model. They are defined in the Tables 3.1 till 3.6. Please, note that the variables given in the Table 3.5 are used only if the calculations are performed with the internal thermal-hydraulics model. The variables described in the Table 3.6 are used only if the external thermal-hydraulics model is used. In the case of pure neutronics calculations the values of parameters given in these tables can be set to 1.

Parameter Name	Description
N_BUNDLE_TYPE	number of different bundle types
N_POLY	number of the bundles (assemblies) in the reactor model
NCHM	maximum number of nodes per bundle (assembly) in X-Y plane
NH	number of the nodes in radial (X-Y) plane; if the calculations are performed with 1 node per assembly NH=N_POLY
NXR	maximum number of bundles in X directions
NX	maximum number of nodes in X direction
NYR	maximum number of bundles in Y directions
NY	maximum number of nodes in Y direction
NZR	number of axial layers defining material composition of the bundle;
NZ	number of axial layers used for the calculations
NDD	dimension of reactor model: 3D calculations NDD=3 (XYZ geometry), NDD=4 (HEX-Z geometry); 2D calculations NDD=2 (XYZ geometry), NDD=3 (HEX-Z geometry);
NDIR	dimension of reactor model: 3D calculations NDD=3 (XYZ geometry), NDD=4 (HEX-Z geometry); 2D calculations NDD=2 (XYZ geometry), NDD=3 (HEX-Z geometry);

Table 3.1 Parameters describing the reactor geometry.

Parameter Name	Description
NP_Reactor_Core	number of fuel bundles in the reactor core
NZR_Core	number of axial layers in the reactor core
NN_FRD_FA	number of the equivalent fuel rods per fuel assembly
NN_FA_TYPE	number of the fuel assembly types

Table 3.2 Parameters describing the reactor core geometry.

Parameter Name	Description
NG	number of neutron energy groups

MD	number of delayed neutron precursors
NNODE	number of material compositions
N_FEEDBACKS	number of feedbacks, presently 4: boron concentration, coolant density or void, Doppler fuel temperature

Table 3.3 Parameters describing the macro cross sections.

Parameter Name	Description
NN_CRod	number of control rods
NN_CRod_Type	number of control rod types
NN_CRod_Comp	number of control rod material compositions
NN_CRod_El	number of control rod elements, for example 2 for PWR: absorber and driver
NN_Crod_Bundle	number of the bundles covered by control rod: 1 in the case of PWR and 4 in the case of BWR

Table 3.4 Parameters describing the control rods.

Parameter Name	Description
NN_FRD_FUEL	number of the heat conduction nodes in the fuel
NN_FRD_CLAD	number of the heat conduction nodes in the cladding

Table 3.5 Parameters used by internal thermal-hydraulics model.

Parameter Name	Description
NN_RT_HC_TRAC	number of the heat conduction channels in the external T/H model
NN_RT_FD_TRAC	number of the fluid dynamics channels in the external T/H model
NN_Z_HC_TRAC	number of the axial layers of the heat conduction mesh in the external T/H model
NN_Z_FD_TRAC	number of the axial layers of the fluid dynamics mesh in the external T/H model

Table 3.6 Parameters used for calculations with an external thermal-hydraulics model.

3.2 Input Data in the Namelist File "SKETCH.INI"

The file "SKETCH.INI" contains several namelists defining the SKETCH input data. The namelist INI_PROBLEM defines the type of the problem and solution methods used by the code. The variables are listed in the Tables 3.7. The namelist INI_FILES defines the names of the input, output and restart files. The variables are given in the Table 3.8. The iteration convergence criteria are given in the namelist INI_CONVERGENCE. The variables are given in the Table 3.9. We recommend to use the default values.

Variable Name	Default value	Description
Problem_Type	"Steady-State"	type of the computed problem: "Steady-State" – steady-state calculations "Burnup" – burnup calculations "Kinetics" – neutron kinetics calculations
Steady_State_Type	"Eigenvalue"	Type of the computed steady-state problem: "Eigenvalue" –eigenvalue calculations "BoronSearch" –critical boron search
TH_Model	"None"	thermal-hydraulics model used for the calculations, variants "None" – no thermal-hydraulics model; "Internal" – SKETCH internal thermal-hydraulics model "External" – external thermal-hydraulics model
Nodal_Method	"SANM"	spatial discretization method used for calculations: "PNM" – polynomial nodal method (for XYZ & HEX-Z geometry); "SANM" – semi-analytic nodal method (XYZ geometry only); "ANM" – analytic nodal method (XYZ geometry only), "MCFD" – finite-difference method, "PNM1" – polynomial nodal method, algorithm based on matrix functions (XYZ geometry only);
Kinetics_Method	"DRT"	method of the solution of kinetics equation: "DRT" – direct method, fully-implicit scheme; "IQS" – improved quasi-static method; "PNT" –point neutron kinetics
Iter_Solver	"CSA"	linear iterative solver for neutron kinetics calculations: "CSA" – Chebyshev Semi-Analytic method; "CSI" – Chebyshev Semi-Iterative method; "CG" – Conjugate Gradient method; "BCGSTAB" – BiConjuagate Gradient Method STABilized, "TFQMR" - Transpose Free Quasi Minimal Residual Method; "FOM" – Arnoldi's Method "GMRES" – Generalized Minimal Residual Method
TRL_Approx	"QLA"	transverse leakage approximation, possible choices 'QLA', 'Flat'
NonlinearIterations	"Smith"	Nonlinear iteration procedure, possible choices "Smith", "Moon"
Xe_Sm_Model	"nn"	Xe and Sm model Possible choices for each isotope: "n" – not changes, for example, fixed value taken from the input file, "s - steady-state values; "t" - solving transient equations, for example in the burnup calulations; "0" – set to zero values. For example in the steady-state calculations XeSm model can be given as "sn", that means that Xe has steady-state value and Sm is fixed value, taken from the burnup file.

Table 3.7 Variables defining a type of the problem and solution methods in the namelist INI_PROBLEM.

Variable Name	Default value	Description
FILE_INPUT	""	name of the input file with the geometry and macro cross section data
File_Reference	""	name of the input file with the reference solution
FILE_MAP	""	name of the input file with the mapping matrices, used only if TH_Model="External"
FILE_DIST	""	name of the input file with the distributions (xenon, burnup, void history, etc.), used in the Ringhals-1 BWR calculation;
FILE_CD	""	name of the input file with macro cross section tables, used in the Ringhals-1 BWR calculation; name of the input file with the XS library in the case of VVER1000 calculations
FILE_DMP_IN	""	Name of the input dump file for restart
FILE_DMP_OUT_ST	""	Name of the output dump file to restart the steady-state calculations
FILE_DMP_OUT_KIN	""	Name of the output dump file to restart the kinetics calculations
File_dmp_Skazka_in	""	Name of the input restart file for SKAZKA module
File_dmp_Skazka_Out	""	Name of the output restart file for SKAZKA module
File_BRN_In	""	Name of the input restart file with burnup distriibution & Xe and Sm concentrations
File_BRN_Out	""	Name of the output restart file with burnup distriibution & Xe and Sm concentrations
file_burnup_history	""	Name of the input file with reactor power and control rod history for burnup calculations

Table 3.8. Names of the input, output and restart files defined in the namelist INI_FILES.

Variable Name	Default value	Description
N_OUT_MAX	 1 1000	number of outer iterations for the nonlinear iteration convergence test: in the steady-state calculations; in the kinetics calculations (1 nonlinear iteration per time step);
N_OUTER	 10 1000	maximum number of the outer iterations per nonlinear iteration: in the steady-state calculations; in the kinetics calculations (1 nonlinear iteration per time step);
E_OUTER_L	1.E-5	convergence criterion for the steady-state eigenvalue
E_FLUX_L	 1.E-5 1.E-4	convergence criterion for the neutron flux: in the steady-state calculations; in the kinetics calculations;
N_INTER	2	maximum number of inner iteration per outer iteration
E_INTER	1.E-8	convergence criterion for the inner iterations (never satisfied, fixed number of inner iterations per outer iteration)
E_BORON_START	1.E-2	accuracy of the eigenvalue estimate when a critical boron search starts
E_CRITICAL	1.E-5	convergence criterion for the critical boron search

Table 3.9. Convergence criteria defined in the namelist INI_CHEBYSHEV.

The namelist INI_CHEBYSHEV defines the parameters used by the Chebyshev iterative methods. The variables are given in the Table 3.10. We recommend to use the default values. Please only note, that the convergence of the steady-state iterations can be significantly improve if you use the value of the Wieland shift DELTA_SHIFT not equal to zero. For the LWR calculations, the value DELTA_SHIFT in the interval [5,20] provide "optimal" convergence. Please, decrease the value of the Wieland shift if the iterations diverge.

Variable Name	Default Value	Description
XME_INI	0.8	estimate of the dominance ratio (steady-state calculations) or spectral radius (kinetics calculations) of the iterative matrix
XBE	0.0	estimate of the minimum eigenvalue of the iteration matrix
F_CHEB	0.0 0.8	adaptive parameter of the Chebyshev iterative method: F_CHEB=0.0 non-adaptive, default in the steady-state Calculations; F_CHEB=0.8 – adaptive, default in the kinetics calculations
NPOLINS	5	number of the outer iteration when the Chebyshev method starts
DELTA_SHIFT	0.	inverse value of the Wieland shift in the steady-state iterations

Table 3.10. Parameters of the Chebyshev iterations defined in the namelist INI_CHEBYSHEV.

The variables related to the time step size selection during neutron kinetics calculations are given in the namelist INI_TIME_STEP. The list is presented in Table 3.11. Even the default value of the flag I_AUTO specified the user defined time step, we strongly encourage to set I_AUTO=1 and to use the automatic time step size selection. In our experience, the time step doubling techniques used in the code is reliable and gives accurate solution.

Variable Name	Default Value	Description
I_AUTO	0	flag of the automatic time step selection: I_AUTO=0 – user defined time step size; I_AUTO=1 – automatic time step selection;
NP_VIEW	1	number of the time step size intervals
TTV(NP_VIEW)	1.	real array of dimension NP_VIEW – right end points of the time step size intervals [s]; the last value TTV(NP_VIEW) is the end of the transient;
DT_INPUT (NP_VIEW)	0.01	real array of dimension NP_VIEW – time step size for the time step intervals, [s].
ST_EPS	5.E-3	accuracy criterion of the automatic time step size selection
FACMAX	2.	maximum increase of the time step size per time step
DT_STEP_MAX	1.	maximum value of the time step size, [s]
N_ZAP	1	output into the SKETCH binary output file per each N_ZAPth time step

Table 3.11. Time step size data defined in the namelist INI_TIME_STEP.

3.3 Input Data in the SKETCH-N Input File

The name of the SKETCH-N input file is defined under the variable FILE_INPUT in the namelist INI_FILES in the file "SKETCH.INI". The examples are given in the following Chapters. Here we present the list of all input data, which can be given in this file. The input file starts with 5 lines of the

problem header, which is always input and is used in the SKETCH output files. The actual data starts on the line 6 and are given in the following form. First we have the identifier, which is 12 characters, actual data starts at the following line and are given in free format. Arbitrary number of the blank lines may precede or follow the data. The variable identifiers and input data are separated into several groups, related to the SKETCH modules. The first characters of the identifier name give the abbreviation of the SKETCH-N module, the other characters encode the variable name. For example, the identifier XS_BASE_DATA stands for the basic macro cross section data of the XS module, CRD_MAT_COMP is the identifier of the control rod material compositions, etc. Some input cards can be omitted, for example the delayed neutron precursors parameters are not needed if only steady-state calculations are performed. If the data are needed, but the code can not find the identifier name in the input file, the code uses the default values and gives the warning message into the output file "Error.msg". If default values are not defined or the code has an error reading the input data, the execution is stopped with an error message into the error message file "Error.msg".

3.3.1 General Reactor Model Data

The first set of the data defines the general reactor model, the identifiers start with the characters CNT (CoNTrol). Their list is given below.

`CNT_RCT_TYPE`

Description: Reactor type, presently only `"PWR"` or `"BWR"`. This variable defines only the control rods positions, in the case of `"PWR"` control rods move from the top of the core, while in the case of `"BWR"` the control rods are inserted from the bottom of the reactor core.

Default value: `"PWR"`

`CNT_RCT_POWR`

Description: Reactor thermal power, [MWt]

Default value: -

3.3.2 Macro Cross Section Data

The set of the data related to macro cross sections is given under identifiers, which start with `XS`. The input data are described below.

`XS_MODL_TYPE`

Description: a type of the macro cross section model, three type are available:

`"POLYNOM"` – polynomial representation

`"TABLE"` – table representation for the BWR Ringhals-1 stability benchmark. XS are given in the separate file, specified by the variable `FILE_CD` in the namelist INI_FILES in the file "SKETCH.INI".

`"SUBSET"` – the most general combination of the multivariate polynomial approximation with the spline interpolation, example is given for VVER-1000 calculations. XS are given in the separate file, specified by the variable `FILE_CD` in the namelist INI_FILES in the file "SKETCH.INI".

Default value: `"POLYNOM"`

`XS_BASE_DATA`

Description: Basic set of the macro cross section data, the input has different form depending on the number of neutron energy groups NG.

Default value: -

Input data format:

The input form depends on the number of neutron energy groups. In the case of two-group calculations, the input is performed as follows

```
   DO k = 1, NNODE
      read(io_unit,fmt=*, iostat=ios)
  &           d(k,1),sik(k,2,1),sa(k,1),sf(k,1),sf_p(k,1),
  &           d(k,2),sa(k,2),   sf(k,2),sf_p(k,2), i
   END DO
```

where

`NNODE` is a number of material compositions defined in the file "parameters.fh";

`d(k,*)` is the diffusion coefficients or neutron transport cross section of the material composition `k`, D *or* Σ_{tr};

`sik(k,2,1)` is the scattering macro cross section from group 1 into 2 of the material composition `k`, Σ_{s21},;

`sa(k,*)` is the absorption macro cross sections of the material composition `k`, Σ_a;

`sf(k,*)` is the production macro cross section of the material composition `k`, $\nu\Sigma_f$;

`sf_p(k,*)` is the fission macro cross sections of the material composition `k`, Σ_f;

`i` is the material composition number, not used in the code.

In the case of multigroup calculations `NG>2`, the input is performed as follows

```
   DO k = 1, NNODE
    read(io_unit,fmt=*, iostat=ios)
  &           (d(k,n), sa(k,n), sf(k,n), sf_p(k,n),
  &                           n = 1, NG)
        read(io_unit,fmt=*, iostat=ios)
  &           ((sik(k,n,m), m = 1, NG), n = 1, NG), i
   END DO
```

The difference is that for each material composition, the scattering macro cross sections are given after all others and all elements of the scattering matrix are given in the input. Please, note that self-scattering within an energy group is not considered in the diffusion theory and the diagonal elements of the scattering matrix should be zero.

Examples:

Two-group macro cross sections of the 1st material composition of the NEACRP PWR rod ejection benchmark are given below:

```
XS_BASE_DATA # Basic set of the macro cross section data
  0.532058E-01 0.264554E-01 0.373279E-03 0.000000E-00 0.000000E-00
  0.386406E-00 0.177215E-01 0.000000E-00 0.000000E-00           1
```

Four-group macro cross sections of the 1st material composition of the 2D PWR KOEBERG benchmark are given below:

```
XS_BASE_DATA # Basic set of the macro cross section data
    2.491869 0.003654 0.008228 0.008228
    1.045224 0.002124 0.000536 0.000536
    0.677407 0.019908 0.007058 0.007058
    0.375191 0.067990 0.083930 0.083930
      0.0      0.0      0.0      0.0
      0.063789 0.0      0.0      0.0
      0.000486 0.064381 0.0      0.001245
      0.0      0.000003 0.050849 0.0       1 Type
```

XS_ADF_DATA

Description: Basic set of the assembly discontinuity factors (ADF).

Default value: - 1.0

Input data format:

The input is performed as follows

```
DO k = 1, NNODE
  DO n = 1, NG
     read(io_unit,fmt=*, iostat=ios)
&           (( adf(k, n, i, nd), i = 1,2), nd = 1, NDD)
   END DO
 END DO
```

where

NNODE is a number of material compositions defined in the file "parameters.fh";

NG is a number of neutron energy groups defined in the file "parameters.fh";

NDD is a number of directions, in the case of XYZ geometry NDD=3, in the case of HEX-Z geometry NDD=4;

2 means left and right face of the node for the fixed direction;

adf(k,n,i,nd) is the assembly discontinuity factor for the material composition k, neutron energy group n, interface i (1 for the left, 2 for the right) of the direction nd.

XSP_POL_COEF

Description: derivatives of the macro cross sections with respect to feedbacks. The following set of feedbacks is used in the code: boron concentration [ppm], coolant density [g/cm^3], coolant temperature [°C] and Doppler fuel temperature [°K]. Please, not that the units are not the SI units. The input form depends on the number of neutron energy groups.

Default value: 0.0

Input data format:

In the case of two-group calculations, the input is performed as follows

```
 DO k = 1, NNODE
    DO i = 1, N_FEEDBACK
&                     d_fb(i,1,k),sik_fb(i,2,1,k),sa_fb(i,1,k),
&                                 sf_fb(i,1,k),sf_p_fb(i,1,k),
&                     d_fb(i,2,k),sa_fb(i,2,k),sf_fb(i,2,k),
&                                 sf_p_fb(i,2,k), fdback00(i,k)
    END DO
 END DO
```

where

NNODE is a number of material compositions defined in the file "parameters.fh";

N_FEEDBACK is a number of feedbacks defined in the file "parameters.fh", N_FEEDBACK=4;

d_fb(i,*,k) is the derivative of the transport macro cross section Σ_{tr} with respect to *i*-th feedback for material composition k;

sik_fb(i,2,1,k) is the derivative of the scattering macro cross section Σ_{s21} with respect to *i*-th feedback for material composition k;

sa_fb(i,*,k) is the derivative of the absorption macro cross section Σ_a with respect to *i*-th feedback for material composition k;

sf_fb(i,*,k) is the derivative of the production macro cross section $\nu\Sigma_f$ with respect to *i*-th feedback for material composition k;

`sf_p_fb(i,*,k)` is the derivative of the fission macro cross section Σ_f with respect to *i*-th feedback for material composition k;
`fdback00(i,k)` is the reference value of *i*-th feedback for material composition k.

In the case of multigroup calculations `NG>2,` the input is performed as follows

```
 DO k = 1, NNODE
    DO i = 1, N_FEEDBACK
         read(io_unit, fmt=*, iostat=ios)
&           (d_fb(k,n,i),sa_fb(k,n,i),sf_fb(k,n,i),
&             sf_p_fb(k,n,i), n = 1, NG)
         read(io_unit,*) ((sik_fb(k,n,m,i),m=1,NG) ,n=1,NG),
&                          fdback00(i,k)
    END DO
 END DO
```

The difference is that for each material composition and each feedback, the derivatives of the scattering macro cross sections are given after all others and all elements of the derivatives of the scattering matrix are given in the input.

Examples:

Two-group derivatives of the macro cross sections of the 1st material composition of the NEACRP PWR rod ejection benchmark are given as:

```
XSP_POL_COEF # Macro cross section derivatives
 0.611833E-07 0.791457E-09 0.187731E-06 0.000000E-00 0.000000E-00
 0.517535E-05 0.102635E-04 0.000000E-00 0.000000E-00       1200.2
 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00
 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00        306.6
 0.745756E-01 0.371310E-01 0.207688E-03 0.000000E-00 0.000000E-00
 0.533634E-00 0.758421E-02 0.000000E-00 0.000000E-00       0.7125
 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00
 0.000000E-00 0.000000E-00 0.000000E-00 0.000000E-00       891.45 1
```

`XS_DIFF_FLAG`

Description: Integer flag of the diffusion coefficient in the basic set of the macro cross section data. If `XS_DIFF_FLAG==1,` the diffusion coefficient is given in the basic macro cross section set, otherwise it is the transport macro cross section.

Default value: `1`

`XS_FEED_INIT`

Description: Initial values of the feedbacks used in the first thermal-hydraulics iteration, real array of dimension `N_FEEDBACK=4`

Default value: `1.0`

`XS_CROD_COEF`

Description: Differential macro cross sections for the control rod material compositions; the input form is the same as described above for the basic macro cross sections under identifier `XS_BASE_DATA.`

Default value: `0.0`

`XS_CROD_CUSP`

Description: Homogenization method of the macro cross sections for the partially rodded nodes. Two choices:

"FLUX-WEIGHTING" - flux-weighting homogenization
"VOLUME-WEIGHTING" - volume-weighting homogenization
Default value: "FLUX-WEIGHTING"

XS_NEUT_SPEC
Description: Prompt neutron spectrum, real array of dimension NG
Default value: -

XS_POWR_CONV
Description: Energy release per fission [Ws/fission], real array of dimension NG
Default value: -

XS_POWR_COOL
Description: Part of the energy directly deposited into the coolant
Default value: 0.0

XS_NEUT_VELC
Description: Prompt neutron velocity [cm/s] , real array of dimension NG
Default value: -

XS_PREC_ALFA
Description: Decay constants of the delayed neutron precursors [1/s], real array of dimension MD
Default value: -

XS_PREC_BETA
Description: Fraction of the delayed yields, the input can be absolute or relative values.
Default value: -
Input data format: Either relative or absolute values can be given. First you input the integer flag i_beta. If i_beta==0 the code expects absolute values of the delayed neutron fractions. If i_beta==1 the code first reads the total fraction of the delayed neutrons and then the relative fractions for each delayed neutron groups.
Examples:
The input of the relative fractions of the delayed neutron precursors for the NEACRP PWR rod ejection benchmark is given as:

```
XS_PREC_BETA
  1 # Relative beta
  0.0076 # Total yield
  0.034 0.200 0.183 0.404 0.145 0.034 # Relative fractions (MD)
```

The input of the absolute fractions of the delayed neutron precursors for the NEACRP BWR cold water injection benchmark is given as:

```
XS_PREC_BETA
  0 # Absolute beta
  0.00026 0.00152 0.00139 0.00307 0.00110 0.00026 # bet(MD)
```

3.3.3 Geometry Description

The set of the data related to the reactor geometry model is given under identifiers, which start with GMT. The list of the identifier and the data descriptions are given as follows.

GMT_CRD_TYPE

Description: type of the geometry, can be “XYZ” or “HEXZ”

Default value: - “XYZ”

GMT_NUM_BNDL

Description: the numbering of the reactor bundles (assemblies), integer array of dimension (NXR,NYR)*:* The different approach is used in the cases of “XYZ” or “HEXZ” geometries, see examples

Default value: -

Example:

Reactor model of the NEACRP PWR rod ejection benchmark is described as follows:

```
GMT_NUM_BNDL # Numbering of the reactor assemblies (bundles)
  1  2  3  4  5  6  7  8  9
  10 11 12 13 14 15 16 17 18
  19 20 21 22 23 24 25 26 27
  28 29 30 31 32 33 34 35  0
  36 37 38 39 40 41 42 43  0
  44 45 46 47 48 49 50  0  0
  51 52 53 54 55 56  0  0  0
  57 58 59 60 61  0  0  0  0
  62 63 64  0  0  0  0  0  0
```

Reactor model of the VVER-1000 reactor of the 3 unit of Kalinin NPP is described as follows:

```
GMT_NUM_BNDL # Numbering of the reactor assemblies (bundles)
 2 8
 1 10
 1 11
 1 12
 1 13
 1 14
 1 15
 1 16
 2 16
 2 17
 3 17
 4 17
 5 17
 6 17
 7 17
 8 17
 10 16
```

GMT_MSH_RDIR

Description: spatial mesh for HEX geometry (can not be subdivided);

Default value: -

Example: spatial mesh for VVER-1000 of Unit 3 of Kalinin NPP

```
GMT_MSH_RDIR ## Spatial Mesh for HEX Geometry

 23.6
```

GMT_MSH_XDIR

Description: Number of points per interval and spatial mesh intervals in x-direction [cm], integer and real arrays of dimension (NXR)
Default value: -
Example: spatial mesh in x-direction for the NEACRP PWR rod ejection benchmark is defined as:

```
GMT_MSH_XDIR # Spatial mesh in x-direction

    1 10.803 2 21.606 2 21.606 2 21.606 2 21.606 2 21.606
    2 21.606 2 21.606 2 21.606 # npx(NXR),hx(NXR)
```

where two mesh points are defined per interval 21.606 cm.

GMT_MSH_YDIR
Description: Number of points per interval and spatial mesh intervals in y-direction [cm], integer and real arrays of dimension (NYR)
Default value: -

GMT_MSH_ZDIR
Description: Number of points per interval and spatial mesh intervals in z-direction [cm], integer and real arrays of dimension (NZR)
Default value: -

GMT_COR_LOAD
Description: specification of the reactor loading by the material composition, first input is an integer array of dimension (N_POLY) describing reactor loading by bundle types, then for each bundle type we define the axial material composition.
Default value: -
Input data format: First input of the core loading by the bundle types as follows.

```
READ(io_unit,  fmt=*, iostat=ios)
 &    (Core_Load(np), np = 1, N_POLY),
```

where
N_POLY is a number of the bundles (assemblies) in the reactor model.
Core_Load(np) is a bundle type

Then, we input axial material composition for each bundle type as

```
 DO i = 1, N_Bundle_Type
    READ(io_unit,  fmt=*, iostat=ios)
&                        (Bundle_Compos(n, i), n = 1, NZR)
 END DO
```

where
N_Bundle_Type is a number of the bundle types in the reactor model;
NZR is a number of axial layers in the reactor model;
Bundle_Compos(n, i) is the material composition for each bundle type i and axial layer n;

Example:
Material compositions for NEACRP PWR rod ejection benchmark are defined as follows:

```
GMT_COR_LOAD # Core loading by the material compositions
  1  2  1  2  1  3  1  4  5
```

```
 2  1  6  1  6  1  7  4  5
 1  6  1  6  1  6  4  8  5
 2  1  6  1  6  9  4  5
 1  6  1  6  1  4  8  5
 3  1  6  9  4  8  5
 1  7  4  4  8  5
 4  4  8  5  5
 5  5  5  # core loading by the bundle types, Core_Load(N_POLY)

1  4  15*4   1 # Material composition of the 1st bundle type
1  5  15*9   1 # Material composition of the 2nd bundle type, etc.
1  5  15*7   1 # nb =   3
1  6  15*6   1 # nb =   4
2  2  15*2   2 # nb =   5
1  5  15*8   1 # nb =   6
1  6  15*11  1 # nb =   7
3  3  15*3   3 # nb =   8
1  6  15*10  1 # nb =   9
```

`GMT_BND_COND`

Description: Boundary conditions (BC)

Default value: -

Input data format: At first, we input the integer flag `i_dr` of the boundary conditions for the West (LEFT), East(RIGHT) , North and South boundaries.

If `i_dr==1` we define the logarithmic derivative of the neutron flux as a boundary condition constant. If `i_dr==0` the extrapolated distance should be given as a boundary constant.

Then, we give the boundary condition constants (logarithmic derivative if i_dr==1) as a real array of dimension `NG` for the West (LEFT), East(RIGHT) , North and South boundaries.

The description of the boundary conditions in axial directions is performed in the same way. First we define a type of the boundary conditions for the Bottom and Top boundaries, then we give the boundary condition constants. In the case of 2D calculations, the type of the axial boundary conditions is omitted and the buckling array of dimension `NG [cm^2]` is given instead of the boundary condition constants.

Example:

The boundary conditions for 3D NEACRP PWR rod ejection benchmark are defined as follows:

```
GMT_BND_COND # Boundary conditions (BC)
  1 0 1 0 # I_dr Type of the BC West (LEFT), East(RIGHT) , North and South
  0. 0.   0. 0.   0. 0.  0. 0. # BC constants
  0  0 # I_dz Type of the axial BC (Bottom, Top)
  0. 0.   0. 0. # BC constants for axial BC
```

The input data define the reflective boundary condition at the *West (LEFT)* and *North* boundaries and zero flux boundary conditions on the other boundaries.

An another example is the boundary conditions for four-group 2D KOEBERG PWR benchmark.

```
GMT_BND_COND # Boundary Conditions (BC)
  1 1 1 1 # I_dr Type of the BC West (LEFT), East(RIGHT) , North and South
  0. 0. 0. 0.   0.5 0.5 0.5 0.5   0. 0. 0. 0.
              0.5 0.5 0.5 0.5 # BC constants
  0. 0. 0. 0. # Axial buckling
```

The input data define the reflective boundary conditions at the *West (LEFT)* and *North* boundaries and vacuum boundary conditions on the *East(RIGHT) and South* boundaries. The problem is two-dimensional, the axial buckling is zero.

3.3.4 Control Rod Description

The set of the data related to the control rods is given under identifiers, which start with `CRD`. The list of the identifier and the data descriptions are given as follows.

`CRD_COR_LOAD`
Description: control rod types, integer array of dimension of the number of control rods `NN_Crod`.
Default value: `1`

`CRD_MAT_COMP`
Description: material compositions for each control rod type `NN_CRod_Type` and control rod element `NN_CRod_El`, integer array of dimension `(NN_CRod_El, NN_CRod_Type).` Two control rod elements are usually defined: absorber and driver.
Default value: `1`
Input data format:

```
DO n = 1, NN_CRod_Type
   READ(io_unit,  fmt=*, iostat=ios)
&              (CR_Compos(ie, n), ie = 1, NN_CRod_El)
END DO
```

Example:
The control rod material compositions for NEACRP PWR rod ejection benchmark are defined as follows:

```
CRD_MAT_COMP
 1 3 # Material composition for 1st type of CRD
 2 3 # Material composition for 2nd type of CRD
```

`CRD_LOCATION`
Description: location of the control rods in the reactor core, an index of the assembly (bundle) covered by the control rod, an integer array of dimension `(NN_CRod_Bundle, NN_Crod).` `NN_CRod_Bundle` is the number of assemblies (bundles) covered by control rod. In the case of PWR, `NN_CRod_Bundle=1;` in the case of BWR, `NN_CRod_Bundle=4.`
Default value: `0`
Example:
The control rod positions for NEACRP PWR rod ejection benchmark, case A1 are defined as follows:

```
CRD_LOCATION # Locations of control rods in the reactor core
   1     3           7
     11          15
   19    21    23    25
            31
         38    40
      45
   51    53    # index of the assembly covered by control rod
```

`CRD_POSITION`

Description: position of the control rods [cm]. A real array of dimension NN_Crod. In the case of PWR positions are defined from the reactor bottom; in the case of BWR positions are given from the reactor top.
Default value: 0.0

CRD_H_ROD_EL
Description: length of the control rods elements, [cm]. A real array of dimension (NN_CRod_El). NN_CRod_El is the number of the control rod elements, usually we have two elements: absorber and driver.
Default value: 0.0

CRD_BNK_INDX
Description: number of CR Banks and number of CR in each bank
Default value: 0
Example:
The control rod banks for VVER-1000 Unit 3 of Kalinin NPP are defined as follows:

```
CRD_BNK_INDX # number of CR Banks and number of CR in each Bank
 10
 3 6 6 6 6 6 6 9 7 6
```

CRD_BNK_POSA
Description: position of control rod banks in the absolute values [cm] (from the top of the reactor core)
Default value: 0

CRD_BNK_POS%
Description: relative position of control rod banks in percents [%];
Default value: 0
Example:
The control rod banks for VVER-1000 Unit 3 of Kalinin NPP are defined as follows:

```
CRD_BNK_POS% Positin in % CR bank insertion in the core

  0. 0. 0. 0. 0. 0. 0. 0. 0. 20.
```

The following control rod input data are read only for the neutron kinetics problems.

CRD_TOP_POSI
Description: Top in the case PWR or bottom in the case of BWR position of the control rods;
Default value: height of the reactor model.

CRD_BOT_POSI
Description: Bottom in the case PWR or top in the case of BWR position of the control rods;
Default value: 0.0

CRD_TIM_STRT
Description: start time of the control rod movement, [s].
Default value: 0.0

CRD_TIM_END
Description: end time of the control rod movement, [s].

Default value: `1.E+30`

`CRD_NUM_MOVE`
Description: Number of the moving control rods.
Default value: `0`

`CRD_IND_MOVE`
Description: Indexes of the moving control rods, integer array of dimension of the number of the moving control rods.
Default value: `0`

`CRD_MOV_TYPE`
Description: A type of the control rod movement, two variants are available:
`"LIN"` is the linear movement of the control rods;
`"SIN"` is the sinusoidal movement of the control rods.
Default value: `"LIN"`

In the case of the linear movement of the control rods (`CRD_MOV_TYPE=="LIN"),` the data under identifier `CRD_VEL_RODS` may be given as follows

`CRD_VEL_RODS`
Description: Velocity of the moving control rods [cm]
Default value: `0.0`

In the case of the sinusoidal movement of the control rods (`CRD_MOV_TYPE=="SIN"),` the data under identifiers `CRD_SIN_AMPL` and `CRD_SIN_FREQ` may be given as follows

`CRD_SIN_AMPL`
Description: Amplitude of the moving control rods [cm], real array of dimension of the number of the moving control rods.
Default value: `0.0`

`CRD_SIN_FREQ`
Description: Frequency of the moving control rods [1/s], real array of dimension of the number of the moving control rods.
Default value: `1.0`

`CRD_FLG_SCRM`
Description: Set of the data related to the reactor scram. If this identifier is given the scram is "ON", otherwise it is "OFF".
Default value: scram is "OFF"
Input data format: The following data should be given under this identifier:

```
read(io_unit,fmt=*,iostat=ios) v_rods_scram
read(io_unit,fmt=*,iostat=ios) Nrod_Scram
read(io_unit,fmt=*,iostat=ios)
   &     (Num_Rod_Scram(i), i= 1, Nrod_Scram)
read(io_unit,fmt=*,iostat=ios) Power_Scram
read(io_unit,fmt=*,iostat=ios) Time_Scram_Delay
```

where
`v_rods_scram -` velocity of the scram control rods;
`Nrod_Scram –` number of the control rods participating in scram;
`Num_Rod_Scram -` indexes of the control rods participating in scram;

`Power_Scram` – power level [MWt], when scram signal is activated;
`Time_Scram_Delay` – time delay [s] after the scram signal before the control rods start moving.

3.3.5 Data for Internal Thermal-Hydraulics Model

The set of the data related to the internal thermal-hydraulics model is given under identifiers, which start with `TH` and `FRD`. This data are input only the variable `TH_Model="Internal"` in the namelist `IN_PROBLEM` in the namelist file "SKETCH.INI". The list of the identifier and the data descriptions are given as follows.

`TH_TEMC_INLT`
Description: inlet coolant temperature, [K]
Default value: -

`TH_PRES_COOL`
Description: coolant pressure, [Mpa]
Default value: -

`TH_MFRT_ASSM`
Description: coolant mass flow rate per assembly, [kg/(m^2 s)]
Default value: -

`TH_HYDR_DIAM`
Description: equivalent hydraulic diameter, [m]
Default value: -

`TH_HTCF_CNST`
Description: constants of the Dittus-Boelter formula for the heat transfer coefficient
Default value: 0.023, 0.4, 0.8
Example:

```
TH_HTCF_CNST # heat transfer coefficient constants (Dittus-Boelter)
   0.023  0.8  0.4 # Const_DB, Pow_Reynolds, Pow_Prandtl
```

`TH_SURF_VOLM`
Description: ratio of the surface area of cladding to the volume of the coolant, [1/m]
Default value: -

`TH_FLOW_AREA`
Description: relative flow area
Default value: -

`FRD_RAD_PELT`
Description: radius of fuel pellet, [m]
Default value: -

`FRD_RAD_CLAD`
Description: inner and outer radiuses of the cladding
Default value: -

`FRD_DNS_F&CL`
Description: densities of the fuel and cladding [kg/m^3]
Default value: -

FRD_GAP_COND
Description: gap conductance [watts/(K m^2)]
Default value: -

FRD_ALF_DOPL
Description: interpolation parameter to compute the Doppler fuel temperature
Default value: -

FRD_RAT_ASFL
Description: ratio of the assembly volume to fuel volume
Default value: -

FRD_POW_FROD
Description: power distribution inside a fuel rod, the real array Power_Pin of dimension NN_FRD_FUEL+1, if the identifier is missing the flat power distribution is assumed and Power_Pin=1.0
Default value: 1.0

3.3.6 Data for Thermal-Hydraulics Model SKAZKA

The set of the data related to the thermal-hydraulics model SKAZKA is given under identifiers, which start with TH, FRD, ASS and ASS0. The identifiers, starting with TH and FRD have the same meaning as described in the previous section for the internal thermal-hydraulics model. These data are input only when the variable TH_Model="SKAZKA" is defined in the namelist IN_PROBLEM in the file "SKETCH.INI". The list of the identifier and the data descriptions, used only in the SKAZKA model are given as follows.

ASS_TYP_CULC
Description: method of the geomatry specification for SKAZKA model
Default value: -

AS0_NUM_TUBE
Description: number of the non-fuel tubes in the fuel assembly
Default value: -

AS0_NUM_PINS
Description: number of the fuel pins in the fuel assembly
Default value: -

AS0_DIA_TUBE
Description: outer diameter of the control rod tubes [m]
Default value: -

AS0_LEN_WREN
Description: fuel assembly pitch including the water gap [m]
Default value: -

AS0_DEL_WGAP
Description: size of the water gap between fuel assembly [m]
Default value: -

AS0_DEL_CASI
Description: width of the fuel assembly channel [m]
Default value: -

ASS_LBS_SIEV
Description: number of the fuel assembly spacers and their axial positions;
Default value: -

ASS_HEI_CORE
Description: ??
Default value: -

ASS_HEI_UPCH
Description: ??
Default value: -

ASS_HEI_DWCH
Description: ??
Default value: -

TH_MAP_PARTS
Description: a ratio of the fuel assembly area used in the neutronics model to the full fuel assembly area;
Default value: -