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Institut für Neutronenphysik und Reaktortechnik
Projekt Schneller Brüter

Calculation of Group Constants for Use in the Two Dimensional Dynamics Code KINTIC-2

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Abstract:

The scheme for treating group constants, which is used in the space dependent dynamics code KINTIC /1/, has been revised to include microscopic group constants depending on material composition. A description of the new scheme is given. The different calculational steps to be performed for creating a data set of group constants for KINTIC-2 are described together with the special codes to be used in the process. In reading this report, a prospective user of KINTIC-2 will be able to prepare the group constants for the code.

Berechnung von Gruppenkonstanten für den zweidimensionalen Dynamikcode KINTIC-2

Kurzfassung:

Das in dem ortsabhängigen Dynamikcode KINTIC /1/ benutzte Gruppenkonstantenschema wurde so abgeändert, dass die Abhängigkeit mikroskopischer Gruppenkonstanten von der Materialzusammensetzung behandelt werden kann. Das neue Schema wird vorgestellt. Die verschiedenen Rechenschritte, die bei der Erstellung eines Datasets von Gruppenkonstanten für KINTIC-2 durchlaufen werden müssen, werden zusammen mit den dafür benötigten Spezialroutinen beschrieben. Der Report soll zukünftige Benutzer von KINTIC-2 in die Lage versetzen, die Gruppenkonstanten für den Code zu berechnen.

Contents:

1. Introduction

The two dimensional dynamics program KINTIC has been developed for the calculation of the predisassembly phase of hypothetical core disruptive accidents. Its first version, KINTIC-1 /1/, was completed in 1972. Subsequently, a number of modifications were made leading to the newer version KINTIC-2 /2/, which has recently been included in the Karlsruhe nuclear code system KAPROS /3/. Currently it is being coupled to the thermodynamics modules of the point kinetics safety analysis code CAPRI-2 /4/.

As soon as KINTIC-1 was used for production runs, it became obvious that the initial scheme for treating group constants was not suited for big problems. In this scheme one set of macroscopic group constants is used for each 'feedback zone', i. e. each zone that differs from its neighbors not only in material composition and neutron spectrum but, in addition, in temperature and material density. These macroscopic group constants are broken up into the contributions of the so-called macro-materials, e. g. fuel, clad, coolant, etc., which are added up at each time step to result in the total macroscopic group constants. The effects of temperature and density changes on macroscopic group constants can be accounted for in this scheme, but not the effect of density changes on microscopic group constants. (For an evaluation of the importance of treating composition dependent microscopic group constants in practical cases see /5/.) If this last effect is to be included, one would have to use several sets of macroscopic group constants per feedback zone. This would lead to unacceptably big data blocks and a big number of calculational operations per time step.

For KINTIC-2, another scheme has therefore been adopted, which links the data sets of group constants containing all information on microscopic group constants depending on densities and temperature to the basic reactor zones only, i. e. to the zones differing in initial material composition or - if group-collapsing is used - in neutron spectrum. The total number of these zones is limited even in a big assembly, and the resulting data set has therefore an acceptable length.

One result of the altered scheme for treating group constants is the ability to treat the effects of microscopic group constants depending on density changes, e. g. of sodium or fuel. First results of comparative calculations have been published elsewhere /5/ and need not be repeated here.

When changing the scheme for treating group constants, programs have to be provided for producing the data sets to be used in KINTIC-2. As far as possible, use has been made of the old programs described in the report on KINTIC-1 /1/, but one program, KINCO, had to be added. The resulting set of programs has now been included in the KAPROS library, and an additional module, KINWQ, was written, which is to be used together with KINCO and the older programs for producing a file of group constants in one step.

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This report intends to enable a prospective user of KINTIC-2 to produce a file of group constants for the code. It starts with a description of the scheme for treating group constants in chapter 2. In chapter 3, the user is introduced to the different stages in the production of the file of group constants - calculation of group constants, calculation of temperature derivatives of group constants, reorganization. The special programs to be used in this process together with already existing programs are described in chapters 4-7, and the input for two illustrative sample cases is listed in an appendix.

2. The scheme for treating group constants used in KINTIC-2

The new scheme for treating group constants in KINTIC-2 was developed in order to achieve the following three objectives:

1. to get data blocks of group constants, which are of manageable size even for a big number of prompt neutron groups (>6) and feedback zones;
2. to include microscopic group constants depending on material composition;
3. to dispose of a flexible scheme admitting a simple as well as a sophisticated treatment of group constants.

These goals are reached with the introduction of a reactor subzone concept for the group constants, in which each subzone is provided with a data set containing all information on group constants depending on composition and temperature. The number of subzones to be used depends on the degree of sophistication desired. At the very minimum they comprise all zones with different material compositions. Slight deviations in one zone due to e. g. steady state temperature distributions need not be taken into account. If necessary, these zones are to be divided into as many subzones as are needed for the adequate treatment of the different neutron spectra. The subzones need not be geometrically coherent. For example, one core enrichment zone may be divided into two subzones characterized by different spectra, one pertaining to the core zone central region, the second one to the two regions adjacent to the upper and lower blanket.

One must then determine for each subzone seperately, how many sets of group constants are to be used for an adequate description of the effect of the material movements taking place during the transient. In a void case one may use one with and one without coolant for each subzone in which voiding is expected, and only one set for the normal composition for subzones, which are not affected by voiding. Simpler schemes using but one set for each subzone and much more complicated ones taking into account the effects of alterations in clad and fuel contents in addition to voiding may be realized. It must be stressed, that the way in which the group constants in one subzone are treated does not affect the scheme to be used in another subzone. Thus, one may e. g. treat the core zone of a reactor with the most complicated scheme comprising 12 different sets of group constants and Doppler data and in the same calculation use the most simple scheme, i. e. one set without Doppler data, for reflector zones.

The number of variants that may be used for treating changes of material composition is the following:

1. For changes of coolant contents (voiding), two sets may be used, one for the normal and one for the voided case.
2. Changes of clad contents (clad slumping) may be treated with two sets also, the first of which pertains to the normal

conditions. The second one may pertain to zero clad contents in cases where only clad slumping is anticipated, or to zero clad + structural material contents, if movements of the structural material are to be treated in addition.

3. Changes of fuel contents (fuel slumping) may be treated with three sets for normal, zero, and twice normal fuel concentration.

If this scheme is used to its full extent, 12 sets of group constants per subzone result. Practically, this will be done only for core zones and possibly for blanket zones. For all other zones (reflectors, absorbers, etc.) simpler versions of the scheme will be used, mostly only one set.

For including composition dependent microscopic group constants it is not necessary to store the group constants of each isotope seperately. Rather, the group constants of all isotopes forming one macro-material are summarized - as it was done in the old scheme already - resulting in the macroscopic group constants of this macro-material in the standard composition. If this value is divided by the density and volume fraction of the macro-material in the standard composition, the resulting value is equivalent to a microscopic group constant for the macro-material. In the following, the term 'microscopic group constant' will always be used in this sense if not explicitely stated otherwise.

With the programs to be described in the following chapters the data sets of group constants are calculated and converted into the form suitable for KINTIC-2. Apart from the file thus created, the only additional information KINTIC-2 needs for the calculation of group constants is on which feedback zone pertains to which subzone. In case the initial composition of the feedback zone deviates from the steady state composition of the subzone, e. g. in the case of coolant densities depending on axial position, the deviation must be specified. The group constants for the actual state of the reactor are determined in KINTIC-2 by interpolating the values of the microscopic group constants in the different sets. The interpolation is not linear and will be specified in detail later.

The file of group constants, with which KINTIC-2 is provided, thus contains for each subzone group constants for different variants of the steady state composition, each of which is characterized by a set of standard densities and volume fractions for the macro-materials (fuel, clad, etc.) contributing to the composition. The following macro-materials may be specified: Fuel ('BRENN'), clad ('HUELL'), coolant ('KUEHL'), and structural material ('STRUK'). For physical reasons, densities and volume fractions are always defined seperately, but in the treatment of the group constants, only the product is of any importance.

The sets of group constants pertaining to the different variants of compositions are calculated for the reference temperature T_0. For subzones containing fuel, the temperature derivatives of the macroscopic fission and capture group constants at different temperatures are calculated in addition for each variant. They are not tabulated directly, but are

approximated before by

$$\frac{\partial \Sigma}{\partial T} = A \left(\frac{T_o}{T} \right)^x \quad ; \quad T_o = 300^\circ K \tag{1}$$

Thus, the temperature dependence of group constants is transfered to KINTIC-2 via the group dependent Doppler parameters A and x. One set of these parameters is calculated for each variant of a composition containing fuel.

In KINTIC-2, actual group constants for each feedback zone are calculated from the data collected in the file of group constants using the actual material densities, volume fractions and temperatures. First, the group constants of the macro-materials and their derivatives are interpolated with regard to the microscopic group constants depending on the standard compositions. Then, the derivatives of the group constants are integrated up to the actual fuel temperature and added to the group constants, resulting in the group constants of the macro-materials for the actual temperatures. At last, the contributions of the macro-materials are added to result in the actual macroscopic group constant of the total composition. These operations are performed by the module QSUM, which is part of the KINTIC-2 system.

For a better understanding, the formulas used in QSUM will be listed here. The actual state of a feedback zone is characterized by the set of densities, volume fractions and fuel temperature:

actual state: $(\rho V F)_1, \ldots (\rho V F)_M, T$

The total macroscopic group constant of this zone is the sum of the contributions of the different macro-materials:

$$\Sigma \left[(\rho V F)_1, \ldots (\rho V F)_M, T \right] = \sum_{m=1}^{M} \Sigma_m \left[(\rho V F)_1, \ldots (\rho V F)_M, T \right] \tag{2}$$

Σ total macroscopic group constant

Σ_m macroscopic group constant of macro-material m

M total number of macro-materials

$(\rho V F)_m$ product of actual density * actual volume fraction of macro-material m

T temperature of fuel

The macroscopic group constant of macro-material m is given by the interpolated group constant for the reference temperature and the integrated temperature derivative (if any):

$$\Sigma_m [(\rho V)_1, \ldots (\rho V)_M, T] =$$

$$= (\rho V)_m \left\{ \sigma_m^i [(\rho V)_1, \ldots (\rho V)_M, T_o] + \right.$$

$$\left. + \int_{T_o}^{T} \frac{\partial \sigma_m^i}{\partial T} [(\rho V)_1, \ldots (\rho V)_M, T'] \, dT' \right. \qquad (3)$$

σ_m^i interpolated microscopic group constant

$\frac{\partial \sigma_m^i}{\partial T}$ interpolated derivative of microscopic group constant ($\neq 0$ only for m=fuel)

T_o reference temperature

The interpolation is performed with the values of the group constants for the macro-material calculated for the different standard variants of the composition of the adequate subzone for the reference temperature. Each of these variants is characterized by a set of volume fractions and densities for the macro-materials, i. e.:

variant n: $(\rho V)_1^n, \ldots (\rho V)_M^n, T_o$

The value of the group constant of macro-material m for variant n is Σ_m^n. This is the macroscopic group constant contained in the file. The interpolation is performed on

$$\sigma_m^n = \Sigma_m^n / (\rho V)_m^n \qquad (4)$$

i. e. on the microscopic group constant of the macro-material. Thus, the interpolated group constant for the reference temperature is given by:

$$\sigma_m^i [(\rho V)_1, \ldots (\rho V)_M, T_o] = F [\sigma_m^1, \ldots \sigma_m^N ;$$

$$(\rho V)_1^1, \ldots (\rho V)_M^1, (\rho V)_1^2, \ldots (\rho V)_M^N ; \qquad (5)$$

$$(\rho V)_1, \ldots (\rho V)_M]$$

N number of variants

F interpolation function depending on type of group constant and on number of variants

For the calculation of the temperature derivatives in eq. (3), the parameters A and x from eq. (1) are treated in the same way as the group constants. The Doppler parameters of variant n are A^n and x^n. The interpolation is performed on:

$$a^n = A^n / (\varrho F)^n_{fuel} \qquad (6)$$

$$x^n$$

Here, a^n is equivalent to the derivative of a microscopic group constant, whereas x^n, being an exponent, need not be normalized. For the interpolation, eq. (5) is used with a or x, respectively, instead of σ. The integration in eq. (3) is then performed using the interpolated parameters.

The interpolation function F depends on the type of data to be interpolated - group constant, a, or x - and on the macro-material on which the data depend. It is mostly nonlinear owing to the nonlinear dependence of self-shielding factors on material composition. The way in which these formulas were established has been described in detail elsewhere /5/. The functions F, which are used in KINTIC-2, are listed in table 1.

As an example, formulas (2)-(5) will be given for a case, in which group constants are to be interpolated between the voided and the unvoided case (N=2) for only two macro-materials, fuel and coolant, present. The two standard variants are characterized by:

1. variant: $(\varrho V F)^1_{fuel} = (\varrho V F)_{fuel}$, $(\varrho V F)^1_{Na} = (\varrho V F)^{normal}_{Na}$

2. variant: $(\varrho V F)^2_{fuel} = (\varrho V F)_{fuel}$, $(\varrho V F)^2_{Na} = (\varrho V F)^{void}_{Na}$

In the second variant, the sodium contents is assumed to be a small, non-zero fraction of the normal sodium contents in crder to get non-zero sodium group constants for the interpolation. The group constants contained in the set of group constants for fuel and sodium are:

$$\Sigma^1_{fuel} = \Sigma_{fuel}\left[(\varrho F)_{fuel}, (\varrho F)^{normal}_{Na}, T_0\right]$$

$$\Sigma^2_{fuel} = \Sigma_{fuel}\left[(\varrho F)_{fuel}, (\varrho F)^{void}_{Na}, T_0\right]$$

$$\Sigma^1_{Na} = \Sigma_{Na}\left[(\varrho F)_{fuel}, (\varrho F)^{normal}_{Na}, T_0\right]$$

$$\Sigma^2_{Na} = \Sigma_{Na}\left[(\varrho F)_{fuel}, (\varrho F)^{void}_{Na}, T_0\right]$$

Group constants of fuel and sodium for interpolation:

$$\sigma^{1}_{fuel} = \Sigma^{1}_{fuel} / (\rho V F)_{fuel} \quad ; \quad \sigma^{2}_{fuel} = \Sigma^{2}_{fuel} / (\rho V F)_{fuel} \qquad (4a)$$

$$\sigma^{1}_{Na} = \Sigma^{1}_{Na} / (\rho V F)^{normal}_{Na} \quad ; \quad \sigma^{2}_{Na} = \Sigma^{2}_{Na} / (\rho V F)^{void}_{Na}$$

The interpolated group constants for fuel and sodium are, with actual material densities and volume fractions $(\rho V F)_{fuel}$, $(\rho V F)_{Na}$:

$$y = \frac{(\rho V F)_{Na}}{(\rho V F)^{normal}_{Na}}$$

$$\sigma^{i}_{fuel}\left[(\rho V F)_{fuel}, (\rho V F)_{Na}, T_0\right] = \frac{\sigma^{1}_{fuel}}{\left(\frac{\sigma^{1}_{fuel}}{\sigma^{2}_{fuel}} - 1\right)\sqrt{1-y}^{\,3} + 1} \qquad (5a)$$

$$\sigma^{i}_{Na}\left[(\rho V F)_{fuel}, (\rho V F)_{Na}, T_0\right] = \frac{\sigma^{1}_{Na}}{\left(\frac{\sigma^{1}_{Na}}{\sigma^{2}_{Na}} - 1\right)\sqrt{1-y}^{\,3} + 1}$$

If no temperature effects are present, the macroscopic group constant in this example is given by:

$$\Sigma\left[(\rho V F)_{fuel}, (\rho V F)_{Na}, T_0\right] = \qquad (2,3a)$$

$$= \sigma^{i}_{fuel} (\rho V F)_{fuel} + \sigma^{i}_{Na} (\rho V F)_{Na}$$

In the above, we have mainly been concerned with the calculation of actual macroscopic group constants from the data provided in a file of group constants for KINTIC-2. In the remaining part of the report, a description will be given of the process, by which this file of basic group constants is to be created.

3. Creation of a data set of group constants for KINTIC-2

The calculation of the group constants for KINTIC-2 comprises six steps:

0. Establishing compositions and providing collapsing spectra for all subzones.
1. Calculation and collapsing of group constants depending on the different isotopes.
2. Evaluation of group constants for the different macro-materials.
3. Transformation of block format.
4. Calculation of Doppler parameters.
5. Reorganization.

Of these steps, the zero'th is left to the user. One could think of a more automatic procedure which does part of the work for this step too, mainly the setup of the different variants of the steady state composition of one subzone. Since this would entail a number of important changes in already existing programs, mainly the programs for evaluation of group constants for KINTIC-1, and since a new set of group constants is only calculated once in a while, work on such a procedure was postponed for the moment.

Thus, the user has to determine the necessary number of subzones, and for each subzone, the number of composition variants to be used, and has to calculate the isotopic composition of each variant himself. In the case of group collapsing, adequate collapsing spectra have to be determined for each variant.

In performing this zero'th step, the user has to observe a number of rules. The NUSYS programs used for calculating the group constants cannot make a difference between compositions pertaining to different subzones, but calculate the sets of group constants in the order in which the isotope compositions are given in the input (i. e. the KOMPO block). The user must therefore provide for the right order. The rules are:

1. No intermixing of compositions for different subzones is allowed.
2. If microscopic group constants are to depend on coolant contents, the composition with normal coolant contents is to be listed first, followed by the one for the voided case. Likewise for dependence on clad contents, first the normal composition and then the one with zero clad contents is to be given. If the group constants depend on fuel contents, the compositions are to be listed in the order: Normal contents, zero contents, twice normal contents.
3. If microscopic group constants are to depend on more than one macro-material, the order is the same as above with the contents of the first variable component varying most rapidly, the contents of the last one varying least rapidly. For the programs, the order of macro-materials is determined

by the order, in which they are listed in the input for KINCO (see chapter 6). In the most general case with group constants depending on fuel, clad, and coolant contents, the twelve variants are to be given in the following order (order of macro-materials: 1. fuel; 2. clad; 3. coolant):

Nr.	Fuel	Clad	Coolant
1	normal	normal	normal
2	'zero'	"	"
3	2 * normal	"	"
4	normal	'zero'	"
5	'zero'	"	"
6	2 * normal	"	"
7	normal	normal	'zero'
8	'zero'	"	"
9	2 * normal	"	"
10	normal	'zero'	"
11	'zero'	"	"
12	2 * normal	"	"

Of course, if the order of macro-materials is changed, the order of compositions in the above table is to be changed accordingly.

In the foregoing list, zero contents has been put in quotation marks because mostly the contents in this case should not be zero but a small fraction of the normal contents. Otherwise, zero group constants may result making an interpolation impossible. This is not the case if another macro-material having the same isotope composition is present and is not reduced to zero, as e. g. in the case of clad slumping only, when the contents of the structural material is not altered. The fourth rule is therefore:

4. Unless the group constants depend on clad contents excluding structural material contents, zero material contents is to be replaced by ε * normal material contents. $\varepsilon = 10^{-4}$ is recommended for clad + structural material and for the coolant. For the fuel, $\varepsilon = 10^{-2}$ should be used, because the temperature derivatives are not calculated for smaller fuel concentrations.

As far as possible, steps 1-5 are done with the programs, which were used already for the KINTIC-1 set of group constants /1/, but in an updated version. The main differences are:

1. All programs are integrated in the KAPROS system.
2. Doppler data have not to be transfered to KINTIC-2 via cards, but are part of the file of group constants.
3. A program (KINCO) for reorganizing the data for use in KINTIC-2 has to be run at the end of the compilation of group constants.

In addition, the module KINWQ has been developed, which is

to be used to mastermind the different steps of the calculation. It especially transfers the blocks containing the compositions and the collapsing spectra (KOMPO and SPEKT) from the program part for calculating group constants to the Doppler part. For the KINTIC-1 group constants calculation, these blocks had to be duplicated. Optionally, one may use preprogrammed checkpoints after the calculation of group constants and after the Doppler calculation for checking intermediate results before continuing.

Before starting with the input description for the special programs to be used in steps 1-5, a more detailed description of what is performed in each step will be given. It is assumed, that the reader is acquainted with the Karlsruhe NUSYS system.

-- Step 1: Calculation and collapsing of group constants depending on the different isotopes --

This step is performed with the KAPROS-NUSYS programs for calculation of group constants. Normally, the block of group constants for all isotopes in all compositions is far too big before collapsing to be stored in the fast memory of, e. g. the IBM 370/168. Therefore, groups of 3-7 compositions depending on the number of isotopes must be calculated seperately and stored externally after collapsing. In this case, step 1 is run repeatedly before proceeding with step 2. The operations to be done in each run - calculation of group constants, collapsing, external storage of results - are controlled by the user via the NUSYS input. At the end of step(s) 1, either one block of group constants and one block of isotope compositions is in internal storage - for only one group of compositions - or several blocks are on an external file - for more than one group of compositions. In addition, the block containing the collapsing spectra is in internal storage.

-- Step 2: Evaluation of group constants for the different macro-materials --

The program to be used for this is the KAPROS-NUSYS code 02250 (chapter 4). This program expects the block of group constants and the one containing the isotope compositions in internal storage. Therefore, in the case of but one group of compositions, one may directly start step 2 with 02250. In the case of more than one group, one must use the KAPROS-NUSYS code 02291 for reading the results from external storage and combining them in one block of group constants and one block of isotope compositions. NUSYS program 0225C summarizes the group constants for the macro-materials from the group constants for the different isotopes and incorporates the data of the delayed neutrons.

-- Step 3: Transformation of block format --

The block of group constants resulting after step 2 has the so-called SIGMA structure and must be converted to the SIGMN structure, which is the one used by KINTIC-2. This is done by the KAPROS module CCSCTN. Whereas in step 1 and 2 the user has to determine the operations via input, this step is run automatically by KINWQ. A checkpoint is possible after step 3. (If the group constants are to be used for KINTIC-1 instead of KINTIC-2, the further steps are to be omitted.)

-- Step 4: Calculation of Doppler parameters --

The program for evaluation of Doppler data, formerly called DOPKIN, has now been incorporated in the KAPROS version of NUSYS and is to be refered to as 04100 (chapter 5). Its function is unaltered. It makes successive calls to the NUSYS program 01706 for calculating the temperature derivatives of the capture and fission group constants in all compositions and in the end collapses the results and approximates them by eq. (1). The results are stored on the intermediate file of group constants.

-- Step 5: Reorganization --

The last part of the organization is performed by the program KINCO. It enlarges the block of macroscopic group constants if necessary, deletes superfluous blocks, which are created by 02250 for use in KINTIC-1 but are not used in KINTIC-2, and sets up two new blocks. The result is an external file containing four blocks (three in case of a calculation without feedback):

I. A block of macroscopic group constants with at least as many compositions as there are feedback zones in the reactor to be calculated. At this stage of the calculation the actual values of the group constants contained in the block are irrelevant. It serves to transfer the special structure of the SIGMN block to KINTIC-2, which in the course of the calculations fills it up with the macroscopic group constants for the actual state of the reactor. The name of this block in KINTIC-2 is TOTCRO.

II. A block containing the group constants of all macro-materials in all compositions pertaining to all subzones. This is the basic block of group constants for the reference temperature, from which actual macroscopic group constants are calculated. In KINTIC-2, this block is called MATCRO.

III. A block containing information on densities and volume fractions of the macro-materials in all compositions. It consists mainly of the input for the program KINCO (see chapter 6) and is called CORE1 in KINTIC-2.

IV. A block containing the temperature derivatives of the

fission and capture group constants in all compositions. This block is called DOPLER in KINTIC-2.

For the calculation of group constants for KINTIC-2, four programs have to be used, which were especially written for this purpose: The KAPROS-NUSYS codes 02250 (written by H. Bachmann /1/) and 04100, and the KAPROS modules KINCO and KINWQ. Though the first two of these have been described elsewhere already /1/, their input description will be included for completeness in the next two chapters of this report. In the following two chapters, a description of the two new programs, KINCO and KINWQ, is given, and some special input considerations for the use of all programs with KINWQ, including those KAPROS-NUSYS codes which are not described here, are included in chapter 7.

4. The KAPROS-NUSYS code 02250

In this chapter and the following ones, some input lists are given. They are written in the usual NUSYS format for unformatted input with Kn signifying a new card and Sn a logical decision. Variable names starting with I-N indicate fixed point numbers, all others are floating point numbers. All input is subject to the KAPROS input specifications.

The input description of the code 02250 was given in /1/ already. The input for the KAPROS version differs from the old one at two points only: In K2, the first constant number is altered, and in K14 and K15, a dummy input employing existent ccmposition numbers is used instead of the old input. (If the file of group constants is to be used for KINTIC-1, K14 and K15 have their old meaning.)

Input list for 02250:

K1	'02250'	Constant
K2	0	Constant
	NG	Number of energy groups ($\leq$26)
	MI	Number of compositions in the KOMPO block
	NMW	Number of original compositions to be duplicated for use in KINTIC
S3	if NMW=0 continue with K5, otherwise with K4	
K4	(NID(I), NM1(I), NM2(I), I=1,NMW)	The number of compositions is enlarged in the following way: Compositions NM1(I) through NM2(I) are identical to composition NID(I). For I=1, NM1 must equal MI+1; for I>1, NM1(I)=NM2(I-1)+1
K5	NBETA	Number of precursors ($\leq$6)
	MBETA	Number of heavy isotopes producing delayed neutrons
S6	for each precursor K7	
K7	(CHID(I), I=1,NG)	Group dependent delayed neutron spectrum
S8	for each of the MBETA heavy isotopes K9	
K9	NAME	Name of the isotope as given in the KOMPO block (e. g. 'U2350')
	(BETA(I), I=1,NBETA)	Fraction of precursors produced in fission for each precursor group
	(XLAM(I), I=1,NBETA)	Decay constant for each precursor group
S10	for each of the MI original compositions K11 - K13	

K11	NAK	Number of macro-materials in the composition (≤ 5). Normally NAK = 1 for compositions in non-feedback zones and NAK = 4 or 5 in feedback zones
S12	for each macro-material in the composition K13	
K13	LABEL	Name of the macro-material. Possible names: 'BRENN' for fuel, 'HUELL' for clad, 'KUEHL' for coolant, 'STRUK' for structural material, and 'BONDI' for bonding. The macro-material 'BONDI' may be used for gathering contributions, which for some reason shall not turn up in the other macro-materials.
	NIS (NAMIS(I), FRACT(I), I=1,NIS)	Number of isotopes contributing to the material For each isotope: Its name as given in the KOMPO block, e. g. 'AL270'; the fraction of its concentration contributing to the macro-material, i. e. $0<FRACT(I)\leq 1$. The sum of the fractions of each isotope in all macro-materials pertaining to one composition must equal 1.
K14	1	Constant
K15	1	Constant
	1	Constant

5. The KAPROS-NUSYS code 04100

This was formerly the NUSYS code DOPKIN, which had to be linked to the NUSYS-system via a compile-and-link step for each use. It is now integrated in the KAPROS-NUSYS system and given the number 04100. The results are not punched on cards any more, but written on the intermediate file of group constants. According to the change of name, the first input card is altered, but otherwise the input is the same as before.

The expansion polynomial cited below may be used for varying the fuel density with temperature. For KINTIC-2, let P1=P2=0 for all compositions.

Input list for 04100:

K1 '04100' Constant

K2 NTEMP Number of temperatures to be calculated (≤ 15)
(TEMP(I), Temperatures ($^{\circ}$K)
I=1,NTEMP)

K3 NPOLY Number of expansion polynomials (≤ 6)
(P1(I), Constant and linear coefficient for each poly-
P2(I), nomial
I=1,NPOLY)

K4 (MIPOL(I), For each composition, number of the adequate
I=1,MI) expansion polynomial. MI is the total number of compositions as given in the KOMPO block

S5 for group collapsing continue with K6 - K7, otherwise K8

K6 'COND' Constant

K7 NGG New number of groups
(NGRGR(I), For each new group, number of the last old group
I=1,NGG) it contains (as in group collapsing program 00352 of NUSYS)

6. The module KINCC

As has been stated already, KINCO serves to transform the data blocks calculated by the programs for group constants and Doppler into the form needed by KINTIC-2. Especially, the input for KINCO is needed for setting up the relation between the subzones and the different compositions. The name of the input block for KINCO is KINCOI, its testmodule is PM=PKINCO. Thus the card input for KINCO is to be preceded by the KAPROS control card:

```
*KSIOX DBN=KINCOI,TYP=CARD,PM=PKINCO
```

Input list for KINCO:

K1 NMN — Maximum number of feedback zones to be used in KINTIC-2
NFE — 1: Calculation with feedback; 0: No feedback
NMB — Number of subzones

S2 for each composition, including those duplicated by 02250, one card K3

K3 MB — Number of subzone to which the composition belongs
NMAMA — Number of macro-materials
(MANA(I), — Name of macro-material (8 alphanumerical characters; possible: 'BRENN', 'HUELL', 'KUEHL', 'STRJK', and 'BONDI')
KONU(I), — Control number for dependence of microscopic group constants:
- 0: Microscopic group constants do not depend on macro-material I
- 1: Interpolation with 2 points, nonlinear formula (coolant voiding, i. e. for MANA(I) = 'KUEHL')
- 2: Interpolation with 2 points, linear function (clad slumping without structural material, i. e. for MANA(I) = 'HUELL')
- 3: Interpolation with 2 points, nonlinear formula, clad and structural material are treated together (slumping of clad + structural material, i. e. for MANA(I) = 'HUELL' and MANA(I) = 'STRUK')
- 6: Interpolation with 3 points, nonlinear formula (fuel slumping, i. e. for MANA(I) = 'BRENN')

RHO(I), — Stationary material density (kg/m^3)
VF(I), — Stationary volume fraction
I=1,NMAMA)

NDOP	0:	No Doppler paramaters for composition MB
	1:	Doppler parameters are to be calculated
	-N:	Take Doppler parameters of composition N.

Remember, that the order of macro-materials in K3 determines the order, in which all programs expect the different variants (see chapter 3). Macro-materials, on which the microscopic group constants do not depend, may be inserted at any place, but the order of all macro-materials should be the same for all compositions belonging to the same subzone and should be identical with the order used in the input for the NUSYS-program 02250.

The module KINCO can be run seperately. In this case the necessary KAPROS control card is:

```
*GO SM=KINCO
```

The computer region needed by KINCO is 12K without space for the KAPROS system and the data blocks. The group constants are expected on an external file with data set number 20 and the file of transformed blocks for use in KINTIC-2 has the number 25.

7. The module KINWQ

KINWQ is the module supervising the creation of a file of group constants for KINTIC. The input for KINWQ is very simple, since nearly all modules which are called from KINWQ have their own input blocks. The following KAPROS modules are called from KINWQ (in the order of the steps listed in chapter 3):

1. KAPROS-NUSYS for calculation of group constants for groups of compositions. The module is called NNUS times for NNUS groups of compositions. After each call, KINWQ transfers the results onto a file with data set number 20 except for NNUS = 1, in which case the results are kept in the KAPROS life line.
2. KAPROS-NUSYS for combination of group constants and composition blocks (only if NNUS>1) and for reorganization of group constants with the program 02250. For NNUS>1, the blocks are read from file 20 and transformed into the two comprehensive blocks. For this, NUSYS program 02291 is to be called before 02250.
3. Module CCSOTN for a transformation of blocks of group constants. The transformed blocks are stored on file 20.
4. KAPROS-NUSYS for calculation of the Doppler parameters with programs 04100/01706. The results are stored on file 20.
5. KINCO for data set transformation. The blocks are read from file 20, the final results are stored on file 25.

Preprogrammed check points can be made after step 3 and after step 4. In each case, only file 20 has to be reserved for the restart, but the full input should be provided before and after each check point.

The input block for KINWQ is called KINWQI and is to be preceded by the KAPROS control card:

```
*KSIOX DBN=KINWQI,TYP=CARD,PM=KINCOI
```

One should use concatenation for the blocks KINWQI and KINCOI.

Input list for KINWQ:

K1	N1	1: Steps 1 - 3 are to be performed 0: Steps 1 - 3 are not to be performed (restart)
	N2	1: Step 4 is to be performed 0: Step 4 is not to be performed (restart or calculation without feedback)
	N3	1: Step 5 is to be performed 0: Step 5 is not to be performed
	NNUS	Number of composition groups

-- Input considerations for step 1 --

Each call to KAPROS-NUSYS in step 1 is to result in a set of group constants for one group of compositions. Thus the NUSYS programs to be used include the startup program 00397, the program 00446 for calculation of group constants, and, for collapsing, the program 00352. For NNUS>1 and collapsing, the block SPEKT containing all collapsing spectra must be brought into the lifeline in the first call to KAPROS-NUSYS using the utility program 00451. The blocks SABBR and KOMPO (and only these two blocks) must be specified for inclusion in the lifeline. Intermediate blocks, e. g. blocks of uncollapsed group constants in the case of collapsing, must be deleted. Since for successive calls of KAPROS-NUSYS several input blocks are to be specified, block indexing is to be used. In step 1, the input block pertaining to the N'th call to KAPROS-NUSYS is to be given the index N+3; e. g. for the first call, the KAPROS control card for the input block is:

*KSIOX DBN=NUDABL,IND=4,TYP=CARD,PMN=NUTEST

It is recommended that the input block KINCOI be provided for the first step already. The step will be run without it too, but input tests are imperfect without it.

-- Input considerations for step 2 --

The NUSYS programs to be specified in this step are 00397, for NNUS>1 the program 02291 for the coupling of blocks, and the program 02250. In the input for 02291, 20 is to be specified for the number of the file containing the blocks, and the blocks KOMPO and SABBR are to be coupled. The number of energy groups in the new KOMPO block is to be the number before collapsing. - The index of the input block for this step is 1.

-- Input considerations for step 3 --

This step is performed automatically. Input for CCSOTN must not be provided.

-- Input considerations for step 4 --

In this step, the programs 00397 and 04100, formerly DOPKIN, are to be used. The blocks KOMPO and SPEKT, which in the old version of DOPKIN had to be provided using 00451, need not be specified any more, since they are transfered to this step from the foregoing steps. In accordance with the rules for programs in NUSYS the number 04100 is to be specified in the input of 00397 for transfer of control to 04100. The input block for this step has the index 3. - The input block KINCOI is to be specified for this step already, since it is used for determining the compositions, for which temperature derivatives

are to be calculated.

-- Input considerations for step 5 --

This is the input for KINCO, which was described in the foregoing chapter.

-- Control cards for KINWQ --

For starting KINWQ, the following KAPROS control card is needed:

*GO SM=KINWQ

The necessary region even for small cases is about 480K due mainly to the length of the blocks of group constants, and gets larger for bigger cases. The data sets GROUCO and KEDAK3 have to be provided on files 4 and 1, respectively. In addition, the intermediate file 20 and file 25 for the KINTIC-2 group constants must be provided. For the dimensions of computer region and data sets the sample cases may provide some guidance.

It is hoped that this compilation and the complementary information in /1/ will enable the user to do his own evaluation of group constants for KINTIC-2. For an illustration, the full input, comprising all control cards for two sample cases, is listed in the appendix.

This report will be complemented by a report on KINTIC-2, which will be issued after the KINTIC system has been coupled to the CAPRI-2 thermodynamics modules.

Literature

/1/ L. Mayer, H. Bachmann: KINTIC-1: A program for the calculation of two-dimensional reactor dynamics of fast reactors with the quasistatic method; KFK 1627 (1972)

/2/ L. Mayer: Ortsabhängiger Dynamikcode KINTIC; KFK 1273/2, p. 123-1 (1973)

/3/ H. Bachmann, G. Buckel, W. Höbel, S. Kleinheins: The modular program system KAPROS for efficient management of complex reactor calculations; Proceedings of the Conference on Computational Methods in Nuclear Engineering, Charleston, USA, 15. - 17. 4. 1975

/4/ D. Struwe, P. Royl, P. Wirtz, et al.: CAPRI, a computer code for the analysis of hypothetical core disruptive accidents in the predissassembly phase; Proceedings of the ANS Topical Meeting on Fast Reactor Safety, Beverly Hills, USA, 2. - 4. 4. 1974

/5/ L. Väth, D. Struwe: Space-time dependent codes and problems of few group cross section schemes; Proceedings of the European Nuclear Conference, Paris, 21. - 25. 4. 1975

APPENDIX

Input samples

On the following pages, two examples for calculating group constants for KINTIC-2 are given. All input data, ASP-, CS-, and KAPROS-control cards are listed. The characteristics of the samples are: 2 subzones (core and blanket), each containing an initial composition consisting of fuel, clad, coolant, and structural material. 13 isotopes make up the initial core composition, 9 isotopes the blanket composition. 6 isotopes produce 6 groups of delayed neutrons. For the final step, it is assumed, that 10 feedback zones are required in the KINTIC-2 calculations.

In the first case, the microscopic group constants are constant. Thus, only one variant is calculated for each subzone. The group constants are calculated in one step (NNUS=1) without collapsing.

In the second case, the microscopic group constants are to depend on the sodium contents. Consequently, two variants per subzone are calculated. In this case, two groups of compositions are used (NNUS=2) and the original 26 groups are collapsed to 5 groups.

A few explanations should be given regarding the control cards. The libraries used in both cases are: GROUC0 containing the 26 group KFKINR group constant set, and KNDF (KEDAK2) containing nuclear data for the calculation of the Doppler effect. If KEDAK3 is to be used, NUSYS0 must be replaced by GFK050 and KNDF by KEDAK3. The final data set is stored on TSTLIB with the data set name WQDS.iiinnn, with iiinnn signifying the user identification. The SPACE parameters in the OS control cards for data sets 20 and 25 are adapted to the cases under consideration as well as region and time parameters on the job card.

Sample 1

```
//...JOBCARD...,
// REGION=480K,TIME=(,30)
/*SETUP DEVICE=2314,ID=NUSYS0
/*FORMAT PR,DDNAME=FT42F001
// EXEC KSG
//K.FT01F001 DD DSN=KNDF,UNIT=2314,VOL=SER=NUSYS0,
// DISP=(OLD,KEEP)
//K.FT04F001 DD DSN=GROUCO,UNIT=3330,VOL=SER=KAPROS,DISP=SHR
//K.FT20F001 DD UNIT=DISK,SPACE=(TRK,12)
//K.FT25F001 DD DSN=WQDS.iiinnn,UNIT=3330,VOL=SER=TSTLIB,
// DISP=(NEW,KEEP),SPACE=(TRK,10)
*KSIOX DBN=KINWQI,TYP=CARD,PM=KETT
1 1 1 1
*$*$
*KSIOX DBN=KINCOI,TYP=CARD,PM=PKINCO
10 1 2
1 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 0 .86 .465
'STRUK' 0 8. .09 1
2 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 0 .86 .465
'STRUK' 0 8. .09 1
*$*$
*KSIOX DBN=NUDABL,IND=4,TYP=CARD,PMN=NUTEST
1 4
'00397'
446 0 0 0
'ENDE'
'00446'
0 0 0 2 446
'SABBR' 'KOMPO' 446
0 0 0 446
'KOMPO'
'26-GR' '.KFKI' 'NR001' 0 26 2 0 13 446
'CR520' 'FE560' 'NA230' 'NB930' 'NI590' 'O 160' 'PU390' 'PU400'
'PU410' 'PU420' 'SI280' 'U2350' 'U2380' 446
13 1 .002869 2 .011405 3 .010472 4 1.0038-4 5 .0022636 6 .01335
7 8.02-4 8 2.35-4 9 2.7-5 10 5.-6 11 1.494-4 12 1.4-5 13
.005592 446
9 1 .0031128 2 .012374 3 .0069586 4 1.0891-4 5 .002456 6
.018953 11 1.621-4 12 2.3957-5 13 .0094527 446
'WQFIN'
'NUFIN'
*$*$
*KSIOX DBN=NUDABL,IND=1,TYP=CARD,PMN=NUTEST
0
'00397'
2250 0 0 0
'ENDE'
'02250'
0 26 2 0
6 6
```

```
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
0 0 0 .029 .147 .353 .263 .147 .051 .01 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0
'PU390' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU400' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU410' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU420' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'U2350' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'U2380' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
4
'BRENN' 7 'O 160' 1. 'PU390' 1. 'PU400' 1. 'PU410' 1. 'PU420'
1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
4
'BRENN' 3 'O 160' 1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
1
1 2
'NUFIN'
*$*$
*KSIOX DBN=NUDABL,IND=3,TYP=CARD,PMN=NUTEST
2 1 4
'00397'
4100 0 0 0
'ENDE'
'04100'
5 300. 600. 900. 1500. 2100.
1 0 0
1 1
'NUFIN'
*$*$
*GO SM=KINWQ
```

Sample 2

```
//...JOBCARD...,
// REGION=480K,TIME=(,35)
/*SETUP DEVICE=2314,ID=NUSYS0
/*FORMAT PR,DDNAME=FT42F001
// EXEC KSG
//K.FT01F001 DD DSN=KNDF,UNIT=2314,VOL=SER=NUSYS0,
// DISP=(OLD KEEP)
//K.FT04F001 DD DSN=GROUCC,UNIT=3330,VOL=SER=KAPROS,DISP=SHR
//K.FT20F001 DD UNIT=DISK,SPACE=(TRK,10)
//K.FT25F001 DD DSN=WQDS.iiinnn,UNIT=3330,VOL=SER=TSTLIB,
// DISP=(NEW,KEEP),SPACE=(TRK,10)
//K.SYSIN DD *
*KSIOX DBN=KINWQI,TYP=CARD,PM=KETT
1 1 1 2
*$*$
*KSIOX DBN=KINCOI,TYP=CARD,PM=PKINCO
10 1 2
1 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 1 .86 .465
'STRUK' 0 8. .09 1
1 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 1 .86 .465-4
'STRUK' 0 8. .09 1
2 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 1 .86 .465
'STRUK' 0 8. .09 1
2 4 'BRENN' 0 9.5 .338 'HUELL' 0 8. .107 'KUEHL' 1 .86 .465-4
'STRUK' 0 8. .09 1
*$*$
*KSIOX DBN=NUDABL,IND=4,TYP=CARD,PMN=NUTEST
1 4
'C0397'
451 0 0 0
'ENDE'
'C0451'
446 0 1 0
0 'SPEKT'
26 12.49 71.26 186.5 374.1 484.2 941.9 1193. 1334. 1182. 1014.
656.4 376.9 117.1 219.4 116.1 33.54 7.918 .8773 .1139 .007037
.4188-3 .1764-3 .1807-4 .1339-5 .3965-7 .151-8
26 13.25 75.12 191.9 370.6 517.8 944.7 1339. 1288. 1187. 944.4
540.9 337.7 165.1 84.49 38.45 9.99 2.159 .2244 .02881 .001731
.9901-4 .4801-4 .5011-5 .3583-6 .1019-7 .4223-9
26 10.53 59.23 163.2 344.6 505.9 1220. 1939. 2488. 2604. 2483.
1788. 1157. 398.9 727.8 530.6 241.1 97.39 28.94 5.573 .6612
.03979 .01564 .005457 .001148 .1435-3 .5292-5
26 13.32 74.32 199. 411.7 659.7 1527. 2640. 3002. 3200. 2868.
1897. 1309. 735.9 462.9 299. 125.4 47.15 12.96 2.291 .2494
.01368 .005002 .001609 .3079-3 .3545-4 .1208-5
0 'ENDE'
'C0446'
352 0 0 3 446
'SIGMA' 'SABBR' 'KOMPO' 446
```

```
0 0 0 446
'KOMPO'
'26-GR' '.KFKI' 'NR001' 0 26 2 0 13 446
'CR520' 'FE560' 'NA230' 'NB930' 'NI590' 'O 160' 'PU390' 'PU400'
'PU410' 'PU420' 'SI280' 'U2350' 'U2380' 446
13 1 .002869 2 .011405 3 .010472 4 1.0038-4 5 .0022636 6 .01335
7 8.02-4 8 2.35-4 9 2.7-5 10 5.-6 11 1.494-4 12 1.4-5 13
.005592 446
13 1 .002869 2 .011405 3 1.0472-6 4 1.0038-4 5 .0022636 6
.01335 7 8.02-4 8 2.35-4 9 2.7-5 10 5.-6 11 1.494-4 12 1.4-5 13
.005592 446
'WQFIN'
'00352'
0 0 -2 1
'SIGMA' 'SABBR'
'SABBR'
'ST352'
26 2 0 -2 1 1 0
1 2 4
'CDKNT'
5 5 8 12 13 26 1
'ENDE'
'NUFIN'
*$*$
*KSIOX DBN=NUDABL,IND=5,TYP=CARD,PMN=NUTEST
1 4
'00397'
446 0 0 0
'ENDE'
'00446'
352 0 0 3 446
'SIGMA' 'SABBR' 'KOMPO' 446
0 0 0 446
'KOMPO'
'26-GR' '.KFKI' 'NR001' 0 26 2 0 13 446
'CR520' 'FE560' 'NA230' 'NB930' 'NI590' 'O 160' 'PU390' 'PU400'
'PU410' 'PU420' 'SI280' 'U2350' 'U2380' 446
9 1 .0031128 2 .012374 3 .0069586 4 1.0891-4 5 .002456 6
.018953 11 1.621-4 12 2.3957-5 13 .0094527 446
9 1 .0031128 2 .012374 3 .69586-6 4.018953 11 1.0891-4 5 .002456 6
.018953 11 1.621-4 12 2.3957-5 13 .0094527 446
'WQFIN'
'00352'
0 0 -2 1
'SIGMA' 'SABBR'
'SABBR'
'ST352'
26 2 0 -2 1 1 0
3 4 4
'CDKNT'
5 5 8 12 13 26 1
'ENDE'
'NUFIN'
*$*$
*KSIOX DBN=NUDABL,IND=1,TYP=CARD,PMN=NUTEST
```

```
0
'00397'
2291 0 0 0
'ENDE'
'02291'
2250 20 1 26 4
1 'SABBR' 5
'02250'
0 5 4 0
6 6
.176 .763 .061 0 0
.176 .763 .061 0 0
.176 .763 .061 0 0
.176 .763 .061 0 0
.176 .763 .061 0 0
.176 .763 .061 0 0
'PU390' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU400' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU410' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'PU420' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'U2350' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
'U2380' .8103-4 6.8724-4 6.1204-4 11.3811-4 5.1203-4 1.6955-4
.0129 .0311 .134 .331 1.26 3.21
4
'BRENN' 7 'O 160' 1. 'PU390' 1. 'PU400' 1. 'PU410' 1. 'PU420'
1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
4
'BRENN' 7 'O 160' 1. 'PU390' 1. 'PU400' 1. 'PU410' 1. 'PU420'
1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
4
'BRENN' 3 'O 160' 1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
4
'BRENN' 3 'O 160' 1. 'U2350' 1. 'U2380' 1.
'HUELL' 5 'CR520' .5429 'FE560' .5429 'NB930' .5429 'NI590'
.5429 'SI280' .5429
```

```
'KUEHL' 1 'NA230' 1.
'STRUK' 5 'CR520' .4571 'FE560' .4571 'NB930' .4571 'NI590'
.4571 'SI280' .4571
1
1 1
'NUFIN'
*$*$
*KSIOX DBN=NUDABL,IND=3,TYP=CARD,PMN=NUTEST
2 1 4
'00397'
4100 0 0 0
'ENDE'
'04100'
5 300. 600. 900. 1500. 2100.
1 0 0
1 1 1 1
'COND'
5 5 8 12 13 26
'NUFIN'
*$*$
*GO SM=KINWQ
/*
//
```

Dependence on	Number of compositions	Group constants	Doppler parameters	
			x_c, x_f	a_c, a_f
Sodium	2	$\frac{1}{a\sqrt{1-y^3}+b}$	$\frac{1}{a(1-y)^2+b}$	$\frac{1}{ay+b}$
Can only	2	$ay+b$	"	"
Can + structure	2	$\frac{1}{a\sqrt{1-y^3}+b}$	"	"
Fuel	3	$a+\frac{1}{by+c}$	$a+\frac{1}{by+c}$	$a+\frac{1}{by+c}$

Table 1: Interpolation functions for microscopic group constants and Doppler parameters

($y = \frac{\text{actual density x actual volume fraction}}{\text{normal density x normal volume fraction}}$)