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EFFECTS OF NEUTRON DATA LIBRARIES AND CRITICALITY CODES ON IAEA CRITICALITY BENCHMARK PROBLEMS

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Effects of Neutron Data Libraries and Criticality Codes on IAEA Criticality Benchmark Problems

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In order to compare the effects of neutron data libraries and criticality codes to thermal reactors(LWR), the IAEA criticality benchmark calculations have been performed. The experiments selected in this study include TRX-1 and TRX-2 with a simple geometric configuration. Reactor lattice calculation codes WIMS-D/4, MCNP-4, JACS(MGCL,KENO), and SRAC were used in the present calculations. The TRX cores were analyzed by WIMS-D/4 using WIMS original library and also by MCNP-4, JACS(MGCL,KENO), and SRAC using the libraries generated from JENDL-3 and ENDF/B-IV nuclear data files. An intercomparison work for the above mentioned code systems and cross section libraries was performed by analyzing the LWR benchmark experiments TRX-1 and TRX-2. The TRX cores were also analyzed for supercritical and subcritical conditions and these results were compared. In the case of critical condition, the results were in good agreement. But for the supercritical and subcritical conditions, the difference of the results obtained by using the different cross section libraries become larger than for the critical condition.

Keywords: Cross Section Library, Nuclear Data, Continuous Energy, NJOY, WIMS-D/4, JACS(MGCL,KENO), SRAC, JENDL-3, ENDF/B-IV, Monte Carlo, Criticality, Supercritical, Subcritical, Benchmark

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ＩＡＥＡ臨界ベンチマーク問題に対する核データライブラリと臨界コードの効果

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（1993年９月14日受理）

熱中性子炉（軽水炉）に対する核データライブラリと臨界コードの効果を比較するために，ＩＡＥＡ臨界ベンチマーク問題の計算を行った。本研究で選択した臨界実験は，単純な幾何形状の炉心構成であるＴＲＸ－１とＴＲＸ－２である。計算は，格子計算コードであるＷＩＭＳ－Ｄ／４，ＭＣＮＰ４，ＪＡＣＳ（ＭＧＣＬ，ＫＥＮＯ）とＳＲＡＣで行った。ライブラリについては，ＷＩＭＳ－Ｄ／４にはオリジナルのＷＩＭＳライブラリを用い，ＭＣＮＰ４，ＪＡＣＳ（ＭＧＣＬ，ＫＥＮＯ）とＳＲＡＣにはＪＥＮＤＬ－３およびＥＮＤＦ／Ｂ－Ⅳから作成したライブラリを用いた。これらのコードシステムやライブラリの相互比較をＴＲＸ－１とＴＲＸ－２のＬＷＲベンチマーク実験を解析することにより行った。ＴＲＸの炉心に対しては，臨界超過，臨界未満の状態についても解析を行い，同様の比較を行った。臨界状態では解析結果はよく一致したが，臨界超過，臨界未満の状態では，ライブラリの違いによる結果の差異は臨界状態の時に比べて大きくなった。

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1. Introduction

Benchmark calculations for thermal reactor critical assemblies have been performed to compare the effects of neutron data libraries and criticality codes used for thermal reactors. Criticality codes WIMS-D/4[1], MCNP-4[2], JACS(MGCL,KENO)[3], and SRAC[4] were used in the present calculations. WIMS-D/4 and SRAC are the reactor lattice cell calculation codes. MGCL-KENO is a Monte Carlo code using multigroup model and MCNP-4 is a continuous energy Monte Carlo code. The experiments TRX-1 and TRX-2[5] selected were water-moderated lattices of slightly enriched 1.3% uranium metal rods. The objective of the present study is to compare the K_{eff} values obtained by executing the codes MCNP-4, JACS, and SRAC with that value obtained from WIMS-D/4 which is being used at Atomic Energy Research Establishment in Dhaka, Bangladesh. The TRX cores have been analyzed by WIMS-D/4 using WIMS original library and also by MCNP-4, JACS(MGCL,KENO), and SRAC, using the libraries generated from JENDL-3 and ENDF/B-IV.

2. Neutronic Calculation Codes and Cross Section Libraries

Table 1 summarizes neutronic calculation codes and their characteristics used in the present benchmark problems. In WIMS-D/4 code, diffusion coefficients are calculated by Benoist's method which are used to obtain the migration areas. The original WIMS library is used for the WIMS-D/4 code. Continuous energy cross section library for MCNP is generated using NJOY[6] code system for Al-27, H-1, O-16, U-235, and U-238 from ENDF/B-IV nuclear data file. This cross section library has been necessary to execute the MCNP-4 code system for IAEA criticality benchmark problems TRX-1 and TRX-2. A macroscopic cross section library for the Monte Carlo code KENO in JACS system is generated from JENDL-3 and ENDF/B-IV by using the computer code system MGCL-ACE[7]. The cross section library used for SRAC code is generated from JENDL-3 and ENDF/B-IV by the TIMS-PGG[8] processing system.

3. Benchmark Calculation Model

In order to obtain reliable results, it is essential to select accurate and simple benchmark experiments. The TRX cores with uranium fuel were selected. The TRX cores are water-moderated lattices of slightly enriched 1.3% uranium metal rods. WIMS-D/4 and SRAC calculate K_∞ and M^2 (M^2: migration area), and obtain K_{eff} by using geometrical bucklings which were obtained at the experiments as shown in Table 2. Monte Carlo codes MCNP-4 and KENO calculate K_{eff} with considering the full cores model as shown in Figs. 1 and 2. Materials of the TRX experiments are presented in Table 3.

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4. Implementation of Computer Codes

NJOY91.13 code system has been implemented on the FACOM M-780 Mainframe computer at JAERI to generate the continuous energy cross section library for MCNP-4 from ENDF/B nuclear data file and executed some sample problems successfully. WIMS-D/4 code system has been also implemented on the FACOM M-780 Mainframe computer at JAERI to calculate the criticality for the IAEA criticality benchmark problems TRX-1 and TRX-2 and executed some sample problems successfully.

5. Generation of the Cross Section Libraries in MCNP Format from ENDF/B-IV Nuclear Data Files

There are sixteen modules in NJOY91.13 data processing code system. NJOY modules used to process ENDF/B-IV nuclear data file for MCNP are : MODER, RECONR, BROADR, HEATR, UNRESR, THERMR, GROUPR, and ACER as well as the main programme NJOY. During cross section generation for the nuclides U-235, U-238, and Al-27 from ENDF/B-IV nuclear data file, some bugs have been found in several modules of NJOY code system. These modules are RECONR, GROUPR, and ACER. Later on, some modification in the source program have been made and successfully overcome the above problem. A cross section library has been generated in MCNP format using NJOY91.13 code system for H-1, O-16, Al-27, U-235, and U-238 from ENDF/B-IV nuclear data file. This cross section library was used to execute the MCNP-4 code system for IAEA criticality benchmark problems TRX-1 and TRX-2.

6. Comparison of the Calculated Results

6.1 Critical condition

In order to compare the differences involved among criticality codes and cross section libraries, TRX-1 and TRX-2 were analyzed (for critical condition).

6.1.1 Comparison among Code Systems

The TRX-1 and TRX-2 have been analyzed by WIMS-D/4, MCNP-4, JACS (MGCL, KENO), and SRAC codes and these results were compared. The calculated values of effective multiplication factor (K_{eff}) and ([C/A]-1.0)×100 [C : Calculative value and A : Average] values for TRX-1 and TRX-2 are shown in Table 4 and 5 respectively. Table 4, and Figs. 3 and 4 show the effects of the nuclear codes on IAEA criticality benchmark problems. The calculated values of K_{eff} obtained by executing the above codes were in good agreement.

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The TRX-1 and TRX-2 have been analyzed by WIMS-D/4, MCNP-4, JACS (MGCL, KENO), and SRAC codes and these results were compared. The calculated values of effective multiplication factor (K_{eff}) and ([C/A]-1.0)×100 [C : Calculative value and A : Average] values for TRX-1 and TRX-2 are shown in Table 4 and 5 respectively. Table 4, and Figs. 3 and 4 show the effects of the nuclear codes on IAEA criticality benchmark problems. The calculated values of K_{eff} obtained by executing the above codes were in good agreement.

6.1.2 Comparison among Nuclear Data Libraries

The TRX-1 and TRX-2 have been also analyzed using JENDL-3, ENDF/B-IV and WIMS original libraries. The calculated values of effective multiplication factor (K_{eff}) and ([C/A]-1.0)×100 for TRX-1 and TRX-2 are shown in Table 6 and 7 respectively. Table 6 and Figs. 5 and 6 show the effects of the neutron data libraries on IAEA criticality benchmark problems. The calculated values of K_{eff} using the different neutron data libraries mentioned earlier were in good agreement.

6.2 Supercritical and Subcritical conditions

In order to compare the differences involved among criticality codes and cross section libraries, IAEA criticality benchmark problems TRX-1 and TRX-2 have been analyzed for supercritical and subcritical conditions. The supercritical and subcritical conditions have been made by increasing and decreasing the atomic number density of U-235 respectively. The atomic number densities of U-235 are selected for K_{eff} to be about 1.2 and 0.7 for TRX-1, and 1.4 and 0.9 for TRX-2. The number densities are 1.505E-03 and 2.245E-04 atoms/barn·cm for TRX-1, and 4.525E-03 and 4.725E-04 atoms/barn·cm for TRX-2.

6.2.1 Comparison among Code Systems

IAEA benchmark problems TRX-1 and TRX-2 have been analyzed using ENDF/B-IV cross section library by MCNP-4, JACS(MGCL,KENO), and SRAC codes for supercritical and subcritical conditions and these results were compared. The calculated values of effective multiplication factor (K_{eff}) are shown in Table 8. Table 8, and Figs. 7 and 8 show the effects of the criticality codes on IAEA criticality benchmark problems for supercritical and subcritical condition. The calculated values of K_{eff} executing the above codes were in good agreement.

6.2.2 Comparison among Nuclear Data Libraries

IAEA benchmark problems TRX-1 and TRX-2 have been also analyzed using JENDL-3, ENDF/B-IV and WIMS original libraries for supercritical and subcritical conditions and these results were compared. The calculated values of effective multiplication factor (K_{eff}) are shown in Table 9. Table 9, and Figs. 9 and 10 show the effects of the neutron data libraries on IAEA criticality benchmark problems for supercritical and subcritical conditions. The differences among the calculated values of K_{eff} obtained by using the different neutron data libraries mentioned earlier were a little bigger (i.e., 0.7%) than it is obtained in the case of critical condition.

7. Conclusions

The TRX-1 and TRX-2 have been analyzed by the criticality code systems WIMS-D/4, MCNP-4, JACS(MGCL,KENO), and SRAC. In case of critical condition, the results calculated with the cell calculation code WIMS-D/4 underpredicted K_{eff} by less than 0.5% for the uranium fuel TRX cores. The above problems have been also analyzed by using the different cross section libraries, i.e., JENDL-3, ENDF/B-IV, and WIMS original. In case of critical condition, the discrepancy between the K_{eff} with JENDL-3 and ENDF/B-IV is 0.29% but that between ENDF/B-IV and WIMS library is 0.6%. Table 10 shows the percent differences of K_{eff} for different criticality code systems. It is also found for supercritical and subcritical condition, the discrepancy between the K_{eff} with JENDL-3 and WIMS library is 0.7%. Table 11 shows the percent differences of K_{eff} for different cross section libraries. Even in the U-235 and U-238 system, the differences of K_{eff} values using different cross section libraries for supercritical and subcritical become higher than the critical condition. The system which contains more nuclides, such as spent fuel system, effects of nuclear data libraries become more significant. Also, indicates the need of benchmarking neutron data libraries by using supercritical and subcritical experiments.

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Table 1 Codes and Their Characteristics

Codes	Library Used	Spectrum Calculation
WIMS-D/4	WIMS Library (69 Groups)	Collision Probability
MCNP-4	JENDL-3 (Point) and ENDF/B-IV	Continuous Energy Monte Carlo
MGCL-KENO	JENDL-3 (137 Groups) AND ENDF/B-IV	Monte Carlo
SRAC	JENDL-3 (107 Groups) and ENDF/B-IV	Collision Probability

Table 2 Benchmark Testing Cores

Uranium Cores: TRX-1 and TRX-2; Hexagonal Cell
Fuel Metal Uranium, 1.3wt.% U-235
Cladding Al,Diameter 1.082 cm

	TRX-1	TRX-2
Cell Pitch(cm)	1.806	2.174
Water/Fuel Volume Ratio	2.350	4.020
$B^2(10^{-3}/cm^2)$	5.700	5.469

Table 3 Materials of the Experiments TRX-1 and TRX-2

	Outer Radius (cm)	Isotope	Atomic Number Density (Atoms/barn-cm)
Fuel	0.4915	U-235	6.253E-04
		U-238	4.720E-02
Void	0.5042	---	---
Clad	0.5753	Al	6.025E-02
Moderator	---	H-1	6.676E-02
		O-16	3.338E-02

Table 4 Effective Multiplication Factors (K_{eff}) Calculated for TRX Cores using Different Codes

Codes	K_{eff}		Libraries
	TRX-1	TRX-2	
WIMS-D/4	1.0002 [a]	0.9952	WIMS Original
MCNP-4	1.0003 [0.15]	0.9990 [0.16]	JENDL-3
	1.0004 [0.16]	0.9998 [0.14]	ENDF/B-IV
JACS	0.9993 [0.19]	1.0011 [0.16]	JENDL-3
	0.9972 [0.18]	1.0016 [0.19]	ENDF/B-IV
SRAC	0.9954	0.9979	JENDL-3
	0.9982	1.0008	ENDF/B-IV
Average	0.9987	0.9993	---

[a]All values in ( ) are one standard deviation in %.

Table 5 ([C/A]-1.0)×100 Values of Effective Multiplication Factors (K_{eff}) Calculated for TRX Cores using Different Codes

Codes	([C/A]-1.0)X100		Libraries
	TRX-1	TRX-2	
WIMS-D/4	0.15	-0.41	WIMS Original
MCNP-4	0.16	-0.03	JENDL-3
	0.17	0.05	ENDF/B-IV
JACS	0.06	0.18	JENDL-3
	-0.15	0.23	ENDF/B-IV
SRAC	-0.33	-0.14	JENDL-3
	-0.05	0.15	ENDF/B-IV

Table 6 Effective Multiplication Factors (K_{eff}) Calculated for TRX Cores using Different Cross Section Libraries

Libraries	K_{eff}		Codes
	TRX-1	TRX-2	
JENDL-3	1.0003 [0.15][b]	0.9990 [0.16]	MCNP
	0.9993 [0.19]	1.0011 [0.16]	MGCL-KENO
	0.9954	0.9979	SRAC
ENDF/B-IV	1.0004 [0.16]	0.9998 [0.14]	MCNP-4
	0.9972 [0.18]	1.0016 [0.19]	MGCL-KENO
	0.9982	1.0008	SRAC
WIMS Original	1.0002	0.9952	WIMS-D/4
Average	0.9987	0.9993	---

[b]All values in ( ) are one standard deviation in %.

Table 7 ([C/A]-1.0)×100 Values of Effective Multiplication Factors (K_{eff}) Calculated for TRX Cores using Different Cross Section Libraries

Libraries	([C/A]-1.0)X100 TRX-1	([C/A]-1.0)X100 TRX-2	Codes
JENDL-3	0.16	-0.03	MCNP
	0.06	0.18	MGCL-KENO
	-0.33	-0.14	SRAC
ENDF/B-IV	0.17	0.05	MCNP-4
	-0.15	0.23	MGCL-KENO
	-0.05	0.15	SRAC
WIMS Original	0.15	-0.41	WIMS-D/4

Table 8 Comparison among the Criticality Codes using the ENDF/B-IV Cross Section Library

TRX-1

Codes	K_{eff} Supercritical	K_{eff} Critical	K_{eff} Subcritical
MCNP-4	1.1979 [0.15]	1.0004 [0.16]	0.7005 [0.18]
JACS	1.1947 [0.20]	0.9972 [0.18]	0.7015 [0.15]
SRAC	1.2017	0.9982	0.7024
Average	1.1981	0.9986	0.7015

TRX-2

Codes	K_{eff} Supercritical	K_{eff} Critical	K_{eff} Subcritical
MCNP-4	1.3992 [0.13]	0.9998 [0.14]	0.8995 [0.15]
JACS	1.4053 [0.20]	1.0016 [0.19]	0.9048 [0.17]
SRAC	1.4117	1.0008	0.9067
Average	1.4054	1.0007	0.9037

[a]All values in [ ] are one standard deviation in %.

Table 9 Comparison among the Cross Section Libraries JENDL-3, ENDF/B-IV using the Code MCNP-4 and WIMS Original Library using WIMS-D/4

Libraries	K_{eff}		
	Supercritical	Critical	Subcritical
TRX-1			
JENDL-3	1.1996 [0.14][b]	1.0003 [0.15]	0.6970 [0.15]
ENDF/B-IV	1.1979 [0.15]	1.0004 [0.16]	0.7005 [0.18]
WIMS Original	1.2043	1.0002	0.7022
TRX-2			
JENDL-3	1.4026 [0.15][b]	0.9990 [0.16]	0.8943 [0.16]
ENDF/B-IV	1.3992 [0.13]	0.9998 [0.14]	0.8995 [0.15]
WIMS Original	1.4044	0.9952	0.9011

[b]All values in [ ] are one standard deviation.

Table 10 Percent Difference Values of K_{eff} for Comparison among the Different Criticality Codes using ENDF/B-IV Cross Section Library

Codes	Percent Difference		
	Supercritical	Critical	Subcritical
TRX-1			
MCNP-4	0.00	0.00	0.00
JACS	-0.26	-0.32	0.14
SRAC	0.32	-0.22	0.27
TRX-2			
MCNP-4	0.00	0.00	0.00
JACS	0.44	0.18	0.59
SRAC	0.89	0.10	0.80

Table 11 Percent Difference Values of K_{eff} by MCNP-4 using JENDL-3 and ENDF/B-IV, and WIMS-D/4 using WIMS Library for Comparison among the Data Libraries

TRX-1			
Libraries	Percent Difference		
	Supercritical	Critical	Subcritical
JENDL-3	0.00	0.0	0.00
ENDF/B-IV	-0.14	0.01	0.50
WIMS Original	0.39	-0.01	0.75

TRX-2			
Libraries	Percent Difference		
	Supercritical	Critical	Subcritical
JENDL-3	0.00	0.00	0.00
ENDF/B-IV	-0.24	0.08	0.58
WIMS Original	0.13	-0.38	0.76

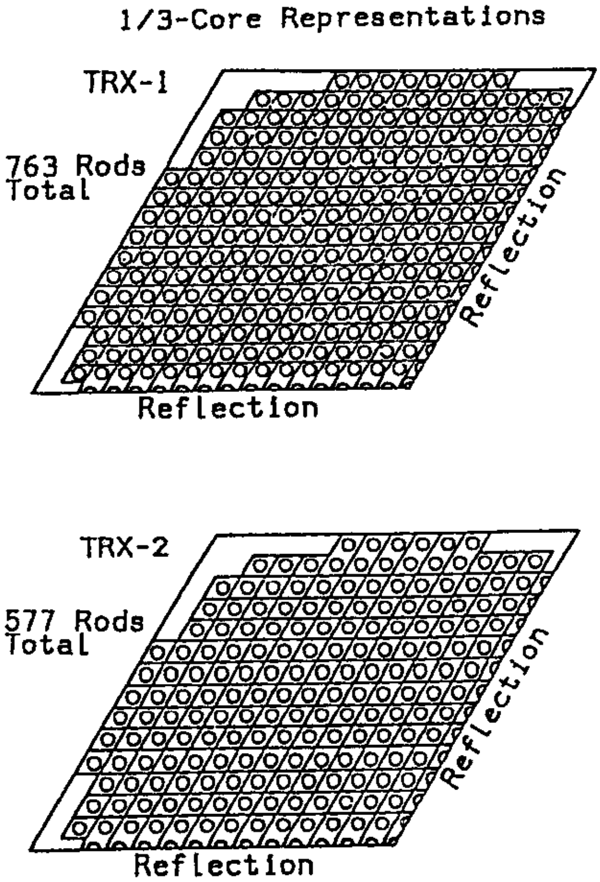

Fig. 1 Configuration model for TRX lattice cores

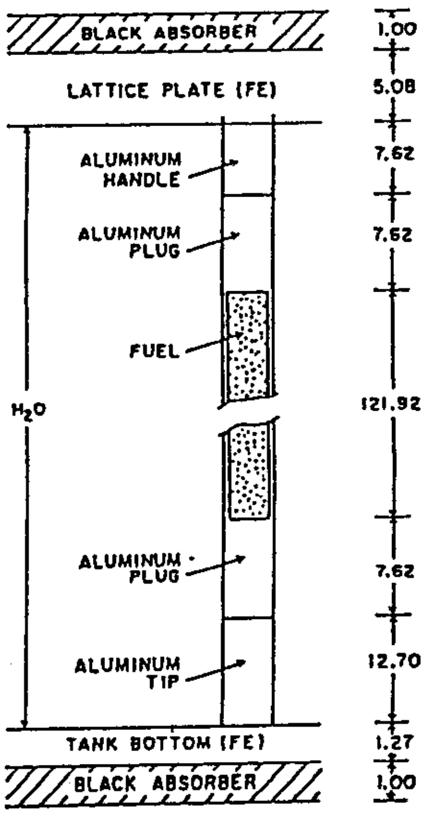

Fig. 2 Axial model of TRX lattice (cm)

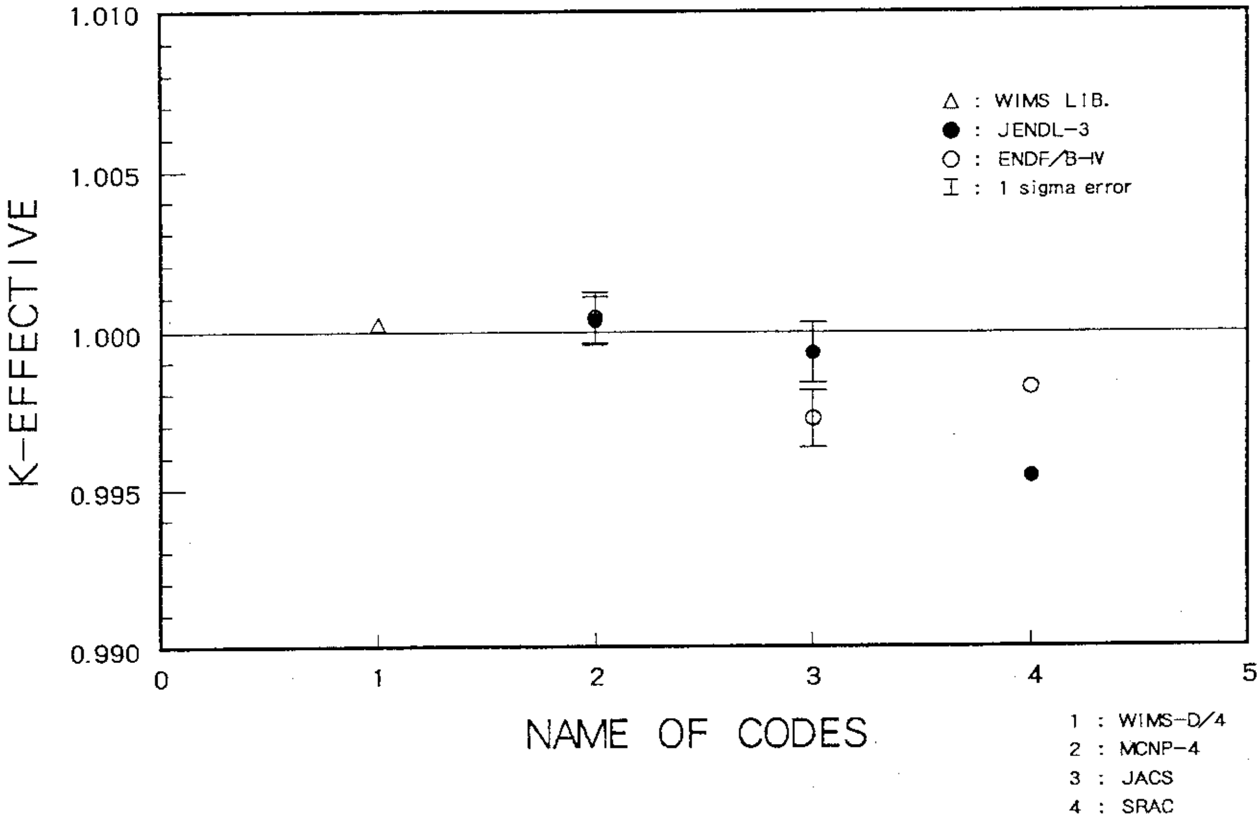

Fig. 3 K-effective calculations using different codes for TRX-1 Geometry

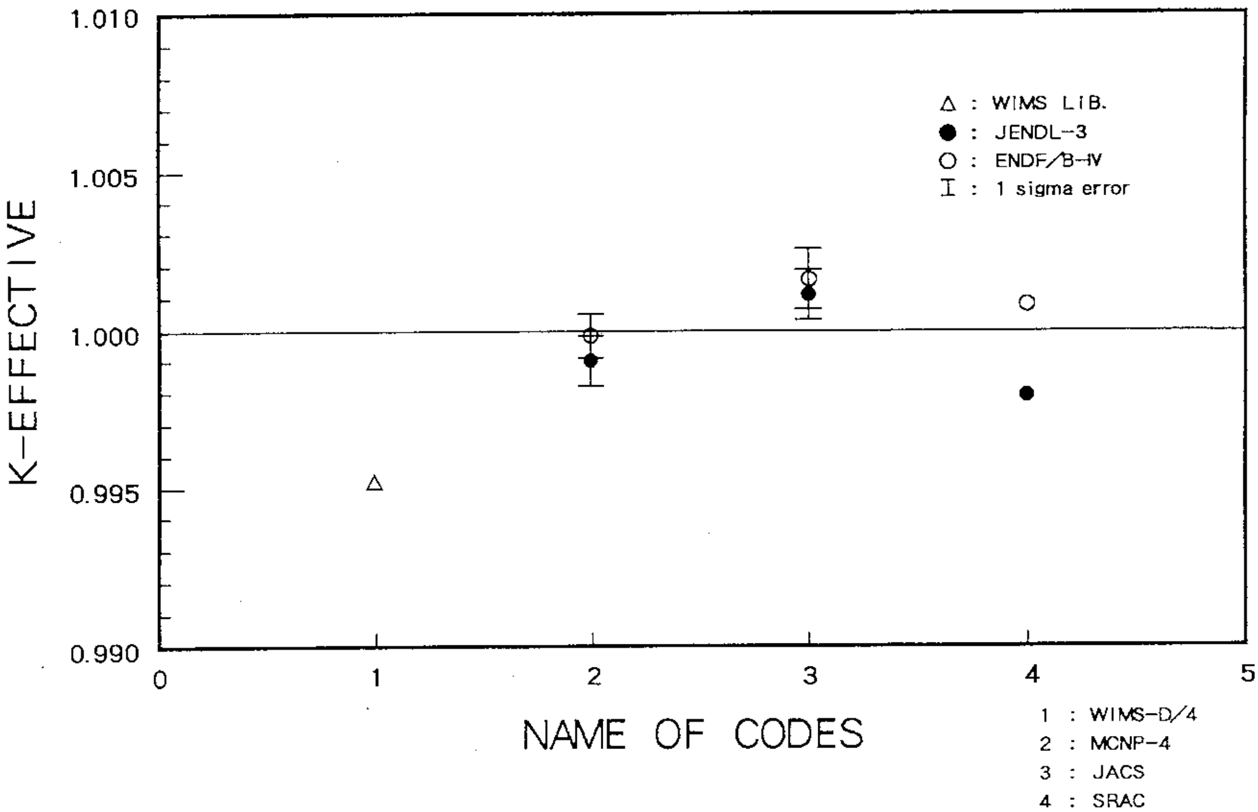

Fig. 4 K-effective calculations using different codes for TRX-2 Geometry

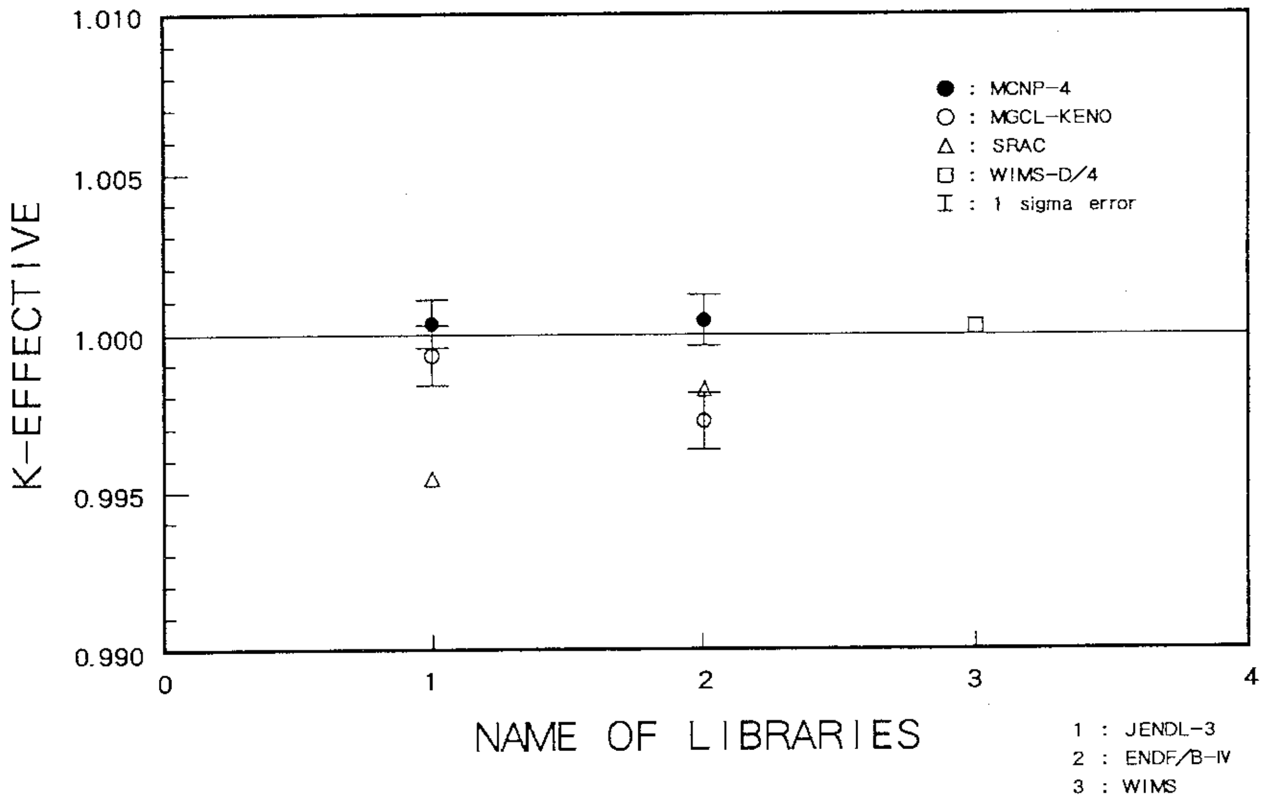

Fig. 5 K-effective calculations using different cross section libraries for TRX-1 Geometry

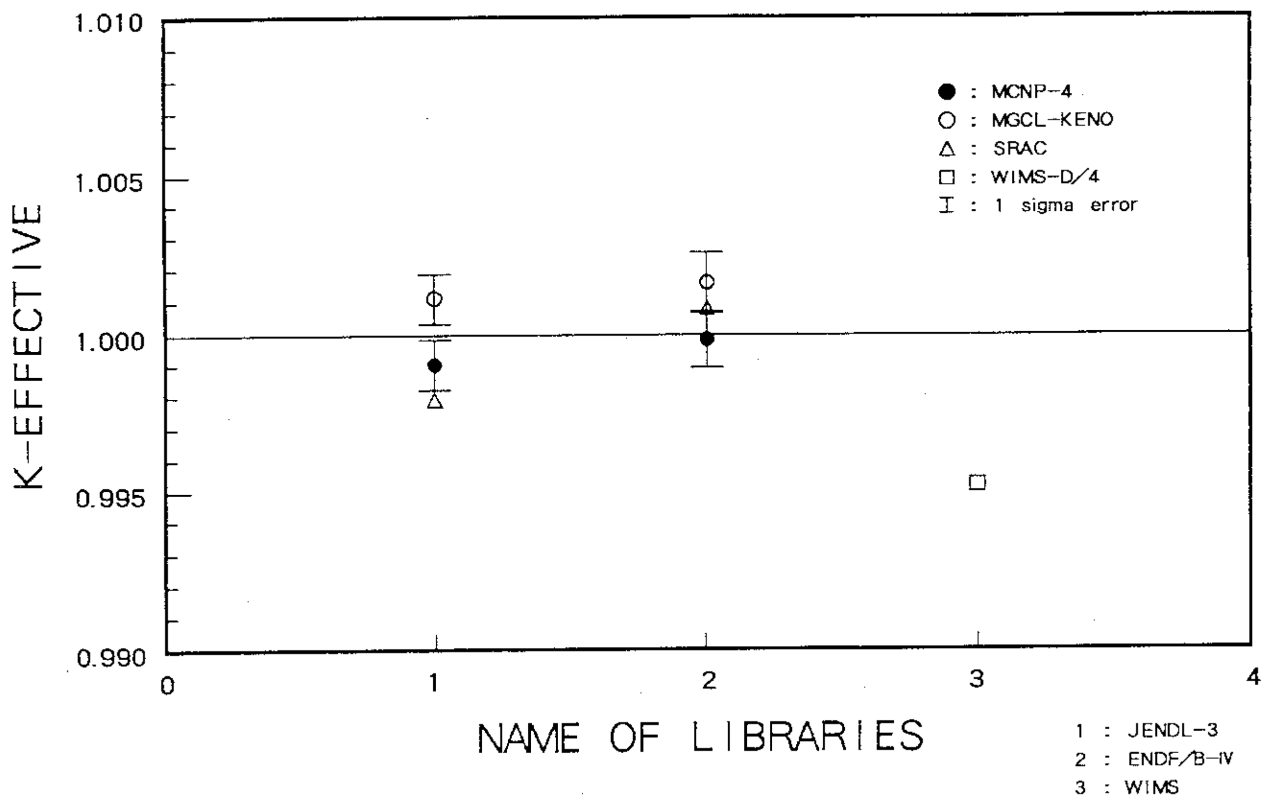

Fig. 6 K-effective calculations using different cross section libraries for TRX-2 Geometry

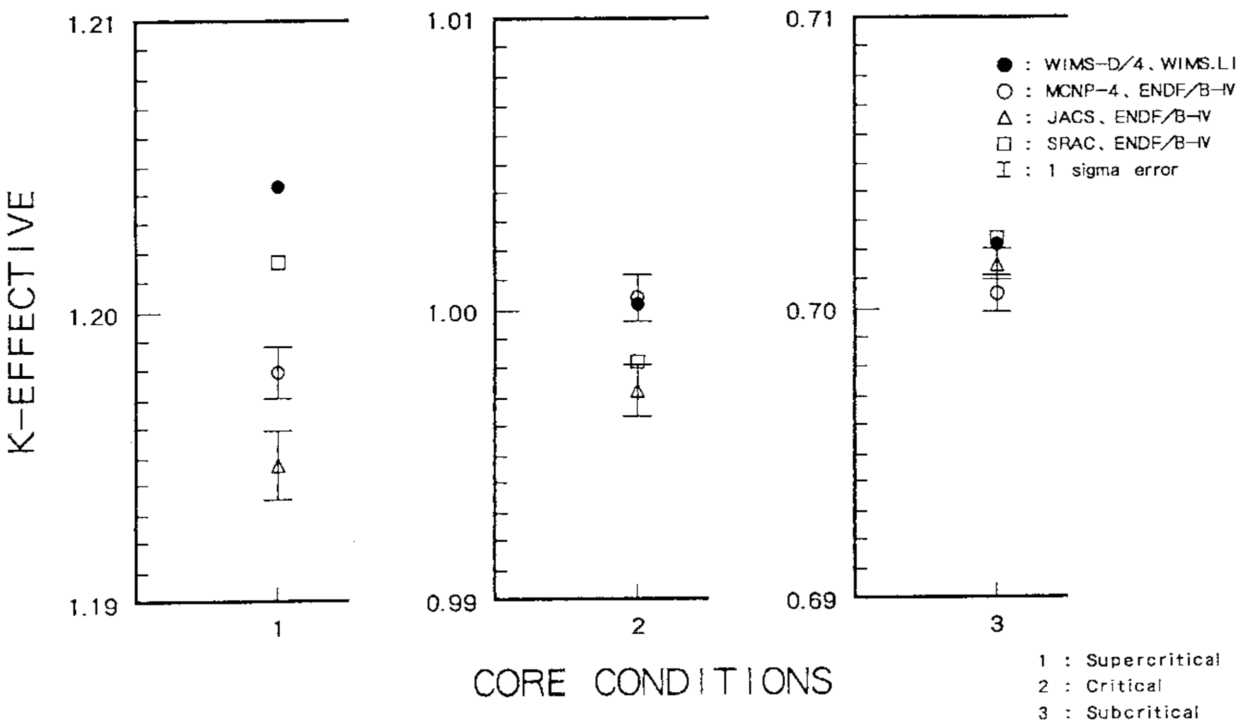

Fig. 7 Comparison among the criticality codes for supercritical & subcritical conditions (TRX-1)

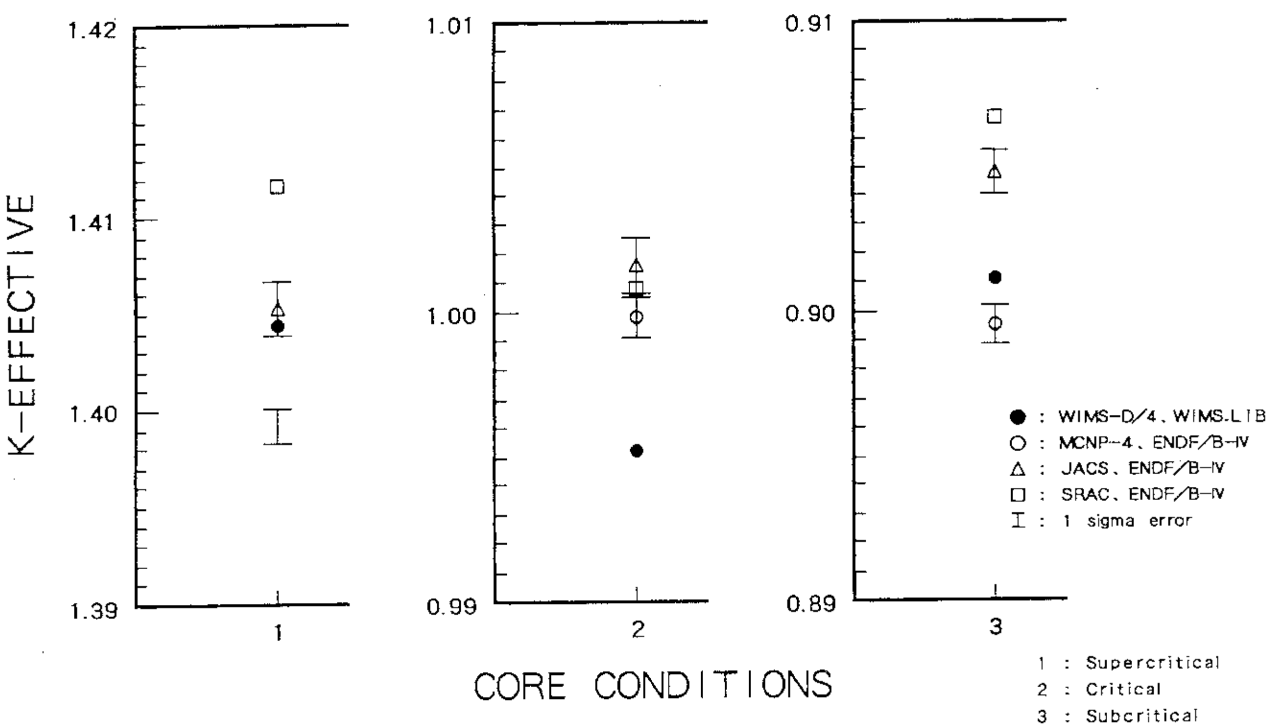

Fig. 8 Comparison among the criticality codes for supercritical & subcritical conditions (TRX-2)

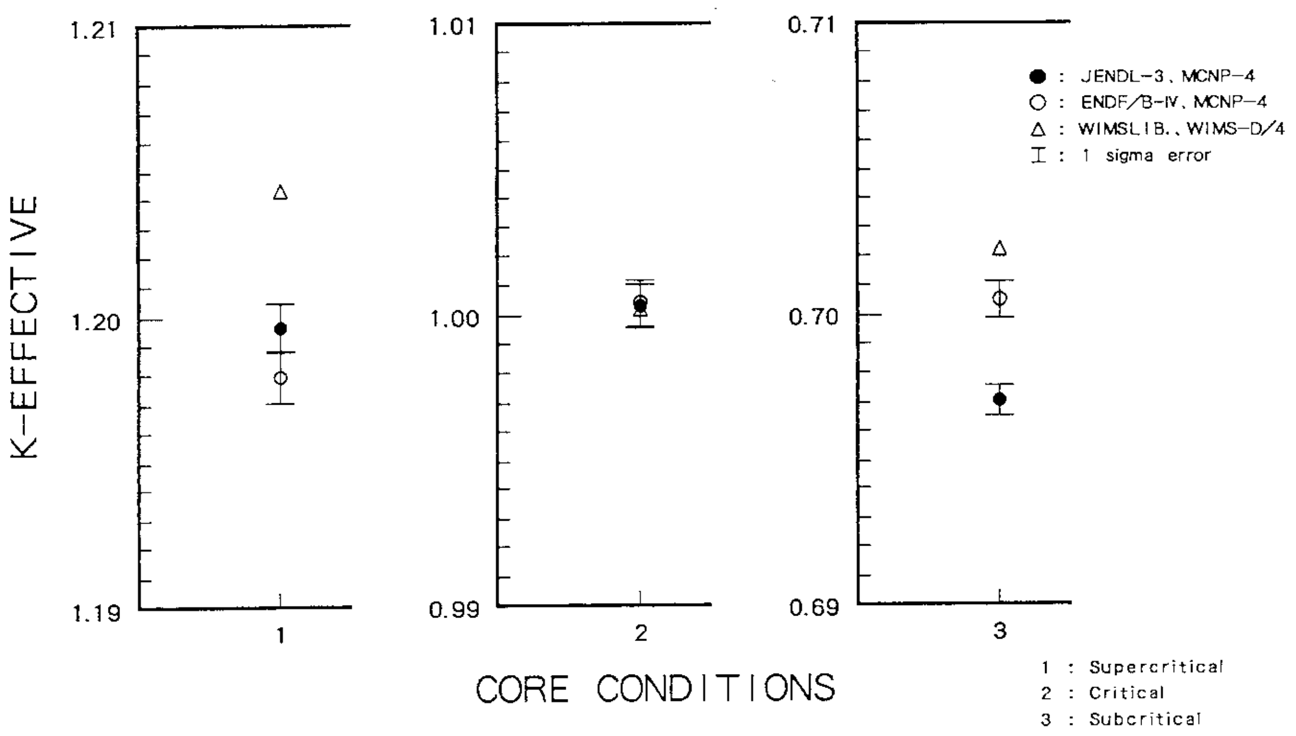

Fig. 9 Comparison among the cross section libraries for supercritical & subcritical conditions (TRX-1)

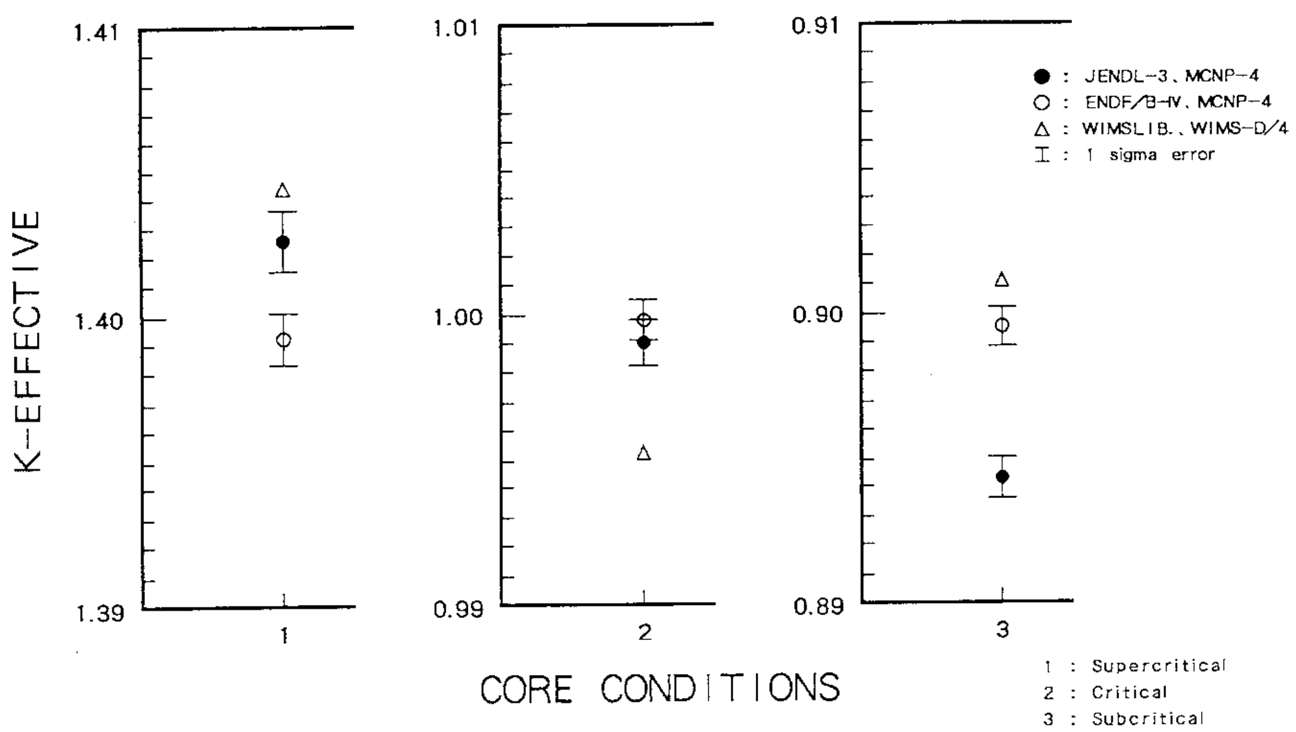

Fig. 10 Comparison among the cross section libraries for supercritical & subcritical conditions (TRX-2)

Appendix 1 Sample JCL and input data of NJOY nuclear data processing system

IAEA criticality benchmark problems TRX-1 and TRX-2 were analyzed by the different criticality code systems and as well as for the different cross section libraries JENDL-3, ENDF/B-IV and WIMS original. The general Monte Carlo Code MCNP-4 have been used to calculate the criticality for the above problems. At the moment, the cross section library in MCNP format for the nuclides U-235 and U-238 (from ENDF/B nuclear data file) has not produced yet at JAERI. So the NJOY91.13 code system was installed on FACOM M-780 Mainframe computer at JAERI to generate the continuous energy cross section library for MCNP-4 (from ENDF/B nuclear data file) and executed some sample problems successfully. The MCNP continuous energy cross section library was generated for H-1, O-16, Al-27, U-235, and U-238 from ENDF/B-IV nuclear data file with the nuclear data processing system NJOY of version 91.13. Figure A1 shows the processing flow to generate the continuous energy cross section library for MCNP from the nuclear data file ENDF/B-IV by NJOY. The concrete explanation of NJOY is not given here. Please see the reference 6. The sample JCL and some inputs of NJOY91.13 are shown in Table A1 and A2 respectively.

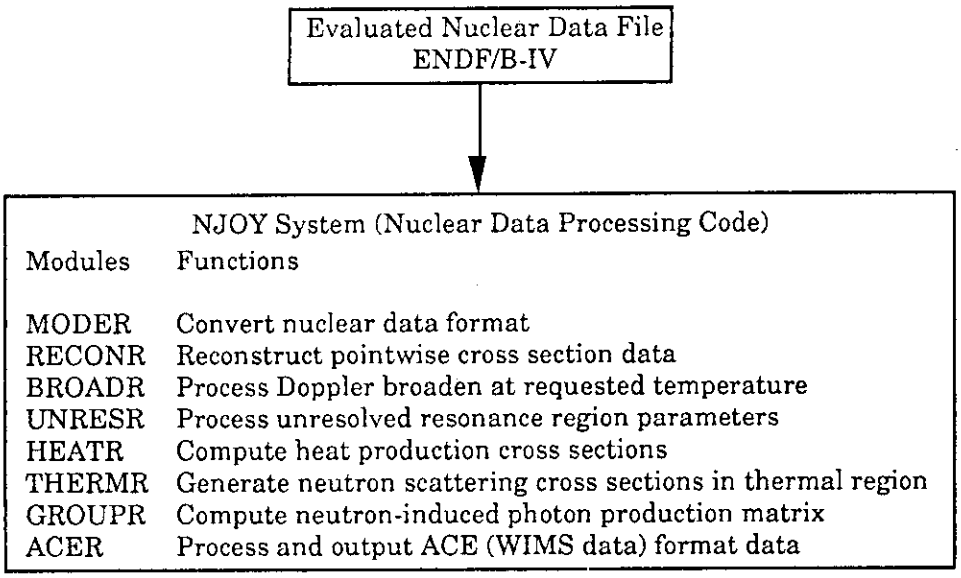

Fig. A1 Processing flow of a continuous energy cross section library for MCNP code

Table A1 Sample JCL for NJOY nuclear data processing system

```
  T(7) W(4) C(2) I(5) E(1)
//*   ***********************************************
//*   * NJOY91.13 : NUCLEAR DATA PROCESSING SYSTEM  *
//*   *                                             *
//*   ***********************************************
// EXEC FORT77,SO='J9150.NJOY91',Q='.FORTEX',A='ELM(*)'
// EXEC LKED
// EXEC GO
//SYSPRINT DD DUMMY
//FT05F001 DD DSN=J9150.NJOY.DATA,DISP=SHR
//FT06F001 DD DSN=J9150.A80,DISP=(NEW,CATLG),UNIT=TDS,
//          DCB=(RECFM=FBA,LRECL=137,BLKSIZE=13700),
//          SPACE=(TRK,(50,50),RLSE)
//FT20F001 DD DSN=J1615.ENDFB407.DATA,DISP=SHR,LABEL=(,,,IN)
//FT50F001 DD DSN=J9150.A70,DISP=(NEW,CATLG),UNIT=TDS,
//          DCB=(RECFM=FBA,LRECL=137,BLKSIZE=13700),
//          SPACE=(TRK,(50,50),RLSE)
//
```

Table A2 Sample input data for NJOY nuclear data processing system

A) Input data for U-235

```
0
4
*MODER*
20 -21
*RECONR*
-21 -22
*PENDF TAPE FOR U-235 FROM ENDF/B-IV TAPE J1615.ENDFB407.DATA*/
1261 3 0
0.01 0. 5/
*U-235 FROM TAPE ENDFB407*/
*PROCESSED BY THE NJOY NUCLEAR DATA PROCESSING SYSTEM*/
*SEE ORIGINAL ENDF/B-IV TAPE FOR DETAILS OF EVALUATION*/
0/
*BROADR*
-22 -23
1261 1 0 0 0.0
0.01 1.0+6/
300.0
0/
*UNRESR*
-21 -23 -24
1261 1 1 1
300.0
1.0E+10
0/
*HEATR*
-21 -24 -25
1261 0 0 0 0 0
*THERMR*
0 -25 -26
0 1261 8 1 1 0 1 201 0
300.
.01 4.6
*GROUPR*
-21 -26 0 -27
1261 3 2 3 5 1 1 0
*U-235 CROSS SECTION GROUPWISE* /
300.0
1.0E+10
 3 /
 6 /
16 /
17 /
0 /
0 /
*ACER*
-21 -26 -27 50 51
1 0 1 0.0 0
*FAST DATA OF U-235 FROM ENDF/B-IV FOR MCNP-4*/
1261 300.0
0.01 1
1.00-5 2.00+7 1
*STOP*
```

B) Input data for U-238

```
0
4
*MODER*
20 -21
```

```
*RECONR*
-21 -22
*PENDF TAPE FOR U-238 FROM ENDF/B-IV TAPE J1615.ENDFB409.DATA*/
1262 3 0
.005 0. 5/
*92-U-238 FROM TAPE ENDFB409*/
*PROCESSED BY THE NJOY NUCLEAR DATA PROCESSING SYSTEM*/
*SEE ORIGINAL ENDF/B-IV TAPE FOR DETAILS OF EVALUATION*/
0/
*BROADR*
-22 -23
1262 1 0 0 0.0
0.005 1.0E+6/
300.0
0/
*UNRESR*
-21 -23 -24
1262 1 1 1
300.0
1.0E+10
0/
*HEATR*
-21 -24 -25
1262 0 0 1 0 0
*THERMR*
0 -25 -26
0 1262 8 1 1 0 1 201 0
300.
.01 4.6
*GROUPR*
-21 -26 0 -27
1262 9 2 3 5 1 1 0
*92-U-238 CROSS SECTION GROUPWISE*/
300.0
1.0E+10
 3/
 6/
16/
17/
0/
0/
*ACER*
-21 -26 -27 50 51
1 0 1 0.0 0
*FAST DATA OF U-238 FROM ENDF/B-IV FOR MCNP-4*/
1262 300.0
0.01 1
1.00-5 2.00+7 1
*STOP*
```

Appendix 2　Sample JCL and input data of WIMS code system

WIMS-D/4 code system was also installed on FACOM M-780 Mainframe computer at JAERI to calculate the criticality for the IAEA benchmark problems and executed some sample problems successfully. The criticality for the problems TRX-1 and TRX-2 have been calculated by the WIMS-D/4 code system using the WIMS original cross section library. The sample JCL and some inputs of WIMS-D/4 are shown in Table A3 and A4 respectively.

Table A3　Sample JCL for WIMS-D/4 code system

```
   T(5) W(6) C(3) I(8) E(1)
// EXEC FORT77,SO='J9150.PS04',Q='.DATA',OPT=0,A='LANGLVL(66)'
// EXEC LKED77
// EXEC GO
//FT05F001 DD DSN=J9150.TRX1W.DATA,DISP=SHR
//FT01F001 DD DUMMY
//FT04F001 DD DUMMY
//FT06F001 DD SYSOUT=*
//FT02F001 DD DSN=J9150.WIMS.LIBO,DISP=SHR
//FT03F001 DD DSN=&&TEMP1,UNIT=WK10,SPACE=(3152,(200,5)),
//            DCB=(RECFM=VBS,BLKSIZE=1604,LRECL=1600)
//FT08F001 DD DSN=&&TEMP2,UNIT=WK10,SPACE=(3152,(200,5)),
//            DCB=(RECFM=VBS,BLKSIZE=1604,LRECL=1600)
//FT09F001 DD DSN=&&TEMP3,UNIT=WK10,SPACE=(3152,(200,5)),
//            DCB=(RECFM=VBS,BLKSIZE=1604,LRECL=1600)
//FT12F001 DD DSN=&&TEMP4,UNIT=WK10,SPACE=(3152,(200,5)),
//            DCB=(RECFM=VBS,BLKSIZE=1604,LRECL=1600)
//
```

Table A4 Sample input data of WIMS-D/4 code system

A) Input data for benchmark problem TRX-1

```
***** TRX-1 BENCHMARK RUN USING WIMS-D/4 ON FACOM M-780 AT JAERI  *****
CELL 6
SEQUENCE 1
NGROUP 18 2
NMESH 16
NREGION 4
NMAT 3
NREACT 2
PREOUT
INITIATE
******************  TRX-1 BENCHMARK EXERCISES  ***********************
MATERIAL 1 -1 300 1 235.4 6.253E-04 2238.4 4.7205E-02
MATERIAL 2 -1 300 2 27 6.025E-02
MATERIAL 3 -1 300 3 2001 6.676E-02 16 3.338E-02
ANNULUS 1  0.4915 1
ANNULUS 2  0.5042 0
ANNULUS 3  0.5753 2
ANNULUS 4  0.9482 3
REGULAR 1
FEWGROUPS  2 4 6 8 10 12 14 16 18 20 22 24 27 45 55 63 68 69
MESH 6 2 2 6
BEGINC
SIGPUNCH
BUCKLING 0.0 0.0057
NOBUCKLING
LEAKAGE 5
THERMAL 4
DIFFUSION 1 3 1
BEEONE -1
DNB 1 0.0 0.0 0.0 0.0
DNB 2 0.0 0.0 0.0 0.0
DNB 3 6.676E-02 0.0 3.338E-02 0.0
REACTION 235.4 300 2238.4 300
PARTITION 45 69
PRINTC 1 1 0 1
BEGINC
//
```

B) Input data for benchmark problem TRX-2

```
***** TRX-2 BENCHMARK RUN USING WIMS-D/4 ON FACOM M-780 AT JAERI  *****
CELL 6
SEQUENCE 1
NGROUP 18 2
NMESH 16
NREGION 4
NMAT 3
NREACT 2
PREOUT
INITIATE
******************  TRX-2 BENCHMARK EXERCISES  ************************
MATERIAL 1 -1 300 1 235.4 6.253E-04 2238.4 4.7205E-02
MATERIAL 2 -1 300 2 27 6.025E-02
MATERIAL 3 -1 300 3 2001 6.676E-02 16 3.338E-02
ANNULUS 1  0.4915 1
ANNULUS 2  0.5042 0
ANNULUS 3  0.5753 2
ANNULUS 4  1.14135 3
REGULAR 1
FEWGROUPS  2 4 6 8 10 12 14 16 18 20 22 24 27 45 55 63 68 69
MESH 6 2 2 6
```

```
BEGINC
SIGPUNCH
BUCKLING 0.0 0.005469
NOBUCKLING
LEAKAGE 5
THERMAL 4
DIFFUSION 1 3 1
BEEONE -1
DNB 1 0.0 0.0 0.0 0.0
DNB 2 0.0 0.0 0.0 0.0
DNB 3 6.676E-02 0.0 3.338E-02 0.0
REACTION 235.4 300 2238.4 300
PARTITION 45 69
PRINTC 1 1 0 1
BEGINC
//
```

Appendix 3 Sample input data of MCNP-4 code system

The general Monte Carlo Code MCNP-4 have been used to calculate the criticality for the IAEA criticality benchmark problems TRX-1 and TRX-2. The neutron multiplication factors have been calculated by the MCNP-4 code system using the cross section libraries generated from JENDL-3 and ENDF/B-IV. The sample input data of MCNP-4 code system for TRX-1 and TRX-2 are shown in Table A5 and A6 respectively.

Table A5 Input data of MCNP-4 for benchmark problem TRX-1

```
TRX-1  (  IN 2-D  GEOM  )       JENDL-3   ( CONTINUOUS  ENERGY )
1        1   .0478303  (-1 -10 12) : (-4 -11 12) : (-7 -10 -11)
2        0             (1 -2 -10 12) : (4 -5 -11 12) : (7 -8 -10 -11)
3        2   .06025   (2 -3 -10 12) : (5 -6 -11 12) : (8 -9 -10 -11)
4        3   .10014  3  6  9 -10 -11 12

1        C/Z      -.903  0  0.4915
2        C/Z      -.903  0  0.5042
3        C/Z      -.903  0  0.5753
4        C/Z        .903  0  0.4915
5        C/Z        .903  0  0.5042
6        C/Z        .903  0  0.5753
7        C/Z       0  1.56404   0.4915
8        C/Z       0  1.56404   0.5042
9        C/Z       0  1.56404   0.5753
*10        P      -1.73205  1   0 1.56404
*11        P        1.73205  1   0 1.56404
*12      PY        0

VOL        0.379461    1J   0.120562  0.892442
IMP:N      1 3R
KCODE   2000  1.2   20    100
KSRC    -.85 .02 0.0   .85 .02 0.0   0.0 1.3 0.0
   M1           92235.34C     .0006253
                92238.34C     .047205
   M2           13027.34C     .06205
   M3            1001.34C     .06676
                 8016.34C     .03338
 M119             92235.34C    1
 M129             92238.34C    1
 M219             13027.34C    1
 M319              1001.34C    1
 M329              8016.34C    1
 MT3               LWTR.01T
MT319              LWTR.01T
E0                 .625E-6     3.355E-3       6.7379E-2     10.
F104:N        1
F204:N        3
F304:N        4
FC104                           R   A   T   E          O   F
              ABSORPTION                      (REACTION TYPE  -2:-6)    AND
              PRODUCTION  :  NU * FISSION (REACTION TYPE  -6  -7)  +
                                         N,2N              (REACTION TYPE  16)
                                         N,GAMMA          (REACTION TYPE  102)
                                         GAMMA PRODUCTION  (REACTION TYPR  -5)
                                         FISSION           (REACTION TYPE  -6)
                                         FOR
                    U235   (MATERIAL  TYPE  119)  AND
                    U238   (MATERIAL  TYPE  129)
FM104    (2.37276E-4  119 -2:-6)
                                     (2.37276E-4  119 -6  -7)
                                     (2.37276E-4  119 16)
                                     (2.37276E-4  119 102)
                                     (2.37276E-4  119 -5)
                                     (2.37276E-4  119   -6)
            (1.791241E-2  129  -2 : -6)
                                     (1.791241E-2  129 -6  -7)
                                     (1.791241E-2  129  16)
                                     (1.791241E-2  129  102)
                                     (1.791241E-2  129  -5)
                                     (1.791241E-2  129  -6)
FC204             R   A   T   E          O   F
              ABSORPTION  (REACTION TYPE  -2)
```

```
                                   FOR
                    AL  (MATERIAL TYPE  219)
FM204      (.007264  219 -2)
FC304           R    A     T   E         O   F
              ABSORPTION  (REACTION TYPE  -2)
                                   FOR
                             H (MATERIAL TYPE  319)   AND
                             O (MATERIAL TYPE  329)
FM304      (.059579  319 -2)
           (.029790  329 -2)
PRINT
```

Table A6 Input data of MCNP-4 for benchmark problem TRX-2

```
TRX-2   CRITICAL  EXPERIMENT    JENDL-3   ( CONTINUOUS  ENERGY  )
C        CELL CARDS
1        1      0.10014     1 -2 -3 -4 5 6 9 12
2        2      0.0478303    ((-8 1 -2) : (-11 1 -3) : (-14 -2 -3)) -4 5
3        0               ((8 -7 1 -2) : (11 -10 1 -3) : (14 -13 -2 -3)) -4 5
4        3      0.06025  ((7 -6 1 -2) : (10 -9 1 -3) : (13 -12 -2 -3)) -4 5

C        SURFACE CARDS
*1       PY     0
*2       P      1.88274   1.087     0         2.046538
*3       P     -1.88274   1.087     0         2.046538
*4       PZ    +10
*5       PZ    -10
 6      C/Z     1.087     0         0.57530
 7      C/Z     1.087     0         0.50420
 8      C/Z     1.087     0         0.49150
 9      C/Z    -1.087     0         0.57530
10      C/Z    -1.087     0         0.50420
11      C/Z    -1.087     0         0.49150
12      C/Z     0         1.88274   0.57530
13      C/Z     0         1.88274   0.50420
14      C/Z     0         1.88274   0.49150

C         DATA   CARDS
IMP:N      1 1 1 1
C          SOURCE   CARDS
KCODE   2000   1.17   20  100
KSRC      .84   0.24    0     -0.84    0.24    0     0     1.64     0
C           MATERIAL   CARDS
C           WATER
 M1      1001.34C      .06676
         8016.34C      .03338
C           URANIUM    APPROX.    1.3  W%  ENRICHED
 M2     92235.34C     .0006253
        92238.34C     .047205
C            ALUMINIUM   CLAD
 M3     13027.34C     .06205
 M11           1001.34C   1
 M12           8016.34C   1
 M21          92235.34C   1
 M22          92238.34C   1
 M31          13027.34C   1
C            CARDS    FOR   S(ALPHA-BETA)    TREATMENT    FOR    THERMALS
 MT1           LWTR.01T
MT11           LWTR.01T
C            TALLY   CARDS
C            ENERGY   BINS  FOR   TALLYING
 E0          0.625E-6     3.355E-3      6.7379E-2      10.
C              VOLUMES
 VOL          30.53304     7.58922     0.39727     2.41125
C
C               TALLY   CARDS
F14:N        1
FC14         RATE  OF   ABSORPTION   IN  H1  AND  O16
                 UNITS : ABSORPTION  PER SOURCE  NEUTRON
                 ( C =  CM3 *ATOMS/B-CM )
                 ( PHI = 1/CM2-SOURCE-NEUTRON )
                 ( CS = B/ATOM )
FM14         ( 2.038386      11     -2 )
             ( 1.019193      12     -2 )
F24:N        2
FC24             RATE  OF   ABSORPTION  IN  U-235  &  U-238 :  ABS+FISS
                 RATE  OF   PRODUCTION  IN  U-235  &  U-238 : NU*FISS
```

```
                RATE  OF   PRODUCTION  IN  U-235  &  U-238 : N,2N
                RATE  OF   N-GAMMA     IN  U-235  &  U-238 :  N,GAMMA
                RATE  OF   GAMMA    PRODUCTION   IN  U-235  &   U-238  :  ALL  GAMMAS
                RATE  OF   PRODUCTION  IN   U-235  &   U-238  :  FISSION
                UNITS :  REACTIONS/SOURCE  NEUTRON
FM24         ( 4.74554E-3   21   -2 : -6 )
             ( 4.74554E-3   21   -6   -7 )
             ( 4.74554E-3   21   16 )
             ( 4.74554E-3   21   102 )
             ( 4.74554E-3   21   -5 )
             ( 4.74554E-3   21   -6 )
             ( 0.358249     22   -2 :  -6 )
             ( 0.358249     22   -6   -7 )
             ( 0.358249     22   16 )
             ( 0.358249     22   102 )
             ( 0.358249     22   -5 )
             ( 0.358249     22   -6 )
C
F44:N       4
FC44         RATE   OF   ABSORPTION   IN   ALLUMINUM
                 UNITS :  ABSORPTIONS/SOURCE  NEUTRON
FM44        ( 0.145278   31   -2 )
C             PERIPHERAL   CARDS
PRINT
```

Appendix 4 Sample JCL and input data of JACS (MGCL, KENO) code system

The Monte Carlo code system JACS(MGCL, KENO) have been used to calculate the criticality for the IAEA criticality benchmark problems TRX-1 and TRX-2. The neutron multiplication factors have been calculated by the JACS code system using the cross section libraries generated from JENDL-3 and ENDF/B-IV. The sample JCL and input data of SRAC code system for the benchmark problem are shown in Table A7 and A8 respectively.

Table A7 Sample JCL of JACS(MGCL,KENO) for benchmark problem TRX-1

```
   T(7) C(6) W(6) I(5) GRP OPN NOTIFY(J9150)
// EXEC     FORT77,SO='J3069.MAIL8',Q='.FORT',A='ELM(*)'
// EXEC     LKED77,A='SECTION=24'
// EXEC     GO
//SYSIN DD DSN=J9150.TRXK.CNTL(J3MKHEX1),DISP=SHR
//*FT11F001 DD DSN=J3069.CL137300.DATA,LABEL=(,,,IN),DISP=SHR
//FT21F001 DD DSN=J1446.RAB89B.HTABLE.DATA,LABEL=(,,,IN),DISP=SHR
//*FT31F001 DD DSN=J3069.SM137300.DATA,LABEL=(,,,IN),DISP=SHR
//FT11F001 DD DSN=J3069.MGCLNEW2.DATA,LABEL=(,,,IN),DISP=SHR
//FT31F001 DD DSN=J3069.SMFNEW2.DATA,LABEL=(,,,IN),DISP=SHR
// EXPAND   TPDISK,DDN=FT02F001,RECFM=VBS,RSIZE=19064,BSIZE=19068,DSN=A
// EXPAND   DISKPSN,DDN=FT03F001,DSN=B
/*
// EXEC     FORT77
      SUBROUTINE ALOCAT(PROGM)
      COMMON  D(700000)
      CALL PROGM(D,700000)
      RETURN
      END
// EXEC     LKEDIT77,LM='J3069.MKENOHEX',A='SECTION=24'
// EXEC     GO,OBSIZE=137
//SYSIN     DD DSN=J9150.TRXK.CNTL(MKHEXK1J),DISP=SHR,LABEL=(,,,IN)
//FT06F001 DD SYSOUT=*,DCB=(RECFM=FA,BLKSIZE=137,LRECL=137)
//FT10F001 DD SPACE=(TRK,(20,20)),UNIT=WK10
//FT18F001 DD SPACE=(TRK,(20,20)),UNIT=WK10
// EXPAND   DISKPSO,DDN=FT41F001,DSN=B
//FT51F001 DD SPACE=(TRK,(20,20)),UNIT=WK10
//  EXPAND GRNLP
++
//
```

Table A8 Sample input data of JACS(MGCL,KENO) for benchmark problem TRX-1

A) Input data for MGCL

```
   5  137    2    0                    3
*C-STEEL*
*ALUMINUM*
UO2-PELLET  HEXAGONAL LATTICE PITCH : 1.806 CM
   2   30    3
  3922350   3922380
 6.253 E-4 4.7205E-2
     1.806    0.4915    0.5753  0.004403     1.487
AL + VOID
   1    0    3
  3130270
 5.112 E-2
WATER
   2    0    3
  3010010   3080160
 6.676 E-2 3.338 E-2
```

B) Input data for KENO

```
TRX-1  K-EFF CALCULATION
*
60.0   60  2000 10  2R137  3R5  10  4R1  5  1 0 2000 10R0
4R-0.0 2R-1.0
1 1  1.0    2 2  1.0    3 -3  1.0    4  4  1.0    5  5  1.0
*
SUPER BOX  1  2 33 45 1
BOX TYPE   1
CYLINDER  3    0.4915                              121.92    0.0   137R0.5
CYLINDER  4    0.5753                              121.92    0.0   137R0.5
CYLINDER  2    0.5753                              137.16  -20.32  137R0.5
HEXAGON   5    0.9030                              137.16  -20.32  137R0.5
*
BOX TYPE   2
HEXAGON   5    0.903                               137.16  -20.32  137R0.5
*
CELL BDY  0   28.0     137.16  -20.32     3R0.0                    137R0.5
CUBOID    5   28.0     -28.0    28.0    -28.0      137.16  -20.32  137R0.5
*
CORE BDY  0   28.0     -28.0    28.0    -28.0      137.16  -20.32  137R0.5
CUBOID    5   60.0     -60.0    60.0    -60.0      137.16  -20.32  137R0.5
CUBOID    1   60.0     -60.0    60.0    -60.0      142.24  -21.59  137R0.5
*
-2  1 33  1    1 45  1    3R1      0
-1 14 21  1    7 39 32    3R1      0
-1 10 23  1    8 38 30    3R1      0
-1  9 25  1    9 37 28    3R1      0
-1  8 25  1   10 36 26    3R1      0
-1  8 27  1   11 35 24    3R1      0
-1  6 27  1   12 34 22    3R1      0
-1  6 28  1   13 33 20    3R1      0
-1  5 28  1   14 32 18    3R1      0
-1  5 29  1   15 31 16    3R1      0
-1  4 29  1   16 30 14    3R1      0
-1  4 30  1   17 29 12    3R1      0
-1  3 30  1   18 28 10    3R1      0
-1  3 30  1   19 27  8    3R1      0
-1  3 30  1   20 26  6    3R1      0
-1  3 31  1   21 25  4    3R1      0
-1  2 31  1   22 24  2    3R1      0
-1  3 31  1   22 23  1    4R1
```

```
*
*
17 23  1  2R0.0  60.96
*
*
0
1 0
-36.0   36.0   30.0      36.0  -36.0   30.0
  0.0    1.0    0.0       1.0    0.0    0.0
100  50  0.0  0.0  3
*
1 0
-36.0    0.0  100.0      36.0    0.0    0.0
  0.0    0.0    1.0       1.0    0.0    0.0
100  50  0.0  0.0  3
0  0
END KENO
```

Appendix 5 Sample JCL and input data of SRAC system

The reactor lattice cell calculation code system SRAC have been used to calculate the criticality for the IAEA criticality benchmark problems TRX-1 and TRX-2. The neutron multiplication factors have been calculated by the SRAC code system using the cross section libraries generated from JENDL-3 and ENDF/B-IV. The sample JCL and input data of SRAC code system for TRX-1 and TRX-2 are shown in Table A9 and A10 respectively.

Table A9 Sample JCL and input data of SRAC for TRX-1

```
 T(04) C(04) W(04) I(04) E(02) GRP MSGCLASS(X) NOTIFY(J9150)
//*      ******************************
//*      *      SRAC TFREE VERSION      *
//*      ******************************
//*      *  CASE NAME : TRX-1           *
//*      *  METHOD    : CELL            *
//*      *  LIBRARY   : JENDL-3         *
//*      ******************************
//SRAC  EXEC GO,RGN=25M
//STEPLIB DD DSN=J0752.SRAC.TFREE.LOAD,DISP=SHR
//        DD DSN=J0001.PDSF.LOAD,DISP=SHR
//*T06F001  DD DUMMY
// EXPAND GRNLP,SYSOUT=H
//FT81F001  DD DSN=&&WRK81,SPACE=(TRK,(60,15)),UNIT=WK10,
//             DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT82F001  DD DSN=&&WRK82,SPACE=(TRK,(60,15)),UNIT=WK10,
//             DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT83F001  DD DSN=&&WRK83,SPACE=(TRK,(60,15)),UNIT=WK10,
//             DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT84F001  DD DSN=&&WRK84,SPACE=(TRK,(60,15)),UNIT=WK10,
//             DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT92F001  DD DSN=&&WRK92,SPACE=(TRK,(5,2)),UNIT=WK10,
//             DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT04F001  DD DSN=&&WRK04,SPACE=(TRK,(30,10)),UNIT=WK10
//FT01F001  DD DSN=&&WRK01,SPACE=(TRK,(30,10)),UNIT=WK10
//FT02F001  DD DSN=&&WRK02,SPACE=(TRK,(30,10)),UNIT=WK10
//FT03F001  DD DSN=&&WRK03,SPACE=(TRK,(30,10)),UNIT=WK10
//FT08F001  DD DSN=&&WRK08,SPACE=(TRK,(30,10)),UNIT=WK10
//FT09F001  DD DSN=&&WRK09,SPACE=(TRK,(30,10)),UNIT=WK10
//FT10F001  DD DSN=&&WRK10,SPACE=(TRK,(30,10)),UNIT=WK10
//FT11F001  DD DSN=&&WRK11,SPACE=(TRK,(30,10)),UNIT=WK10
//FT12F001  DD DSN=&&WRK12,SPACE=(TRK,(30,10)),UNIT=WK10
//FT13F001  DD DSN=&&WRK13,SPACE=(TRK,(30,10)),UNIT=WK10
//FT14F001  DD DSN=&&WRK14,SPACE=(TRK,(100,20)),UNIT=WK10
//FT15F001  DD DSN=&&WRK15,SPACE=(TRK,(100,20)),UNIT=WK10
//*T15F001  DD SUBSYS=(VPCS,'SPACE=10M')
//FT16F001  DD DSN=&&WRK16,SPACE=(TRK,(100,20)),UNIT=WK10
//FT17F001  DD DSN=&&WRK17,SPACE=(TRK,(100,20)),UNIT=WK10
//FT18F001  DD DSN=&&WRK18,SPACE=(TRK,(100,20)),UNIT=WK10
//FT19F001  DD DSN=&&WRK19,SPACE=(TRK,(100,20)),UNIT=WK10
//FT20F001  DD DSN=&&WRK20,SPACE=(TRK,(100,20)),UNIT=WK10
//FT21F001  DD DSN=&&WRK21,SPACE=(TRK,(30,10)),UNIT=WK10
//FT22F001  DD DSN=&&WRK22,SPACE=(TRK,(30,10)),UNIT=WK10
//FT26F001  DD DSN=&&WRK26,SPACE=(TRK,(30,10)),UNIT=WK10
//FT28F001  DD DSN=&&WRK28,SPACE=(TRK,(30,10)),UNIT=WK10
//FT31F001  DD DSN=&&WRK31,SPACE=(TRK,(20,5)),UNIT=WK10,
//             DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT91F001  DD DSN=&&WRK91,SPACE=(TRK,(20,5)),UNIT=WK10,
//             DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT92F001  DD DSN=&&WRK92,SPACE=(TRK,(20,5)),UNIT=WK10,
//             DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT32F001  DD DSN=&&WRK32,SPACE=(TRK,(20,5)),UNIT=WK10
//FT33F001  DD DSN=&&WRK33,SPACE=(TRK,(20,5)),UNIT=WK10
//*******************************************************************
//FT50F001  DD DSN=J3973.BURN.DATA(SIMPLEE),DISP=SHR,LABEL=(,,,IN)
//*******************************************************************
//FT51F001  DD DSN=&&WRK51,SPACE=(TRK,(20,5)),UNIT=WK10
//FT52F001  DD DSN=&&WRK52,SPACE=(TRK,(20,5)),UNIT=WK10
//FT96F001  DD DSN=&&WRK96,SPACE=(TRK,(20,5)),UNIT=WK10
//*******************************************************************
//FASTP     DD DSN=J0752.FASTLBJ3.H01.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J2031.FASTLBJ3.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBJ3.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
```

```
//            DD DSN=J0752.FASTLBJ2.FP.MCROSS.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.FASTLBJ2.FINAL.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.FASTLBJ2.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.FASTLBB5.FINAL.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.FASTLBB5.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.FASTLBB4.FINAL.ADD.DATA,DISP=SHR,LABEL=(,,,IN)
//THERMALP    DD DSN=J0752.THERMLJ3.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLJ3.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLB3.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLJ2.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLJ2.TFREE.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLB5.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLB5.TFREE.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.THERMLB4.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//MCROSS      DD DSN=J0752.PMCROSJ3.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.PMCROSJ2.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.PMCROSB5.DATA,DISP=SHR,LABEL=(,,,IN)
//            DD DSN=J0752.PMCROSB4.DATA,DISP=SHR,LABEL=(,,,IN)
//*********** NEW USER FILES *****************************************
//UMCROSS     DD DSN=&&UMCR,DISP=(NEW,DELETE),
//            SPACE=(CYL,(10,1,50)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=11476)
//*********** USER FILES *********************************************
//FASTU       DD DSN=&&FASTU,DISP=(NEW,DELETE),
//            SPACE=(CYL,(3,1,80)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=19069)
//THERMALU    DD DSN=&&THERMU,DISP=(NEW,DELETE),
//            SPACE=(CYL,(2,1,40)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=5000)
//******************************************************************
//MICREF      DD DSN=&&MICREF,DISP=(NEW,DELETE),
//            SPACE=(CYL,(5,1,70)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=5000)
//MACROWRK    DD DSN=&&MCRWRK,DISP=(NEW,DELETE),
//            SPACE=(CYL,(3,1,50)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=2500)
//MACRO       DD DSN=&&MACRO,DISP=(NEW,DELETE),
//            SPACE=(TRK,(10,2,50)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=2500)
//FLUX        DD DSN=&&FLUX,DISP=(NEW,DELETE),
//            SPACE=(TRK,(10,1,50)),UNIT=WK10,
//            DCB=(RECFM=U,BLKSIZE=2500)
//******************************************************************
//FT98F001    DD SYSOUT=*,DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)
//FT99F001    DD SYSOUT=*,DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)
//SYSIN DD *
TRX10000
TRX-1 BENCHMARK PROBLEM USING JENDJ-3 LIBRARY.
 1 1 1 1 2   1 4 3 -2 0   0 0 0 0 2   0 1 0 0 0
 0.0057 / CRITICAL BUCKLING
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
61  46  0   0 /
61(1)         /
46(1)         /

 6 6 6 4 1   1 6 0 0 0   5 0 10 29 0   0 60 1
 0 100 50 5 5 5 0 0.0001 0.0001  0.0001 1.2 100.0 0.8
 1 1 1 2 3 4 / T-R
 1 1 1 1 / R-X
```

```
 1 2 3 3 / R-M
 0.0  0.284 0.40 0.4915   0.5753  0.75  0.9030  / RX
 31 3  1      / PLOT FOR PIJ
  3  / NMAT
METAXM1X   0  2   300.0   0.9830  0.0  /1
XU050001   2  1   6.2530E-04
XU080001   2  1   4.7205E-02
CLADXM2X   0  1   300.0   0.1676  0.0   /2
XAL70001   0  0   5.17276E-02
MOD1XM3X   0  2   300.0   2.000   0.0   /3
XH01H001   0  0   6.6760E-02
XO060001   0  0   3.3380E-02
1/ PEACO

/*
//
```

Table A10 Sample JCL and input data of SRAC for TRX-2

```
 T(07) C(04) W(04) I(04) E(02) GRP MSGCLASS(X) NOTIFY(J9150)
//*      ******************************
//*      *     SRAC TFREE VERSION     *
//*      ******************************
//*      *  CASE NAME : TRX-2         *
//*      *  METHOD    : CELL          *
//*      *  LIBRARY   : JENDL-3       *
//*      ******************************
//SRAC  EXEC GO,RGN=25M
//STEPLIB DD DSN=J0752.SRAC.TFREE.LOAD,DISP=SHR
//         DD DSN=J0001.PDSF.LOAD,DISP=SHR
//*T06F001  DD DUMMY
//  EXPAND GRNLP,SYSOUT=H
//FT81F001  DD DSN=&&WRK81,SPACE=(TRK,(60,15)),UNIT=WK10,
//          DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT82F001  DD DSN=&&WRK82,SPACE=(TRK,(60,15)),UNIT=WK10,
//          DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT83F001  DD DSN=&&WRK83,SPACE=(TRK,(60,15)),UNIT=WK10,
//          DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT84F001  DD DSN=&&WRK84,SPACE=(TRK,(60,15)),UNIT=WK10,
//          DCB=(RECFM=VBS,BLKSIZE=32644,LRECL=4080,BUFNO=2)
//FT92F001  DD DSN=&&WRK92,SPACE=(TRK,(5,2)),UNIT=WK10,
//          DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT04F001  DD DSN=&&WRK04,SPACE=(TRK,(30,10)),UNIT=WK10
//FT01F001  DD DSN=&&WRK01,SPACE=(TRK,(30,10)),UNIT=WK10
//FT02F001  DD DSN=&&WRK02,SPACE=(TRK,(30,10)),UNIT=WK10
//FT03F001  DD DSN=&&WRK03,SPACE=(TRK,(30,10)),UNIT=WK10
//FT08F001  DD DSN=&&WRK08,SPACE=(TRK,(30,10)),UNIT=WK10
//FT09F001  DD DSN=&&WRK09,SPACE=(TRK,(30,10)),UNIT=WK10
//FT10F001  DD DSN=&&WRK10,SPACE=(TRK,(30,10)),UNIT=WK10
//FT11F001  DD DSN=&&WRK11,SPACE=(TRK,(30,10)),UNIT=WK10
//FT12F001  DD DSN=&&WRK12,SPACE=(TRK,(30,10)),UNIT=WK10
//FT13F001  DD DSN=&&WRK13,SPACE=(TRK,(30,10)),UNIT=WK10
//FT14F001  DD DSN=&&WRK14,SPACE=(TRK,(100,20)),UNIT=WK10
//FT15F001  DD DSN=&&WRK15,SPACE=(TRK,(100,20)),UNIT=WK10
//*T15F001  DD SUBSYS=(VPCS,'SPACE=10M')
//FT16F001  DD DSN=&&WRK16,SPACE=(TRK,(100,20)),UNIT=WK10
//FT17F001  DD DSN=&&WRK17,SPACE=(TRK,(100,20)),UNIT=WK10
//FT18F001  DD DSN=&&WRK18,SPACE=(TRK,(100,20)),UNIT=WK10
//FT19F001  DD DSN=&&WRK19,SPACE=(TRK,(100,20)),UNIT=WK10
//FT20F001  DD DSN=&&WRK20,SPACE=(TRK,(100,20)),UNIT=WK10
//FT21F001  DD DSN=&&WRK21,SPACE=(TRK,(30,10)),UNIT=WK10
//FT22F001  DD DSN=&&WRK22,SPACE=(TRK,(30,10)),UNIT=WK10
//FT26F001  DD DSN=&&WRK26,SPACE=(TRK,(30,10)),UNIT=WK10
//FT28F001  DD DSN=&&WRK28,SPACE=(TRK,(30,10)),UNIT=WK10
//FT31F001  DD DSN=&&WRK31,SPACE=(TRK,(20,5)),UNIT=WK10,
//          DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT91F001  DD DSN=&&WRK91,SPACE=(TRK,(20,5)),UNIT=WK10,
//          DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT92F001  DD DSN=&&WRK92,SPACE=(TRK,(20,5)),UNIT=WK10,
//          DCB=(RECFM=FB,BLKSIZE=6240,LRECL=80)
//FT32F001  DD DSN=&&WRK32,SPACE=(TRK,(20,5)),UNIT=WK10
//FT33F001  DD DSN=&&WRK33,SPACE=(TRK,(20,5)),UNIT=WK10
//*********************************************************************
//FT50F001  DD DSN=J3973.BURN.DATA(SIMPLEE),DISP=SHR,LABEL=(,,,IN)
//*********************************************************************
//FT51F001  DD DSN=&&WRK51,SPACE=(TRK,(20,5)),UNIT=WK10
//FT52F001  DD DSN=&&WRK52,SPACE=(TRK,(20,5)),UNIT=WK10
//FT96F001  DD DSN=&&WRK96,SPACE=(TRK,(20,5)),UNIT=WK10
//*********************************************************************
//FASTP     DD DSN=J0752.FASTLBJ3.H01.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J2031.FASTLBJ3.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBJ3.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
```

```
//          DD DSN=J0752.FASTLBJ2.FP.MCROSS.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBJ2.FINAL.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBJ2.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBB5.FINAL.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBB5.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.FASTLBB4.FINAL.ADD.DATA,DISP=SHR,LABEL=(,,,IN)
//THERMALP  DD DSN=J0752.THERMLJ3.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLJ3.FINAL.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLB3.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLJ2.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLJ2.TFREE.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLB5.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLB5.TFREE.FP.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.THERMLB4.TFREE.DATA,DISP=SHR,LABEL=(,,,IN)
//MCROSS    DD DSN=J0752.PMCROSJ3.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.PMCROSJ2.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.PMCROSB5.DATA,DISP=SHR,LABEL=(,,,IN)
//          DD DSN=J0752.PMCROSB4.DATA,DISP=SHR,LABEL=(,,,IN)
//*********** NEW USER FILES ******************************************
//UMCROSS   DD DSN=&&UMCR,DISP=(NEW,DELETE),
//          SPACE=(CYL,(10,1,50)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=11476)
//*********** USER FILES **********************************************
//FASTU     DD DSN=&&FASTU,DISP=(NEW,DELETE),
//          SPACE=(CYL,(3,1,80)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=19069)
//THERMALU  DD DSN=&&THERMU,DISP=(NEW,DELETE),
//          SPACE=(CYL,(2,1,40)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=5000)
//*********************************************************************
//MICREF    DD DSN=&&MICREF,DISP=(NEW,DELETE),
//          SPACE=(CYL,(5,1,70)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=5000)
//MACROWRK  DD DSN=&&MCRWRK,DISP=(NEW,DELETE),
//          SPACE=(CYL,(3,1,50)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=2500)
//MACRO     DD DSN=&&MACRO,DISP=(NEW,DELETE),
//          SPACE=(TRK,(10,2,50)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=2500)
//FLUX      DD DSN=&&FLUX,DISP=(NEW,DELETE),
//          SPACE=(TRK,(10,1,50)),UNIT=WK10,
//          DCB=(RECFM=U,BLKSIZE=2500)
//*********************************************************************
//FT98F001  DD SYSOUT=*,DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)
//FT99F001  DD SYSOUT=*,DCB=(RECFM=FBA,LRECL=137,BLKSIZE=19043)
//SYSIN DD *
TRX20000
TRX-2 BENCHMARK PROBLEM USING JENDJ-3 LIBRARY.
 1 1 1 1 2   1 4 3 -2 0   0 0 0 0 2   0 1 0 0 0
 0.005469 / CRITICAL BUCKLING
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
J1480            0  0
61  46  0   0 /
61(1)          /
46(1)          /

 6 6 6 4 1   1 6 0 0 0   5 0 10 29 0   0 60 1
 0 100 50 5 5 5 0 0.0001 0.0001  0.0001 1.17 100.0 0.8
 1 1 1 2 3 4 / T-R
 1 1 1 1 / R-X
```

```
 1 2 3 3 / R-M
 0.0  0.284 0.40 0.4915   0.5753  0.75  1.0870  / RX
 31 3  1     / PLOT FOR PIJ
  3  / NMAT
METAXM1X   0  2   300.0   0.9830  0.0   /1
XU050001   2  1   6.2530E-04
XU080001   2  1   4.7205E-02
CLADXM2X   0  1   300.0   0.1676  0.0   /2
XAL70001   0  0   6.02500E-02
MOD1XM3X   0  2   300.0   2.0000  0.0   /3
XH01H001   0  0   6.6760E-02
XO060001   0  0   3.3380E-02
1/ PEACO

/*
//
```