#

SRAC CODE EXERCISE

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TRAINING ON THE REACTOR ENGINEERING AND SAFETY I
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PUSAT PENDIDIKAN DAN PELATIHAN
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PENDAHULUAN

Latar Belakang

Diktat SRAC CODE EXERCISE merupakan salah satu mata pelajaran dalam *Training of Reactor Engineering and Safety I* di PUSDIKLAT-BATAN. Seperti sudah diterangkan dalam mata pelajaran yang lain, penentuan parameter teras yang akurat, khususnya dari aspek neutronik, merupakan hal yang penting dalam menentukan tingkat keamanan dan keselamatan suatu reaktor nuklir. Penentuan parameter neutronik yang akurat hanya dapat dilakukan dengan perangkat analitis (*analytical tool*), berupa paket program (*code*), yang sudah terbukti validitasnya. Penggunaan paket program dapat menganalisis ataupun memahami karakteristik suatu teras selama beroperasi. Penggunaan paket program juga ekonomis, karena dengan hanya bermodalkan computer dapat memahami banyak fenomena fisis di suatu reaktor tanpa harus membuat suatu reaktor ataupun simulator. Oleh karena itu paket program merupakan salah satu perangkat dalam mendesain suatu reaktor.

Dalam pelatihan ini, paket program SRAC2006 digunakan sebgai perangkat analitik dalam memahami karaketristik neutronik suatu reaktor daya jenis *Pressurized Water Reactor* (PWR) [1]. Paket program SRAC2006 dikembangkan oleh JAEA sejak tahun 1978 dan sudah teruji akurasinya untuk beberapa jenis reaktor nuklir. Kemampuannya dalam menangani banyak jenis model geometri merupakan salah satu kelebihan dari paket program ini. Paket program SRAC2006 merupakan *deterministic code* dengan mengaplikasikan teori transpor neutron dan difusi neutron.

Dalam diktat ini disamping disajikan secara ringkas deskripsi paket program SRAC2006, maka disajikan pula contoh input dan kasus yang dipilih dalam diklat ini. Kasus yang dipilih adalah teras reaktor PWR berdaya 1000 MWe.

Tujuan Instruksional

Adapun tujuan instruksional umum pelajaran ini dapat memahami pembuatan input SRAC2006 dan pengolahan hasil outputnya untuk dipakai dalam memahami karakteristik neutronik suatu teras reaktor. Sedangkan tujuan instruksional khusus pelajaran ini adalah agar peserta dapat memahami:

1. instalasi paket program SRAC2006;
2. memahami struktur umum paket program SRAC2006;
3. memahami struktur input PIJ;
4. memahami struktur input CITATION;
5. memahami output PIJ;
6. memahami output CITATION;
7. menyiapkan data input SRAC206
8. melakukan penyelesaian masalah reaktor dengan SRAC2006;

Bab I

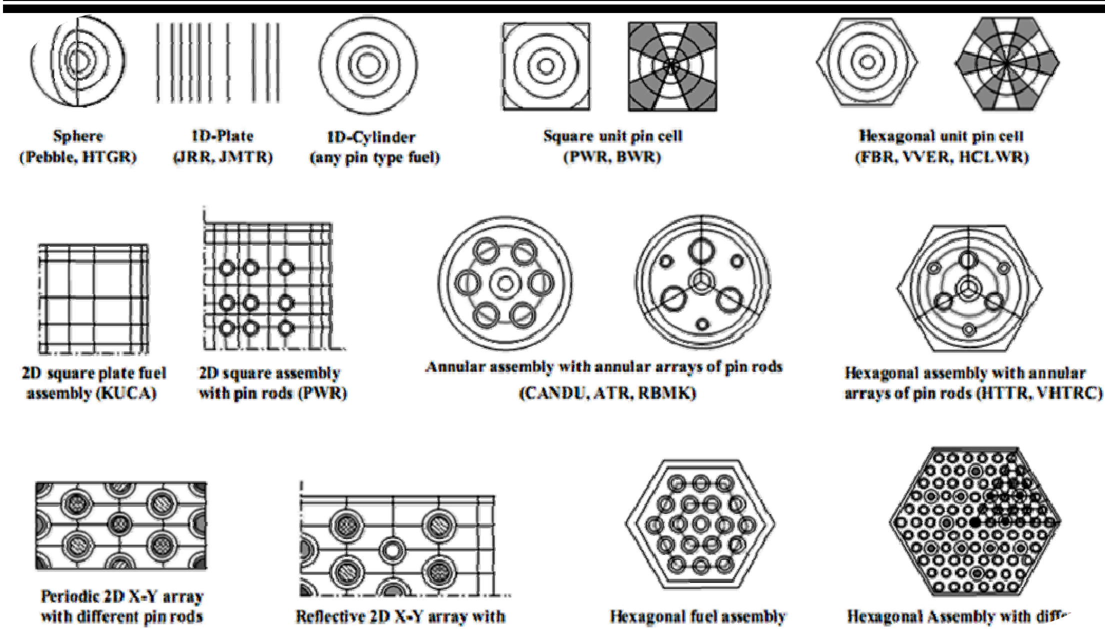
DESKRIPSI RINGKAS SRAC2006 DAN INSTALASI

I.1. SRAC2006

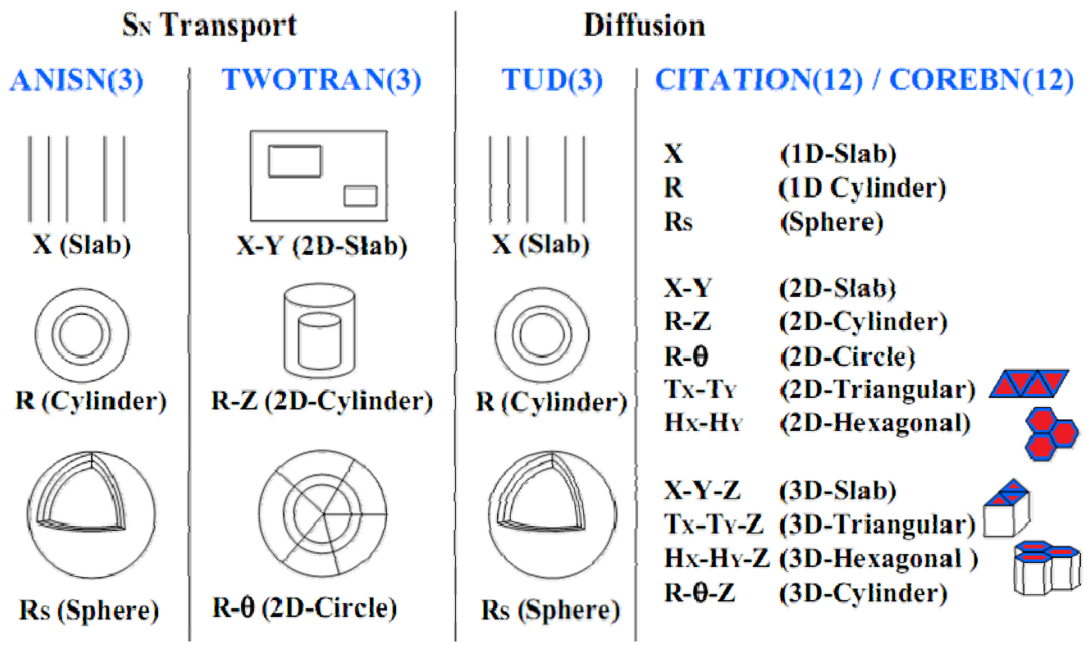
Paket program SRAC2006 merupakan sebuah sistem paket program perhitungan neutronik yang komprehensif. Komprehensif karena menggunakan beberapa metode transpor neutron, seperti PIJ (collision probability method) dan metode S_N, dan difusi neutron. Juga disebut komprehensif karena model geometri dan jumlah dimensi yang dapat dihitung sangat banyak jenisnya. Jenis perhitungan tidak saja maslah eigen value problem (keff), akan tetapi juga perhitungan laju reaksi, perhitungan fraksi bakar (*burn-up*) dan perhitungan resonansi. Disamping itu jenis data nuklir yang dimiliki sangat lah beragam. Oleh karena itu, paket program SRAC2006 terdiri atas:

1. PIJ : paket program metode transpor neutron kebolehjadian tumbukan (collision probability) yang dikembangkan JAEA dengan 16 jenis geometri (lihat Gambar 1).
2. ANISN : paket program metode transpor neutron S_N 1-Dimensi yang dapat menangani kasus *slab* (X), silinder (R) dan bola (R_S).
3. TWOTRAN : paket program metode transpor neutron S_N 2-Dimensi yang dapat menangani kasus *slab* (X-Y), silinder (R-Z) dan lingkaran (R-θ).
4. TUD : paket program metode difusi neutron 1-Dimensi yang dikembangkan JAEA dengan kasus *slab* (X), silinder (R) dan bola (R_S).
5. CITATION : paket program metode difusi neutron dengan multi dimensi untuk 12 jenis geometri termasuk pembagian mesh dalam bentuk triangular atau heksagonal.

Gambar 2 menunjukkan skema masing-masing paket program yang ada di SRAC2006 berdasarkan metode dan geometrinya.

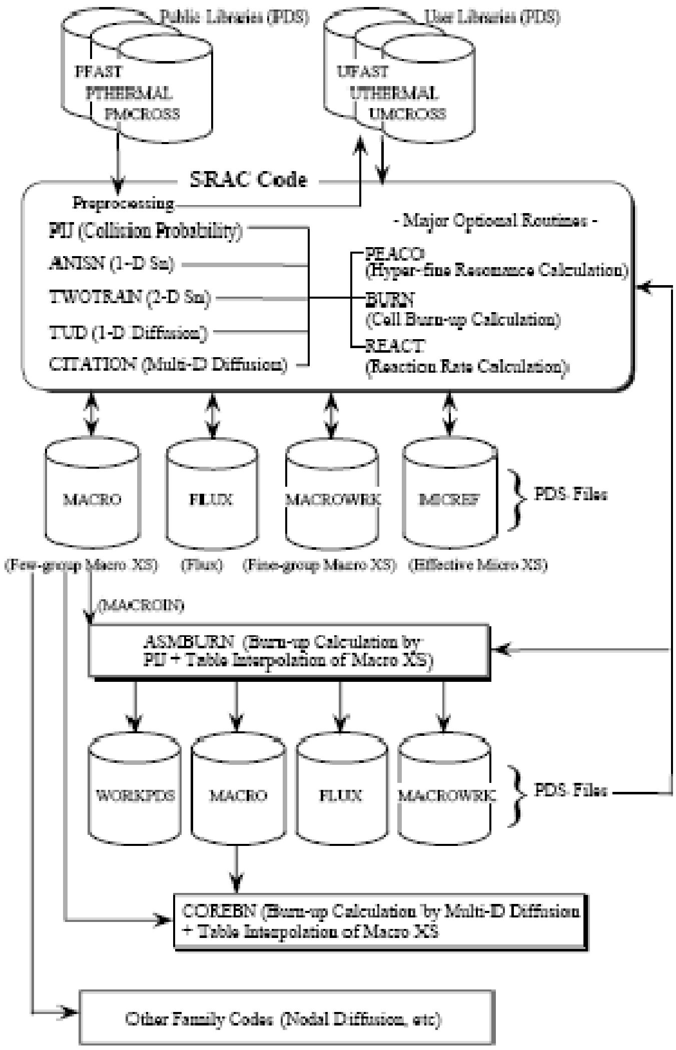


Gambar 1. Beberapa bentuk geometri yang dapat ditangani di SRAC2006



Gambar 2. Pembagian metode dan jenis geometri di SRAC2006

Gambar 3 menunjukkan skema atau diagram alir perhitungan atau modul yang dipakai di SRAC 2006.



Gambar 3. Struktur sistem SRAC2006

I.2. PUSTAKA DATA TAMPANG LINTANG

Seperti ditunjukkan dalam Gambar 3, pustaka tampang lintang, atau sering disebut *data library*, memiliki pengaruh penting dalam proses perhitungan. Dalam SRAC2006 ada beberapa jenis pustaka data tampang lintang terbaru yang digunakan yaitu ENDF/B-VII, JENDL-3.3 dan JEFF-3.1. Data tampang lintang ini disebut sebagai *Public Libraries* (PDS). Pengguna (*user*) dapat menggunakan salah satu jenis data nuklir yang diinginkan. *Public Libraries* menyediakan data tampang lintang dalam rentang energi 1×10^{-5} eV sampai 10 MeV. Sebelum melakukan perhitungan, *User Libraries* dikompilasi dari Public Libraries untuk menghemat memori dan akses data yang cepat selama perhitungan.

Jumlah kelompok energi dalam *Public Libraries* adalah 107 kelompok, 74 kelompok cepat dan 48 kelompok termal dengan 12 kelompok tenaga bertumpang tindih. Dalam manual SRAC2006 dikatakan:

The energy group structure of the current Public libraries consists of 107 groups (74 groups for fast and 48 groups for thermal energy ranges, respectively, with 12 overlapping groups). The energy boundary of each group is shown in Tables 7.3.1 and 7.3.2 in Sect.7.3. The Public Fast Library and the Public Thermal Library cover the cross-section data for neutron energy range 0.41399eV < E < 10MeV and 1E-5eV < E < 3.9279eV, respectively. The user can choose a thermal cut-off-energy from the boundary energies of the fine groups within the overlapping range, that is, 0.41399eV < E < 3.9279eV.

Table 7.3.1 Energy group structure of Public Fast Library

Group	Energy (eV)		Velocity (m/s)	Lethargy		Remarks
	Upper	Lower	Upper	Upper	Width	
1	1.00000E+07	7.78800E+06	4.37400E+07	0.0000	0.2500	(1)Fast-Fiss
2	7.78800E+06	6.06530E+06	3.86000E+07	0.2500	0.2500	
3	6.06530E+06	4.72370E+06	3.40640E+07	0.5000	0.2500	
4	4.72370E+06	3.67880E+06	3.00620E+07	0.7500	0.2500	
5	3.67880E+06	2.86510E+06	2.65290E+07	1.0000	0.2500	
6	2.86510E+06	2.23130E+06	2.34120E+07	1.2500	0.2500	
7	2.23130E+06	1.73770E+06	2.06610E+07	1.5000	0.2500	
8	1.73770E+06	1.35340E+06	1.82330E+07	1.7500	0.2500	
9	1.35340E+06	1.05400E+06	1.60910E+07	2.0000	0.2500	
10	1.05400E+06	8.20850E+05	1.42000E+07	2.2500	0.2500	
11	8.20850E+05	6.39280E+05	1.25320E+07	2.5000	0.2500	(2)Smooth
12	6.39280E+05	4.97870E+05	1.10590E+07	2.7500	0.2500	
13	4.97870E+05	3.87740E+05	9.75960E+06	3.0000	0.2500	
14	3.87740E+05	3.01970E+05	8.61280E+06	3.2500	0.2500	
15	3.01970E+05	2.35180E+05	7.60080E+06	3.5000	0.2500	
16	2.35180E+05	1.83160E+05	6.70770E+06	3.7500	0.2500	
17	1.83160E+05	1.42640E+05	5.91930E+06	4.0000	0.2500	
18	1.42640E+05	1.11090E+05	5.22390E+06	4.2500	0.2500	
19	1.11090E+05	8.65170E+04	4.61010E+06	4.5000	0.2500	
20	8.65170E+04	6.73800E+04	4.06840E+06	4.7500	0.2500	
21	6.73800E+04	5.24750E+04	3.59040E+06	5.0000	0.2500	(3)Reson-I
22	5.24750E+04	4.08680E+04	3.16850E+06	5.2500	0.2500	
23	4.08680E+04	3.18280E+04	2.79620E+06	5.5000	0.2500	
24	3.18280E+04	2.47880E+04	2.46760E+06	5.7500	0.2500	
25	2.47880E+04	1.93050E+04	2.17770E+06	6.0000	0.2500	
26	1.93050E+04	1.50340E+04	1.92180E+06	6.2500	0.2500	
27	1.50340E+04	1.17090E+04	1.69600E+06	6.5000	0.2500	
28	1.17090E+04	9.11880E+03	1.49670E+06	6.7500	0.2500	
29	9.11880E+03	7.10170E+03	1.32080E+06	7.0000	0.2500	

30	7.10170E+03	5.53080E+03	1.16560E+06	7.2500	0.2500	
31	5.53080E+03	4.30740E+03	1.02870E+06	7.5000	0.2500	
32	4.30740E+03	3.35460E+03	9.07790E+05	7.7500	0.2500	
33	3.35460E+03	2.61260E+03	8.01120E+05	8.0000	0.2500	
34	2.61260E+03	2.03470E+03	7.06990E+05	8.2500	0.2500	
35	2.03470E+03	1.58460E+03	6.23910E+05	8.5000	0.2500	
36	1.58460E+03	1.23410E+03	5.50600E+05	8.7500	0.2500	
37	1.23410E+03	9.61120E+02	4.85900E+05	9.0000	0.2500	
38	9.61120E+02	7.48520E+02	4.28810E+05	9.2500	0.2500	(4) PEACO
39	7.48520E+02	5.82950E+02	3.78420E+05	9.5000	0.2500	
40	5.82950E+02	4.54000E+02	3.33960E+05	9.7500	0.2500	
41	4.54000E+02	3.53580E+02	2.94720E+05	10.0000	0.2500	
42	3.53580E+02	2.75360E+02	2.60090E+05	10.2500	0.2500	
43	2.75360E+02	2.14450E+02	2.29520E+05	10.5000	0.2500	
44	2.14450E+02	1.67020E+02	2.02550E+05	10.7500	0.2500	
45	1.67020E+02	1.30070E+02	1.78750E+05	11.0000	0.2500	
46	1.30070E+02	1.01300E+02	1.57750E+05	11.2500	0.2500	(5)Reso-II
47	1.01300E+02	7.88930E+01	1.39210E+05	11.5000	0.2500	
48	7.88930E+01	6.14420E+01	1.22860E+05	11.7500	0.2500	
49	6.14420E+01	4.78510E+01	1.08420E+05	12.0000	0.2500	
50	4.78510E+01	3.72660E+01	9.56800E+04	12.2500	0.2500	
51	3.72660E+01	2.90230E+01	8.44370E+04	12.5000	0.2500	
52	2.90230E+01	2.26030E+01	7.45160E+04	12.7500	0.2500	
53	2.26030E+01	1.76040E+01	6.57600E+04	13.0000	0.2500	
54	1.76040E+01	1.37100E+01	5.80330E+04	13.2500	0.2500	
55	1.37100E+01	1.06770E+01	5.12140E+04	13.5000	0.2500	
56	1.06770E+01	8.31530E+00	4.51960E+04	13.7500	0.2500	
57	8.31530E+00	6.47590E+00	3.98850E+04	14.0000	0.2500	
58	6.47590E+00	5.04350E+00	3.51990E+04	14.2500	0.2500	
59	5.04350E+00	3.92790E+00	3.10630E+04	14.5000	0.2500	
60	3.92790E+00	3.05900E+00	2.74130E+04	14.7500	0.2500	(6)Overlap
61	3.05900E+00	2.38240E+00	2.41920E+04	15.0000	0.2500	
62	2.38240E+00	1.85540E+00	2.13490E+04	15.2500	0.2500	
63	1.85540E+00	1.63740E+00	1.88410E+04	15.5000	0.1250	
64	1.63740E+00	1.44500E+00	1.76990E+04	15.6250	0.1250	
65	1.44500E+00	1.27520E+00	1.66270E+04	15.7500	0.1250	
66	1.27520E+00	1.12540E+00	1.56190E+04	15.8750	0.1250	
67	1.12540E+00	9.93120E-01	1.46730E+04	16.0000	0.1250	
68	9.93120E-01	8.76430E-01	1.37840E+04	16.1250	0.1250	
69	8.76430E-01	7.73440E-01	1.29490E+04	16.2500	0.1250	
70	7.73440E-01	6.82560E-01	1.21640E+04	16.3750	0.1250	
71	6.82560E-01	6.02360E-01	1.14270E+04	16.5000	0.1250	
72	6.02360E-01	5.31580E-01	1.07350E+04	16.6250	0.1250	
73	5.31580E-01	4.69120E-01	1.00850E+04	16.7500	0.1250	
74	4.69120E-01	4.13990E-01	9.47360E+03	16.8750	0.1250	

(1) Upper Boundary of Fast Fission Range

(2) Upper Boundary of Smooth Range

(3) Upper Boundary of Resonance-I Range

(4) Upper Boundary of PEACO Routine, depending on Input IC8 in Sect.2.1

(5) Upper Boundary of Resonance-II Range, IR Approximation(if IC5=1 in Sect.2.1)

(6) Upper Energy Overlapping with Thermal Energy Range (2.3824 eV is recommended for hot water moderated system)

Table 7.3.2 Energy group structure of Public Thermal Library

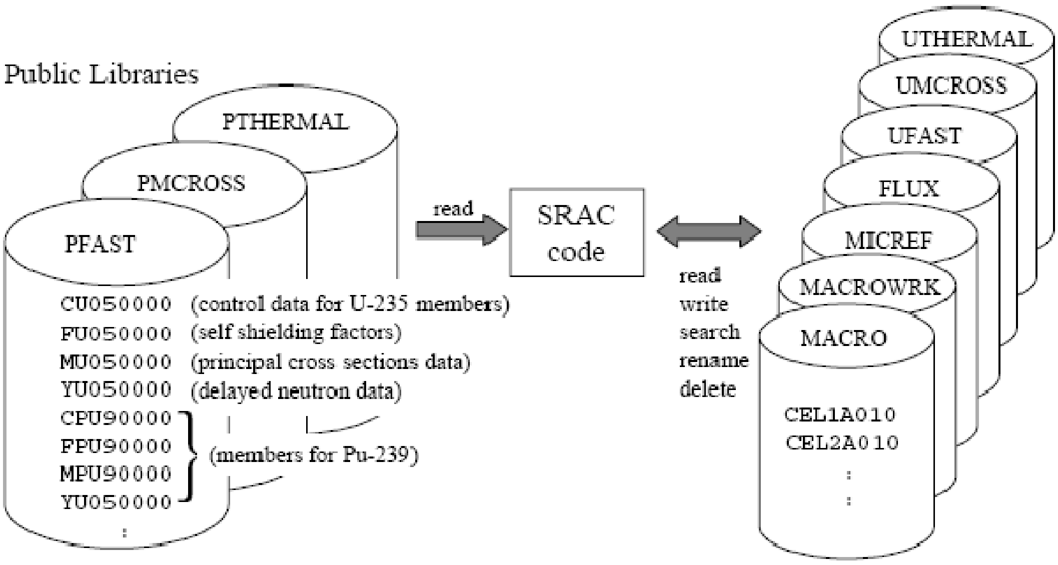
Group	Energy (eV)		Velocity (m/s)	Lethargy		Remarks
	Upper	Lower	Upper	Upper	Width	
1	3.92790E+00	3.05900E+00	2.74130E+04	14.7500	0.2500	
2	3.05900E+00	2.38240E+00	2.41920E+04	15.0000	0.2500	
3	2.38240E+00	1.85540E+00	2.13490E+04	15.2500	0.2500	
4	1.85540E+00	1.63740E+00	1.88410E+04	15.5000	0.1250	
5	1.63740E+00	1.44500E+00	1.76990E+04	15.6250	0.1250	
6	1.44500E+00	1.27520E+00	1.66270E+04	15.7500	0.1250	
7	1.27520E+00	1.12540E+00	1.56190E+04	15.8750	0.1250	
8	1.12540E+00	9.93120E-01	1.46730E+04	16.0000	0.1250	
9	9.93120E-01	8.76420E-01	1.37840E+04	16.1250	0.1250	
10	8.76420E-01	7.73440E-01	1.29490E+04	16.2500	0.1250	
11	7.73440E-01	6.82560E-01	1.21640E+04	16.3750	0.1250	
12	6.82560E-01	6.02360E-01	1.14270E+04	16.5000	0.1250	
13	6.02360E-01	5.31580E-01	1.07350E+04	16.6250	0.1250	
14	5.31580E-01	4.69120E-01	1.00850E+04	16.7500	0.1250	
15	4.69120E-01	4.13990E-01	9.47360E+03	16.8750	0.1250	(1)Overlap
16	4.13990E-01	3.89260E-01	8.89960E+03	17.0000	0.0616	
17	3.89260E-01	3.65280E-01	8.62970E+03	17.0616	0.0636	
18	3.65280E-01	3.42060E-01	8.35960E+03	17.1252	0.0657	
19	3.42060E-01	3.19610E-01	8.08960E+03	17.1909	0.0679	
20	3.19610E-01	2.97920E-01	7.81960E+03	17.2587	0.0703	
21	2.97920E-01	2.76990E-01	7.54960E+03	17.3290	0.0728	
22	2.76990E-01	2.56830E-01	7.27960E+03	17.4019	0.0756	
23	2.56830E-01	2.37420E-01	7.00970E+03	17.4774	0.0786	
24	2.37420E-01	2.18780E-01	6.73960E+03	17.5560	0.0818	
25	2.18780E-01	2.00900E-01	6.46960E+03	17.6378	0.0853	
26	2.00900E-01	1.83780E-01	6.19960E+03	17.7230	0.0891	
27	1.83780E-01	1.67430E-01	5.92960E+03	17.8121	0.0932	
28	1.67430E-01	1.51830E-01	5.65970E+03	17.9053	0.0978	
29	1.51830E-01	1.37000E-01	5.38960E+03	18.0031	0.1028	
30	1.37000E-01	1.22930E-01	5.11960E+03	18.1059	0.1084	
31	1.22930E-01	1.09630E-01	4.84960E+03	18.2142	0.1145	
32	1.09630E-01	9.70800E-02	4.57970E+03	18.3287	0.1216	
33	9.70800E-02	8.53970E-02	4.30960E+03	18.4503	0.1282	
34	8.53970E-02	7.42760E-02	4.04200E+03	18.5785	0.1395	
35	7.42760E-02	6.40170E-02	3.76960E+03	18.7181	0.1486	
36	6.40170E-02	5.45200E-02	3.49960E+03	18.8667	0.1606	

37	5.45200E-02	4.57850E-02	3.22960E+03	19.0273	0.1746	
38	4.57850E-02	3.78130E-02	2.95960E+03	19.2019	0.1913	
39	3.78130E-02	3.06020E-02	2.68960E+03	19.3932	0.2116	
40	3.06020E-02	2.41540E-02	2.41960E+03	19.6048	0.2366	
41	2.41540E-02	1.84670E-02	2.14970E+03	19.8414	0.2685	
42	1.84670E-02	1.35430E-02	1.87960E+03	20.1099	0.3101	
43	1.35430E-02	9.38050E-03	1.60970E+03	20.4200	0.3672	
44	9.38050E-03	5.98040E-03	1.33960E+03	20.7872	0.4501	
45	5.98040E-03	3.34230E-03	1.06960E+03	21.2374	0.5818	
46	3.34230E-03	1.46630E-03	7.99650E+02	21.8192	0.8239	
47	1.46630E-03	3.52380E-04	5.29650E+02	22.6431	1.4258	
48	3.52380E-04	1.00000E-05	2.59650E+02	24.0689	3.5621	
48L	1.00000E-05	***********	4.37380E+01	27.6310	******	

(1) Lower Energy Overlapping with Fast Energy Range

I.3. PENYIMPANAN DATA DALAM PDS FILE

Di dalam paket program SRAC2006, pertukaran informasi tentang tampang lintang atau fluks neutron antara paket program dilakukan dengan menyimpan data dalam PDS (Partitioned Data Set) file. PDS file berisi informasi dalam bentuk *binary*. Gambar 4 menunjukkan proses pembentukan PDS file.



Gambar 4. File I/O PDS file

Dalam manual SRAC2006 dinyatakan:

As shown in **Fig. 1.4.1**, one PDS file can contain a number of sub-files, each of which is called as member. The member name is given by not more than eight alphanumeric characters. In the SRAC system, the role of each constituent character is defined. For example, the Public Fast Library keeps principal cross-section data of U-235 and Pu-239 in the members named as 'MU050000' and 'MPU90000', respectively. On the UNIX operating system, one PDS file is just a 'directory', and a member is a usual sequential access file.

The SRAC code uses the following ten PDS files:

- PFAST : Public Fast Library (read only)
- PMCROSS : Public MCROSS Library for PEACO (read only)
- PTHERMAL : Public Thermal Library (read only)
- UFAST : User Fast Library
- UMCROSS : User MCROSS Library for PEACO
- UTHERMAL : User Thermal Library
- MICREF : Effective microscopic cross sections of mixtures in the fine-group structure of the User Library.
- MACROWRK : Macroscopic cross sections of mixtures and/or those of homogenized materials in the fine-group structure of the User Library.
- MACRO : Macroscopic cross sections of homogenized materials in the few-group structure defined by user.
- FLUX : Flux distribution in the fine-group or few-group structure.

Paling tidak ada dua hal yang perlu dilakukan ketika melakukan pengolahan data:

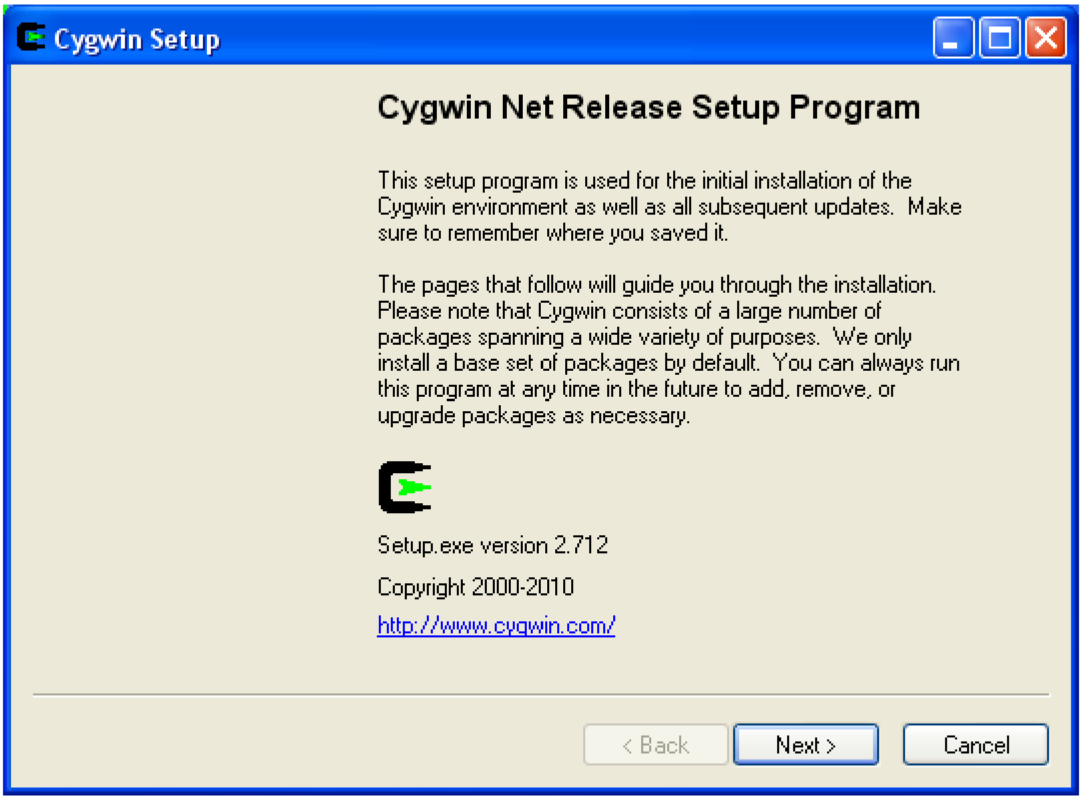
(1) *Entry data*, atau memasukan data dalam proses tabulasi.

(2) Melakukan *editing* ulang terhadap data yang telah ditabulasi untuk mencegah terjadinya kekeliruan memasukan data, atau kesalahan penempatan dalam kolom maupun baris tabel.

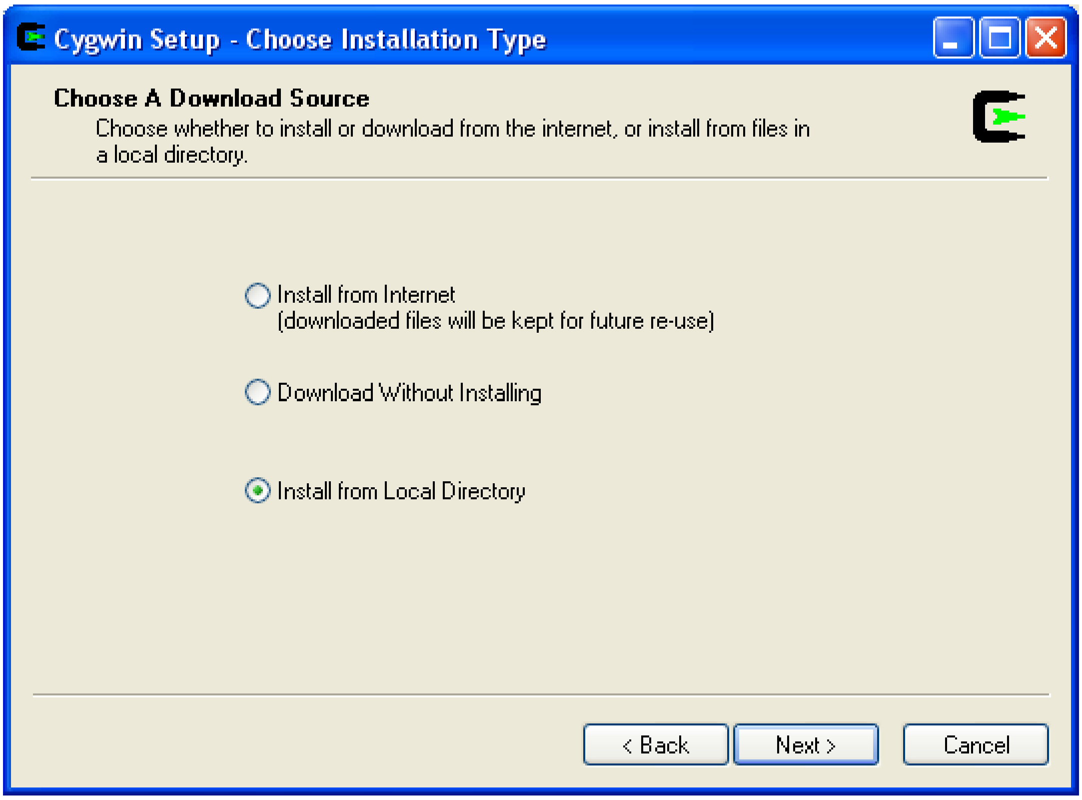
I.4. INSTALASI CYGWIN

Paket program SRAC2006 hanya dapat dijalankan di OS Linux, Unix, Sun dan FreeBSD. Akan tetapi dalam Diklat ini dipilih OS Linux dalam CYGWIN agar dapat jalan di OS Windows. Oleh karena itu, pertama sekali harus dilakukan instalasi CYGWIN seperti ditunjukkan dalam Gambar 5 -8.

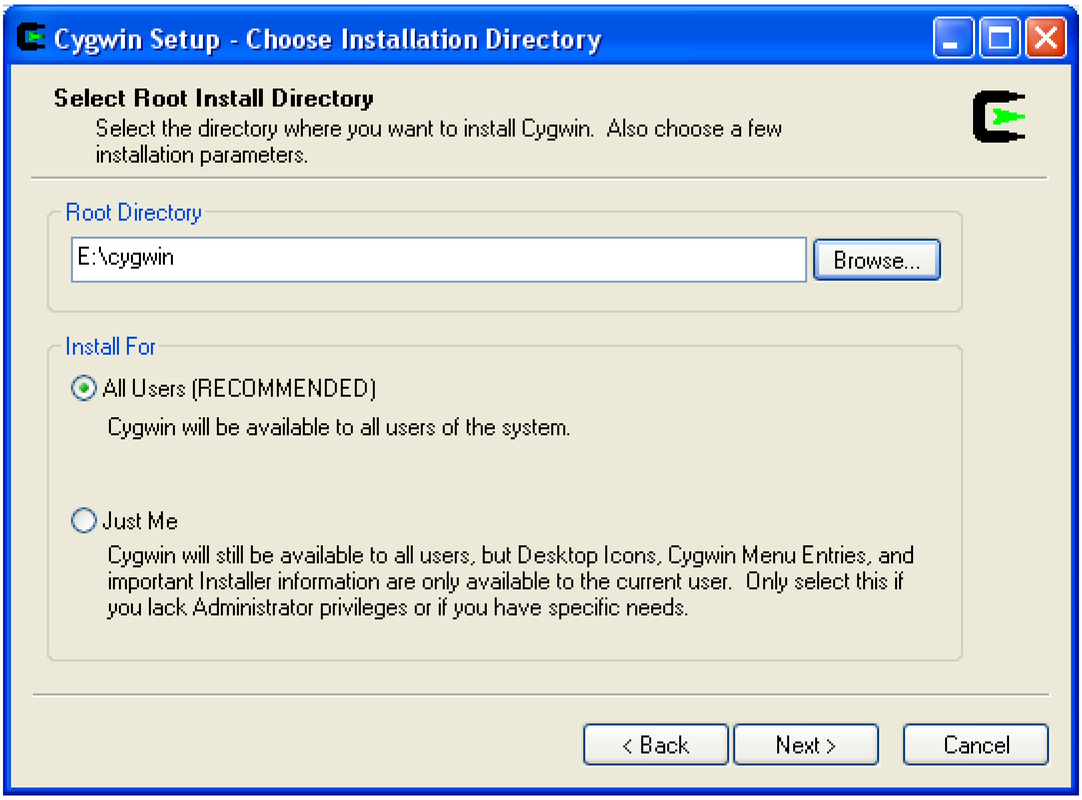
Sewaktu pemilihan paket, maka paket Devel, Shells dan X11 harus dalam keadaan “Install” sedangkan yang lain cukup “Default”.



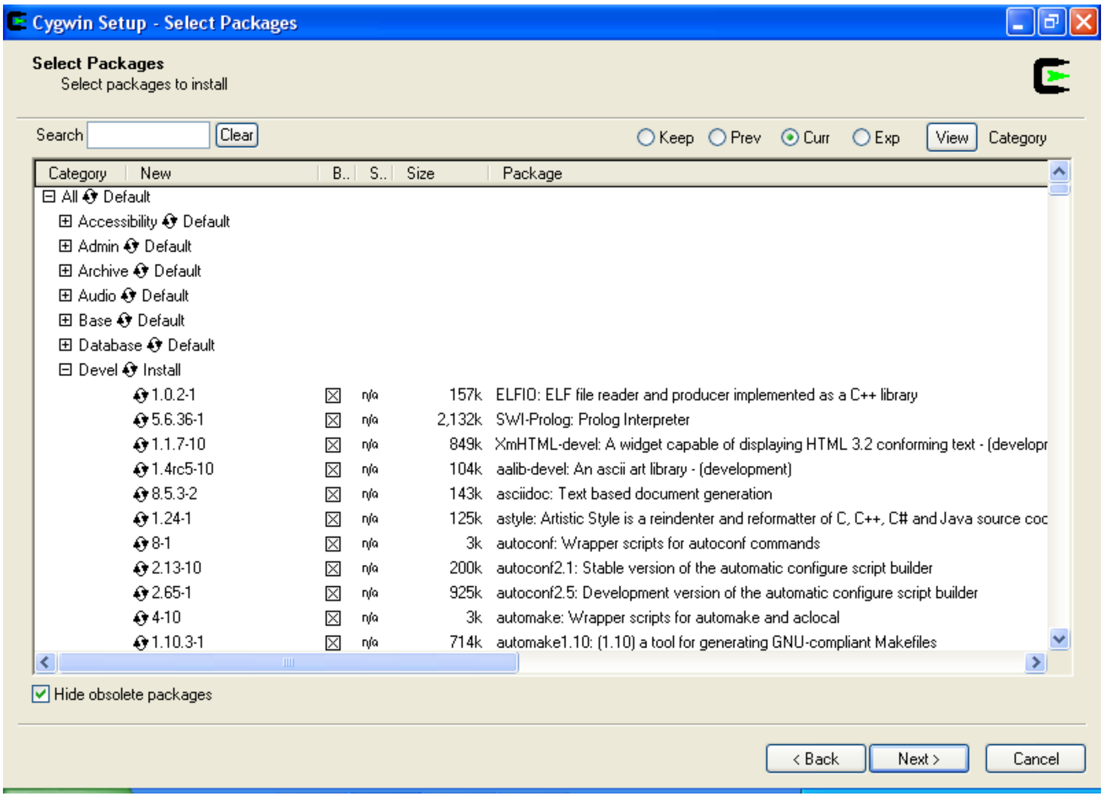
Gambar 5



Gambar 6



Gambar 7



Gambar 8

1.5. INSTALASI SRAC2006

(1) Set computer environment before installation
The installation conductor '@PunchMe' is a command by C-shell-script.
The C-shell (or TC-shell) should be used to install SRAC easily.

(2) Copy the archived files you want to use from CD/DVD to disk.
(You can put them in any directory, but avoid so deep one.)

(3) Extract the archived files

```
tar -xvf SRAC.tar
        ==> SRAC/        (You can rename this.)
        ==> srac/
tar -xvf SRACLIB-JDL33.tar
        ==> SRACLIB-JDL33/
        ==> LIBJ33/      (You can rename this.)
```

(4) Execute the installer (@PunchMe) equipped in each file.

```
cd SRAC
./@PunchMe
```

(The command @PuncMe will guide you, Try any way !)

```
cd SRACLIB-JDL33
./@PunchMe
```

Setelah dilakukan instalasi maka perlu dilakukan pengujian/test apakah 2 sample problem dapat dieksekusi sempurna, yaitu:

- Test.sh
- coba.sh

Kalau ada kegagalan, maka yang perlu diperhatikan di line yang mengandung:

```
   set SRAC_DIR = $HOME/SRAC
   set LMN  = SRAC.100m
   set BRN  = u4cm6fp50bp16T
   set ODR  = $SRAC_DIR/smpl/outp
   set CASE = Test
   set PDSD = $SRAC_DIR/tmp
#
#=============  mkdir for PDS  =============================================
#
#  PDS_DIR : directory name of PDS files
#  PDS file names must be identical with those in input data
#
   set PDS_DIR = $PDSD/$CASE
   mkdir $PDS_DIR
   mkdir $PDS_DIR/UFAST
   mkdir $PDS_DIR/UTHERMAL
   mkdir $PDS_DIR/UMCROSS
   mkdir $PDS_DIR/MACROWRK
   mkdir $PDS_DIR/MACRO
   mkdir $PDS_DIR/FLUX
   mkdir $PDS_DIR/MICREF
#
```

```
#=============  Change if you like ==========================================
#
   set LM       = $SRAC_DIR/bin/$LMN
   set DATE     = `date +%Y.%m.%d.%H.%M.%S`
   set WKDR     = $HOME/SRACtmp.$CASE.$DATE
   mkdir $WKDR
#
#-- File allocation
#  fu89 is used in any plot options, fu98 is used in the burnup option
#  Add other units if you would like to keep necessary files.
   setenv  fu50  $SRAC_DIR/lib/burnlibT/$BRN
   setenv  fu85  $SRAC_DIR/lib/kintab.dat
#  setenv  fu89  $ODR/$CASE.SFT89.$DATE
#  setenv  fu98  $ODR/$CASE.SFT98.$DATE
   setenv  fu99  $ODR/$CASE.SFT99.$DATE
   set OUTLST =  $ODR/$CASE.SFT06.$DATE
#
#=============  Exec SRAC code with the following input data ================
#
cd $WKDR
cat - << END_DATA | $LM >& $OUTLST
TEST : Case name (A4)
UO2 pin cell problem in LWR next generation fuel benchmark (No burn-up)
************************************************************************
*  Benchmark Reference :
*  A.Yamamoto, T.Ikehara, T.Ito, and E.Saji : "Benchmark Problem for
*  Reactor Physics Study of LWR Next Generation Fuels",
*  J. Nucl. Sci. Technol., Vol.39, No.8, pp.900-912, (2002).
************************************************************************
1 1 1 1 2   1 4 3 -2 1   0 0 0 0 1   2 1 0 0 0 / SRAC CONTROL
1.000E-20 / Geometrical buckling for P1/B1 calculation
*- PDS files ------2---------3---------4---------5---------6---------7--
* Note : All input line must be written in 72 columns except comments
*        even when environmental variables are expanded.
/home/tamu/SRACLIB-JDL33/pds/pfast   Old  File
/home/tamu/SRACLIB-JDL33/pds/pthml   O    F
/home/tamu/SRACLIB-JDL33/pds/pmcrs   O    F
$PDS_DIR/UFAST       Scratch  Core
$PDS_DIR/UTHERMAL    S        C
$PDS_DIR/UMCROSS     S        C
$PDS_DIR/MACROWRK    S        C
$PDS_DIR/MACRO       S        C
$PDS_DIR/FLUX        S        C
$PDS_DIR/MICREF      S        C
```

Bab II
STRUKTUR INPUT SRAC2006

Seluruh input data dalam SRAC adalah format bebas kecuali CITATION. Walaupun berformat bebas, akan tetapi data input harus dalam kolom ke 1-72. Diluar itu, maka data diabaikan.

Berdasarkan manual SRAC, maka:

The input data requirements of the SRAC code consist of the following eleven input sections for a calculation case (Ref. Sect. 1.10) in a job.

1) General control and specification of group structure (always required)
2) Specification of User library (always required)
3) PIJ: Collision probability calculation
4) ANISN: one-dimensional S_N transport calculation
5) TWOTRAN: two-dimensional S_N transport calculation
6) TUD: one-dimensional diffusion calculation
7) CITATION: multi-dimensional diffusion calculation
8) Material specification (always required)
9) Reaction rate calculation
10) Cell burn-up calculation
11) PEACO: hyperfine resonance calculation

In the first section, elementary codes and functions to be used in a case are specified. After that, detailed input data for each code or function are specified if necessary. For a job with multiple-cases, a set of the above input sections are repeated necessary times.

Dibawah ini adalah salah satu contoh input PIJ code dengan masing-masing strukturnya:

```
#!/bin/csh
#
#=============================================================================
===
#  <<  run SRAC  >>
#  CitXYZ.sh    : CELL CALCULATION enrichment 3.2
#  Options      : Pij(Geometry type IGT=4), PEACO
#=============================================================================
===
#
   alias   mkdir mkdir
   alias   cat   cat
   alias   cd    cd
   alias   rm    rm
#
#=============                    Set                  by                 user
=====================================================
#
#  LMN    : executable command of SRAC (SRAC/bin/*)
#  BRN    : burnup chain data          (SRAC/lib/burnlibT/*)
```

```
#  ODR    : directory in which output data will be stored
#   CASE    : case name which is refered as name of output files and PDS
directory
#  WKDR   : working directory in which scratch files will be made and deleted
#  PDSD   : top directory name of PDS file
#
   set SRAC_DIR = $HOME/SRAC
   set LMN  = SRAC.100m
   set BRN  = u4cm6fp50bp16T
   set ODR  = $SRAC_DIR/smpl/outp
   set CASE = pin32j33
   set PDSD = $SRAC_DIR/tmp
#
#=============                          mkdir            for              PDS
=================================================
#
#  PDS_DIR : directory name of PDS files
#  PDS file names must be identical with those in input data
#
   set PDS_DIR = $PDSD/$CASE
   mkdir $PDS_DIR
   mkdir $PDS_DIR/UFAST
   mkdir $PDS_DIR/UTHERMAL
   mkdir $PDS_DIR/UMCROSS
   mkdir $PDS_DIR/MACROWRK
   mkdir $PDS_DIR/MACRO
   mkdir $PDS_DIR/FLUX
   mkdir $PDS_DIR/MICREF
#
#=============                   Change         if          you          like
=============================================
#
   set LM       = $SRAC_DIR/bin/$LMN
   set DATE     = `date +%Y.%m.%d.%H.%M.%S`
   set WKDR     = $HOME/SRACtmp.$CASE.$DATE
   mkdir $WKDR
#
#-- File allocation
#  fu89 is used in any plot options, fu98 is used in the burnup option
#  Add other units if you would like to keep necessary files.
   setenv  fu50  $SRAC_DIR/lib/burnlibT/$BRN
   setenv  fu85  $SRAC_DIR/lib/kintab.dat
   setenv  fu89  $ODR/$CASE.SFT89.$DATE
#  setenv  fu98  $ODR/$CASE.SFT98.$DATE
   setenv  fu99  $ODR/$CASE.SFT99.$DATE
   set OUTLST =  $ODR/$CASE.SFT06.$DATE
#
#=============  Exec SRAC code with the following input data ================
#
cd $WKDR
cat - << END_DATA | $LM >& $OUTLST
FUL1
Cell calculation for inner fuel (3.2 w/o UO2) with PIJ
1 1 1 1 2   1 4 3 -2 1   0 0 0 0 1   2 1 0 0 0 / SRAC CONTROL
1.000E-20 / Geometrical buckling for P1/B1 calculation
*- PDS files ------2---------3---------4---------5---------6---------
* Note : All input line must be written in 72 columns except comments
*        even when environmental variables are expanded.
/home/HP/SRACLIB-JDL33/pds/pfast   Old  File
/home/HP/SRACLIB-JDL33/pds/pthml   O    F
/home/HP/SRACLIB-JDL33/pds/pmcrs   O    F
$PDS_DIR/UFAST     Scratch  Core
$PDS_DIR/UTHERMAL  S        C
$PDS_DIR/UMCROSS   S        C
$PDS_DIR/MACROWRK  S        C
$PDS_DIR/MACRO     S        C
$PDS_DIR/FLUX      S        C
$PDS_DIR/MICREF    S        C
************************************************************************
62 45  1 1 /  107 group => 2 group
62(1)      /  Energy group structure suggested for LWR analyses
```

General control and energy structure, lihat manual hal 31 - 43

```
45(1)       /
62          /
45          /
***** Enter one blank line after input for energy group structure

***** Input for PIJ (Collision Probability Method)
4 7 7 3 1   1 7 0 0 0   5 0 6 45 0   0 90 1         / Pij Control
+2 50 50 5 5 5 -1  0.0001 0.00001 0.001 1.0 10. 0.5  /
1 1 1 2 3 3 3  /  R-T
3(1)           /  X-R
1 2 3          /  M-R
0.0 0.236714 0.334764 0.41  0.475  0.5267 0.5783 0.630   / RX
8 1 1  / for geometry plot
3  / NMAT
FUE1X01X  0 3  900.   0.82     0.0  / 1 : Inner fuel 3.2 w/o
XU050000  2 0  7.2270E-4       /1
XU080000  2 0  2.1585E-2       /2
XO060000  0 0  4.4616E-2       /3
CLD1X02X  0 3  600.   0.13     0.0  / 2 : Cladding
XZRN0000  0 0  3.8032E-2       /1
XCRN0000  0 0  6.7152E-5       /2
XFEN0000  0 0  1.3129E-4       /3
MOD1X03X  0 2  581.   1.0      0.0  / 3 : Moderator
XH01H000  0 0  4.7508E-2       /1
XO060000  0 0  2.3754E-2       /2
0  / PEACO

END_DATA
#
#========  Remove scratch PS files ===========================================
#
   cd $HOME
   rm -r $WKDR
#
#========  Remove PDS files if you don't keep them =========================
#
   rm -r $PDS_DIR
#
#  rm -r $PDS_DIR/UFAST
#  rm -r $PDS_DIR/UTHERMAL
#  rm -r $PDS_DIR/UMCROSS
#  rm -r $PDS_DIR/MACROWRK
#  rm -r $PDS_DIR/MACRO
#  rm -r $PDS_DIR/FLUX
#  rm -r $PDS_DIR/MICREF
```

Material Specification, hal 121-128

Soal:

Coba bagi bagian dari input “coba.sh”

Bab III

PERHITUNGAN KERAPATAN ATOM

Salah satu hal yang paling penting dalam mempersiapkan input SRAC2006 adalah perhitungan kerapatan atom penyusun dari bahan bakar, kelongsong, moderator dan bahan struktur lainnya di teras. Dalam Bab ini disajikan tentang perhitungan kerapatan atom.

The basic equation for atom density is: $n = \frac{\rho N_a}{A}$

n= atom density (atoms/cc)

ρ = density of material (g/cc)

N_a = Avogadro's number = $0.6022*10^{24}$

A = atomic weight of isotope (g/mole)

Misal:

$$\rho = 19.1 \frac{g}{cm^3} \qquad N_a = 0.6022 * 10^{24} \frac{atoms}{mole} \qquad A = 238.05 \frac{grams}{mole}$$

maka:

$$n = 4.832 * 10^{22} \frac{atoms}{cm^3}$$

Akan tetapi banyak *computer code* memakai kerapatan atom dalam satuan atom/barncm. Karena 1 barn = 10^{-24} cm^2, maka bilangan Avogadro (N_a) menjadi 0.6022.

Sehingga:

n= 4.832 × 10^{-2} atom/barncm

Untuk memakai Bilangan Avogadro yang tepat, maka dapat digunakan bilangan di bawah ini:

Values of N_A	Units
$6.022\,141\,79(30) \times 10^{23}$	mol^{-1}
$2.731\,597\,57(14) \times 10^{26}$	$lb\text{-}mol.^{-1}$

III.1. DUA NUKLIDA/UNSUR

Rumus:

$$N_i = \frac{\rho_{mix} * wf_i * N_a}{A_i}$$

N_i = atom density of i^{th} material.
ρ_{mix} = mass density of mixture.
wf_i = weight fraction of i^{th} material.
A_i = atomic weight of i^{th} material.

Soal:
Coba hitung kerapatan atom ^{235}U dan ^{238}U dalam uranium yang diperkaya 3%. Diketahui kerapatan uraniumnya 18,9 g/cm^3.

Jika memakai fraksi atom, maka berat atom rerata menjadi:

$$\overline{A} = af_1 * A_1 + af_2 * A_2 + \ldots\ldots + af_i * A_i$$

Sehingga:

$$N_{mix} = \frac{\rho_{mix} * N_a}{\overline{A}}$$

atau:

$$N_i = af_i * N_{mix}$$

Misal:
Natural boron mempunyai kerapatan 2,34 g/cc, dengan fraksi atom ^{10}B dan ^{11}B masing-masing sebesar 0,199 dan 0,801. Hitunglah kerapatan atom masing-masing nuklida.
Jawab:

$$\overline{A} = 0.199 * 10.01 + 0.801 * 11.01 = 10.81 g \frac{B_{nat}}{mole}$$

$$N_{mix} = N_{B_{nat}} = \frac{(2.34 g \frac{B_{nat}}{cm^3}) * (0.6022 \frac{atom - cm^2}{mole - b})}{10.81 g \frac{B_{nat}}{mole}}$$

$$= 1.304 * 10^{-1} \frac{atoms_{B_{nat}}}{b - cm}$$

$$N_{B-10} = 0.199 \frac{atom_{B-10}}{atom_{B_{nat}}} * 1.304 * 10^{-1} \frac{atom_{B_{nat}}}{b - cm} = 2.59 * 10^{-2} \frac{atom_{B-10}}{b - cm}$$

$$N_{B-10} = 0.801 \frac{atom_{B-11}}{atom_{B_{nat}}} * 1.304 * 10^{-1} \frac{atom_{B_{nat}}}{b-cm} = 1.045 * 10^{-1} \frac{atom_{B-11}}{b-cm}$$

Jika memakai fraksi berat, maka:

$$\overline{A} = [\frac{wf_1}{A_1} + \frac{wf_2}{A_2} + ... + \frac{wf_i}{A_i}]^{-1}$$

maka fraksi berat tiap nuklida:

$$wf_i = af_i * \frac{A_i}{\overline{A}}$$

Jika perhitungan diatas kita pakai, maka:

$$wf_{B10} = 0.199 * \frac{10.01}{10.81} = 0.184$$

$$wf_{B11} = 0.801 * \frac{11.01}{10.81} = 0.816$$

Ini mengindikasikan adanya perbedaan fraksi atom dan fraksi berat, sehingga dalam persiapan data perlu hati-hati.

III.2. MOLEKUL

Jika kerapatan air (H2O) adalah 1,0 g/cc, maka:

$$N_{H_2O} = \frac{(1.0g / cm^3)(0.6022atom - cm^2 / mole - b)}{18g / mole} = 3.34 * 10^{-2} \frac{molecules_{H_2O}}{b-cm}$$

$$N_H = 2 * N_{H_2O} = 6.68 * 10^{-2} \frac{atoms_H}{b-cm} \qquad N_O = 1 * N_{H_2O} = 3.34 * 10^{-2} \frac{atoms_O}{b-cm}$$

III.3. MOLEKUL DENGAN CAMPURAN ISOTOP

Hitunglah kerapatan masing-masing nuklida, B-10, B-11 dan C, dalam B4C yang diketahui densitasnya 2,54 g/cc.

Jawab:

$$A_{B_4C} = \frac{4molesB_{nat}}{mole_{B_4C}} * \frac{10.81g}{mole_{Bnat}} + \frac{1mole_C}{mole_{B_4C}} * \frac{12.00g}{mole_C} \qquad A_{B_4C} = 55.24 g/mole$$

$$N_{B_4C} = \frac{(2.54g / cc)(.6022molecules - cm^2 / mole - b)}{55.24g / mole}$$

$$N_{B_4C} = 2.77 * 10^{-2} \frac{molecules_{B_4C}}{b-cm}$$

$$N_{B_{nat}} = 4 * N_{B_4C} = 1.108 * 10^{-1} \frac{atoms_{B_{nat}}}{b-cm}$$

$$N_{B_{10}} = af_{B_{10}} * N_{B_{nat}} = 0.199 * 1.108 * 10^{-1} = 2.205 * 10^{-2} \frac{atoms_{B_{10}}}{b-cm}$$

$$N_{B_{11}} = af_{B_{11}} * N_{B_{nat}} = 0.801 * 1.108 * 10^{-1} = 8.875 * 10^{-2} \frac{atoms_{B_{11}}}{b-cm}$$

$$N_C = 1 * N_{B_4C} = 2.77 * 10^{-2} \frac{atoms_C}{b-cm}$$

Hitunglah kerapatan unsur dalam UO_2 dimana pengkayaan uraniumnya 20% ($U(20)O_2$), jika diketahui kerapatan UO_2 adalah 10,5 g/cc

Jawab:

$$\overline{A}_U = [\frac{0.20}{235.04} + \frac{0.80}{238.05}]^{-1} = 237.44 \frac{gU(20)}{cm^3}$$

$$\overline{A}_{UO_2} = 237.44 + 2 * 16 = 269.44 \frac{gUO_2}{cm^3}$$

$$N_{UO_2} = \frac{(10.5 g_{UO_2} / cc)(.6022 molecules - cm^2 / mole - b)}{269.44 g / mole}$$

$$= 2.35 * 10^{-2} \frac{molecules_{UO_2}}{b-cm}$$

$$N_O = 2 * N_{UO_2} = 4.70 * 10^{-2} \frac{atoms_O}{b-cm}$$

$$N_U = 1 * N_{UO_2} = 2.35 * 10^{-2} \frac{atoms_U}{b-cm}$$

$$af_{U235} = wf_{U235} * \frac{\overline{A}}{A_{235}} = 0.20 * \frac{237.44}{235.04} = 0.202$$

$$af_{U238} = wf_{U238} * \frac{\overline{A}}{A_{238}} = 0.80 * \frac{237.44}{238.05} = 0.798$$

$$N_{U235} = f_{U235} * N_U = 0.202 * 2.35 * 10^{-2} = 4.75 * 10^{-3} \frac{atoms_{U235}}{b-cm}$$

$$N_{U238} = f_{U238} * N_U = 0.798 * 2.35 * 10^{-2} = 1.875 * 10^{-2} \frac{atoms_{U238}}{b-cm}$$

SOAL:

Hitunglah kerapatan atom masing-masing penyusun bahan bakar PWR di bawah ini:

Geometry	Square 17×17 matrix
Fuel assembly dimension	Square 214 x 214 mm
Composition per assembly	Total: 289 Fuel: 264 Control rod guide thimble: 24 Instrumentation thimble: 1
Fuel material	UO_2 (U235,U238,Oxygen)
Cladding material	Zircaloy-4 98.23 weight % zirconium with 1.45% tin, 0.21% iron, 0.1% chromium, and 0.01% hafnium
Gap filler	Helium gas
Fuel average density	95 – 96% Theoretical Density UO_2-TD = 10.96 g/cc
Moderator (coolant)	light water (H_2O) average density 0.7295 gr/cc
H/HM ratio (hydrogen to heavy metal ratio)	1.7 – 3.4 (depends on enrichment level)
Enrichment	2.5 – 5 Wt % U235
Fuel pellet diameter	8.19 mm
Pellet-clad gap	0.082 mm
Clad thickness	0.572 mm
Outer diameter of fuel rods	9.5 mm
Pitch (center-to-center)	12.54 mm
P/D	1.32

Bab IV
DESKRIPSI KASUS

In the present exercise, the specification of fuel assembly and reflector as shown in the SRAC2006 manual pages 204-205 are used. There are two uranium enrichments are used for the fuel, 2.1 w/0 and 3.2 w/0. A fuel assembly is consists of 17 × 17 fuel pin rods. As shown in Fig. 9, fuel pellets of 9.5 mm diameter were clad into the Zirconium tube of 0.65 mm thickness with an active fuel length of 3400 mm. The fuel pin pitch is 12.6 mm. Unlike a typical PWR fuel assembly using some guide tubes, in this case, we assumed the fuel assembly is arranged fully by 17 × 17 of UO_2 fuel pins as shown in Fig.10. Table 1 shows the atomic density of the UO_2 pin cells for 3.2 w/0 and 2.1 w/0.

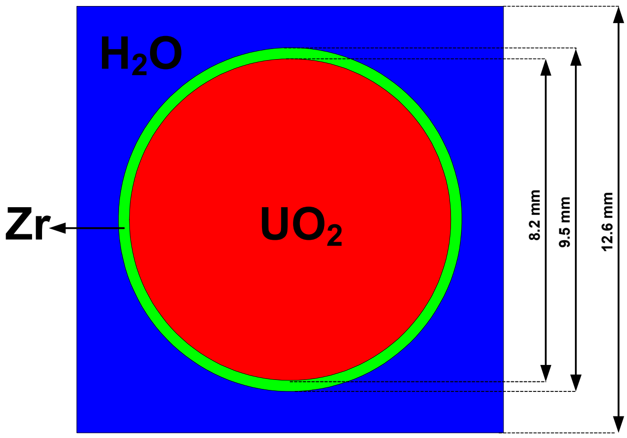


Fig. 9 Cross section view of a fuel pin cell

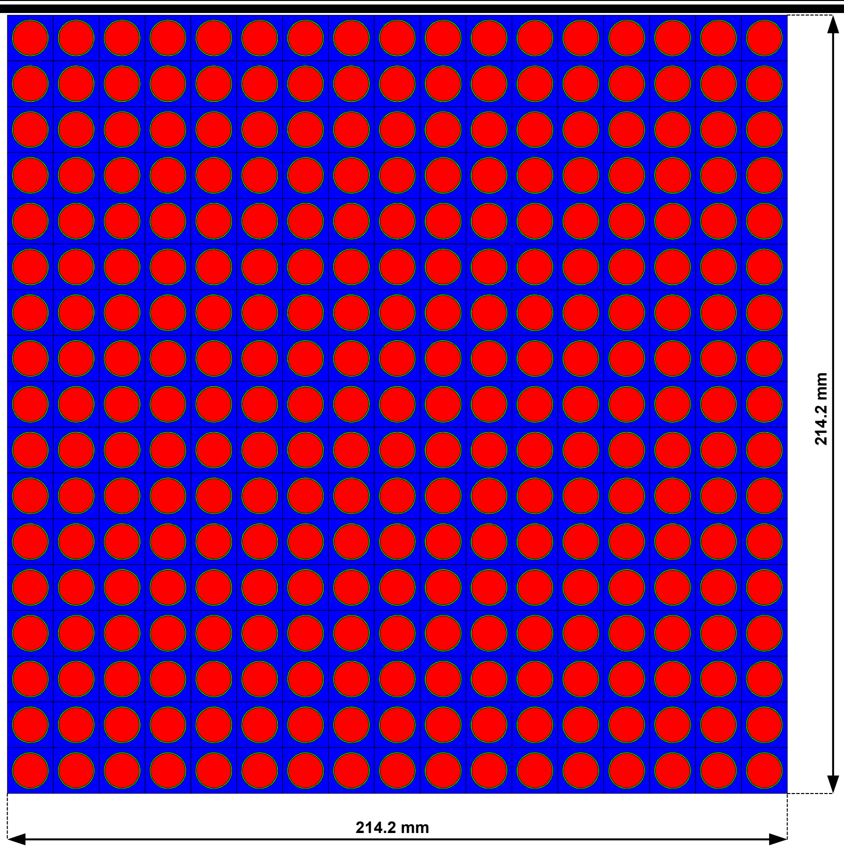


Fig 10. A 17 × 17 type fuel assembly

Table 1 Atomic density of the UO_2 pin cells

No.	Elements	3.2 w/0	2.1 w/0
Fuel, T = 900 K			
1	^{235}U	7.2270×10^{-4}	4.7428×10^{-4}
2	^{238}U	2.1585×10^{-2}	2.1831×10^{-2}
3	O	4.4616×10^{-2}	4.4610×10^{-2}
Cladding, T = 600 K			
4	Zr	3.8032×10^{-2}	3.8032×10^{-2}
5	Cr	6.7152×10^{-5}	6.7152×10^{-5}
6	Fe	1.3129×10^{-4}	1.3129×10^{-4}
Moderator, T = 581 K			
7	H	4.7508×10^{-2}	4.7508×10^{-2}
8	O	2.3754×10^{-2}	2.3754×10^{-2}
Reflector (Coolant + Structure materials), T = 581 K			
9	H	4.7508×10^{-2}	4.7508×10^{-2}
10	O	2.3754×10^{-2}	2.3754×10^{-2}
11	Fe	1.7886×10^{-2}	1.7886×10^{-2}
12	Cr	5.2140×10^{-3}	5.2140×10^{-3}
13	Ni	2.4294×10^{-3}	2.4294×10^{-3}
14	Mn	2.5977×10^{-4}	2.5977×10^{-4}

The core is arranged by the inner (3.2 w/0) and outer regions (2.1 w/0) as shown in the Fig. 11. The axial view of the core is shown in Fig. 12 with a total length of 3800 mm.

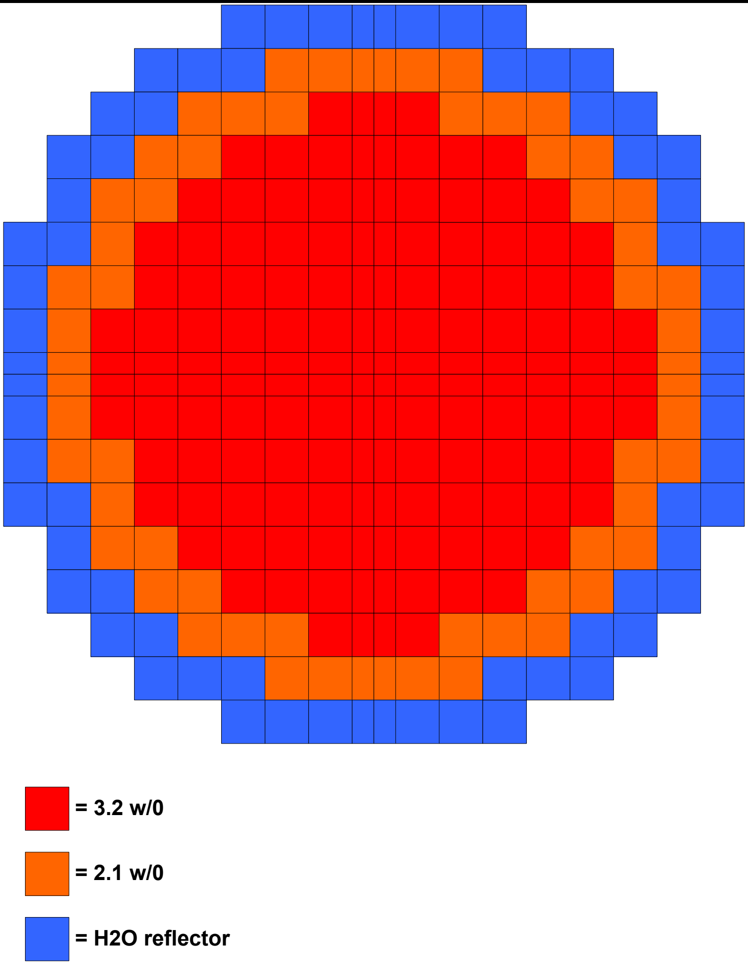


Figure 11 Cross sectional view of the core

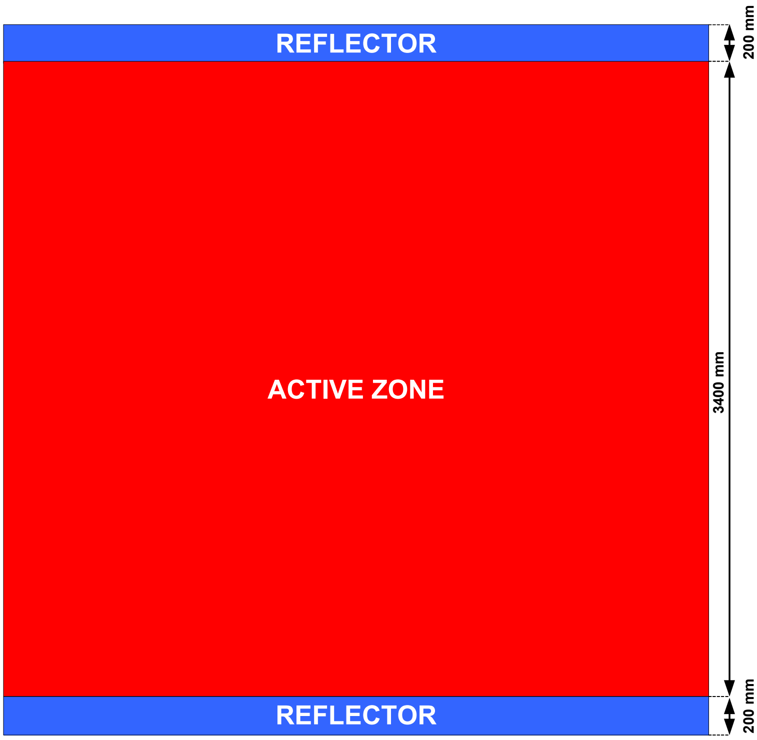


Figure 12 Vertical view of the core

There are 177 fuel assemblies in the core with the 56 fuel assemblies of 2.1 w/0 and the 121 fuel assemblies of 3.2 w/0.

Daftar Pustaka

[1] Keisuke OKUMURA, Teruhico KUGO, Kunico KANENKO and Keichiro TSUCHIHASHI, **SRAC2006: Comprehensive Neutronics Calculation Code System**, JAEA-Data/Code 2007-004 February 2007, JAEA, Japan