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DKPRO: A Radionuclide Decay and Reprocessing Code

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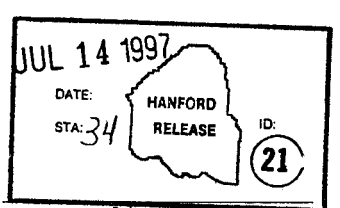
Abstract: The DKPRO code models the decay and reprocessing of Hanford nuclear waste starting from plant history records and ORIGEN2 radionuclide inventories.



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DKPRO: A RADIONUCLIDE DECAY AND REPROCESSING CODE

1.0 INTRODUCTION

The DKPRO code solves the general problem of modeling complex nuclear wastes streams using ORIGEN2 (Croff 1980, Wittekind 1994) radionuclide production files. There is a continuing need for estimates of Hanford radionuclides. Physical measurements are one basis; calculational estimates, the approach represented here, are another. Given a known nuclear fuel history, it is relatively straightforward to calculate radionuclide inventories with codes such as the widely-used Oak Ridge National Laboratory code ORIGEN2.

The long and complex history of Hanford reactor and reprocessing operations has created a need to easily and efficiently model these processes. While ORIGEN2 is well suited for modeling simple process streams, it is not readily applied to the Hanford operations. An alternative approach was adopted whereby ORIGEN2 is used to calculate initial radionuclide inventories with subsequent decay and reprocessing computed by the DKPRO code.

This approach has already been implemented in another context by the RADNUC (Schwarz 1995) code which has been used to estimate radionuclide inventories in the Hanford waste tanks and spent-fuel in the K basins. While RADNUC could be modified to treat the more general problem addressed here, much of the RADNUC code includes specific assumptions and approximations that limit its extension.

The DKPRO code uses the decay and transmutation subroutine from ISOCALC (Schmittroth 1995a). Unlike RADNUC, the decay and transmutation chains are solved completely and can use the same nuclear data as ORIGEN2 assuring consistency with ORIGEN2 calculations. Another design advantage of DKPRO is the inclusion of ORIGEN2-based initial inventories in external files that can be easily added or changed without the need for code modifications.

The DKPRO code, used in conjunction with the ORIGEN2 code, provides an efficient method for modeling radionuclide generation, decay, and reprocessing. The capability to simplify complex processes and the flexibility of this method allow for many potential applications. The primary intended application of the DKPRO code is in the generation of input for global radionuclide inventory estimates for Hanford tank wastes. This use does not impact safety significant systems. The inclusion in one code of the whole process of generating global tank inventories, from radionuclide generation and decay through reprocessing, provides opportunities for easy sensitivity studies and evaluation of what-if scenarios for global tank inventories. The global inventories can also be categorized by reprocessing plant and by specified time periods. In addition to the cumulative totals, output inventories are provided for each of the detailed time steps provided in the input fuel discharge data (such as monthly or yearly records).

The radionuclide inventories generated by the DKPRO code are entirely dependent on the assumptions and accuracy of the historical data represented by the input parameters. These parameters include fuel history, fuel and cladding compositions and impurities, and the effects of the various waste reprocessing splits and recovery factors. Varying these parameters can significantly impact the code output.

2.0 DKPRO OPERATION

The DKPRO code is executed with the command:

```
dkpro < input_file >output_file.
```

The file, input_file, contains a set of user-supplied directives that control the general operation of the code. The code also receives input from several other files. These include an archive file of fuel-discharge records, a PROCESS.DIR file of processing directives, a SUMMARY.DIR file of summary directives, and a set of ORIGEN2 inventory files representing initial unprocessed radionuclide inventories.

The basic operation of the code is to read through the archive file of fuel-discharge records, processing each record in turn. A more detailed description of the code operation is given next. User-supplied directives represented as keywords and parameters are described in Section 3.

2.1 Archive History File

The DKPRO code reads a fuel-discharge history file (default: archive.dat). Each record of the archive history file includes the amount of discharged fuel, the discharge date, the fuel type, and specific burnup. The burnup is used to interpolate between ORIGEN2 output files containing the initial normalized nuclide inventories. These normalized values are then multiplied by the amount of discharged fuel given on the archive record to create an inventory vector of nuclide amounts at the discharge date.

The inventory vector is then processed by a set of user-supplied directives (PROCESS.DIR) that describe decay and reprocessing steps. These directives are identified by a "plant" variable to indicate which archive records the directory updates. Detailed archive record formats are given in Appendix A.

There are two output categories. First, for each archive record, processed nuclide inventories are written to a file (i.e., output.cur) for selected isotopes identified in the input file. Second, summary output, controlled by directives given in the Summary Directive file SUMMARY.DIR, is written to standard output. The summary output can be very useful in providing global checks on the validity of the calculation.

Additionally, two log files are generated that give more detailed information on operations performed by the code. The file, process.log, reports processing operations conducted on each record. The file, library.log, reports data used during the decay calculations.

2.2 Time Conventions

Dates given in the format month/year are used in several places in DKPRO. For example "1/91" represents the beginning of January 1991. Internally these dates are converted into the number of days past January 1, 1920. Two digit or four digit years can be used. Two digit years prior to 1920 are interpreted as the next century. (E.g. 15 becomes 2015.)

2.3 Process Directive File: PROCESS.DIR

The Process Directive file is a free-format keyword-driven text file that governs how the fuel-discharge records on the archive file are processed. A PROCESS.DIR file similar to the validation calculation (discussed later) is shown here. Process directives are described in detail in Section 3.2.

Example PROCESS.DIR file:

```
------------------------
FINAL   1/91   #End of 1990

PROCESS TH
   DECAY 500 d
   REPRO  TH 0.051
           U 0.048

PROCESS  R1
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30

PROCESS  R9
   DECAY  300 d
   REPRO  PU 0.01
           U 0.01
          TC 0.8
------------------------
```

The keyword FINAL causes all records to be decayed to a common final time at the beginning of 1991. The first PROCESS keyword with its corresponding parameter TH causes all archive history records identified by the plant identifier TH to be acted on by the subsequent directives including the 500 day decay followed by reprocessing operations that recover the fractional amounts, 0.051 and 0.048 of thorium and uranium isotopes respectively. Note the spacings and indentations are for readability and are not restricted. Keywords should generally be given on separate lines.

The next PROCESS block acts on records identified by plant R1 and includes a 100 day cooling/decay time. The R9 process directives include a longer 300 day cooling time.

2.4 Summary Directive File: SUMMARY.DIR

The Summary Directive file is a free-format keyword-driven text file that governs how the fuel-discharge records on the archive file are summarized. As an example, the first part of the SUMMARY.DIR file used for the validation calculation (discussed in Section 4.0) is shown here. Summary directives are discussed in detail in Section 3.3.

Example SUMMARY.DIR file:

```
------------------------
SUMMARY  Single-pass
   PLANT  R1 R2 R3 R4 R5 R6 R7 R8 TH  #(SP reactor +
thorium)

SUMMARY  N-Reac
   PLANT R9          # R9 denotes N Reactor
   TIME  (1/44, 1/76)  (1/84, 1/90)

SUMMARY  K-basin
   PLANT R9
   TIME  (1/76, 1/84)

SUMMARY   Thorium
   PLANT  TH
------------------------
```

Each SUMMARY keyword is followed by a summary title to create a column of total inventories whose rows correspond to individual radionuclides. The PLANT keyword identifies the list of plants to be totaled. The TIME keyword restricts the summary to those archive records that meet the specified time range. The second SUMMARY keyword (N-reac) illustrates the use of multiple time ranges.

Specifications given by multiple keywords are "AND"ed. For example, if the two time ranges in the N-reac block were given using two distinct TIME keywords, then no records would be selected since the two TIME ranges do not overlap.

2.5 ORIGDICT File

Each archive record processed by DKPRO corresponds to a particular fuel type, and each fuel type must correspond to one or more ORIGEN2 output files representing normalized inventories the specified type. This correspondence is established by the dictionary file, ORIGDICT. This file only needs to be changed when ORIGEN2 output files are added or deleted.

An example ORIGDICT file is shown here.

```
Example ORIGDICT file
-------------------------
'NAT-U'    800   'SP800.ORG'
'ENR-U'   2000   'NR2000.ORG'
'THORIUM'    1   'TH1MT.ORG'
-------------------------
```

Three fuel types are shown. The natural uranium 'NAT-U' type corresponds to the ORIGEN2 output file 'SP800.ORG'. It represents one metric ton of initial uranium with a specific burnup (second column) of 800 MWd/MTU. A value of 1 is used for 'THORIUM' because the units of thorium-type fuel in the archive records are given in metric tons (MT) instead of burnup (MWd/MTU) which does not apply for an irradiation of a fixed amount of thorium. The use of different sets of units is not a problem. The essential requirement is that the amount of discharged fuel given on the archive records and the amount of fuel represented by the matching normalized ORIGEN2 output files have a consistent set of units.

3.0 DIRECTIVES

Detailed descriptions of DKPRO directives are given in this section. Directives are keywords recognized by the code and may be followed by parameters that further described their action. Only the first three letters of a keyword are significant and they are case-insensitive. Optional parameters are enclosed in brackets [], and [repeat] is used to signify that the previous parameters may appear multiple times. There are three distinct categories: Input directives, Process directives, and Summary directives described in Sections 3.1, 3.2, and 3.3 respectively.

3.1 Input Directives

The primary operations of DKPRO are controlled by PROCESS directives. A few general operations are controlled by directives given on standard input. That is they appear in the file, input_file, as shown in the command line at the beginning of Section 2.0. All input directives are optional.

FILE archive

The FILE keyword changes the default fuel-discharge archive file name from archive.dat to the name given as the archive parameter.

UNIT units

The UNIT keyword changes the output units from curies (default) to those specified by the units parameter. Valid entries are CURIES, GRAMS, and WATTS. Only a single units parameter is allowed.

OUTPUT symbol [repeat]

The OUTPUT keyword causes the final nuclide inventory for selected nuclides to be written to a file OUTPUT.uuu, where "uuu" is "CUR", "GRA", or "WAT", according to the selected output units. The symbol parameter, which may be repeated as needed, is an element designator followed by the atomic mass and an optional "*" for metastable states: e.g., Ba137* representing ^{137*}Ba.

SPLIT

The SPLIT keyword causes two sets of nuclides representing primary and secondary waste streams to be output. It is to be used in conjunction with the same keyword given in the PROCESS.DIR directive file. (See Section 3.2.) Its purpose is so that the code does not have to prescan the PROCESS.DIR file to determine if splitting is invoked.

FORMAT format

This optional directive changes the format of the archive file to one of two alternatives, a HAPO format distinguished by discharge dates given in HAPO days and a LANL format used to support work with Los Alamos National Laboratory. (See Appendix A for file format descriptions.)

3.2 Process Directives

Process keywords and their actions are described here. Two keywords, FINAL and SELECT, must appear first if they are used.

FINAL month/year

Inventories are decayed to the final date "month/year" following all other requested processing. The month parameter is an integer from 1 to 12. The year parameter may given as a two or four digit integer (leading zeros are not needed). Two digit numbers less than 20 are converted to the next century. (See time conventions described in Section 2.2.)

SELECT ss [repeat]

The initial nuclide list is truncated to the selected elements prior to other processing. The two-character element symbol, ss, is repeated as desired. E.g., use "SELECT Cs, U" to select all cesium and uranium isotopes. This action is available to reduce the numbers of computations carried out.

The remaining keywords and actions are:

PROCESS plant [type]

Initiates processing of each archive record that has the plant designator, "plant". Also the fuel type on the archive record must match the optional "type" if given. (If the number of characters in "type" is less than the number of characters in the corresponding archive-record type, only the given characters must match.) E.g,, the type "Al" would match both fuel types, Al-0.71U and Al-0.94U.

Any subsequent matching PROCESS directives are ignored.

SCALE scale

Multiply all nuclide amounts by scale.

REPRO ss f [repeat]

Isotopic amounts for elements matching the two character element symbol, ss, are multiplied by the fractional recovery coefficient f. The fractional recovery coefficient f represents the fractional amount of element ss remaining in the waste stream following reprocessing. The pair (ss, f) can be repeated as necessary. Any pair (ss, f) can be replaced by the keyword **GIVEN**. In this case the values for f are taken from the archive file if available. If ss is multiply encountered, the first entry takes precedence.

DECAY time [units]

Decay for the specified time followed by an optional times units character (s, d, y) corresponding to (seconds, days, years). Seconds is default. The parameter time may be replaced by the keyword **GIVEN**. In this case the cooling time, in days, is taken from the archive file. Use of the GIVEN keyword for archive formats that do not support the cooling time will give unpredictable results.

SPLIT [other]
ss f
[repeat]

The list of nuclides is split into two streams, primary and secondary. For each element designated by the two character element symbol, ss, a fraction f is assigned to the primary stream and a fraction (1-f) is assigned to the secondary stream. The optional value of "other" is used

for all elements not explicitly identified. The default value of "other" is 1.0.

Important: The SPLIT command must also appear in the standard input file; otherwise only the primary list of isotopes is output. (See Section 3.1.)

3.3 Summary Directives

A complete list of summary keywords and their actions are given here.

SUMMARY title

Initiates a new summary column with the heading of title. Titles are restricted to 20 characters. Only 12 characters are printed.

PLANT plant [repeat]

All archive records with the plant identifier, "plant", are summarized (i.e. totaled).

TIME $date_1$ $date_2$ [repeat]

Select one or more time intervals to include in the summary where $date_1$ and $date_2$ are the beginning and end respectively. Each date is in a month/year format such as 3/45 for March 1945. Miscellaneous characters such as parentheses and commas are ignored and may be used to improve readability of the input.

TYPE type [repeat] (Not Implemented)

Select one or more fuel types to summarize.

4.0 VERIFICATION

The primary verification for DKPRO was to replicate a previous ORIGEN2 calculation (Schmittroth 1995b) of all single-pass reactor and N reactor operations. This calculation supported preliminary radionuclide estimates for the Low-level Waste (LLW) program and included multiple fuel types as well as variable reprocessing coefficients and cooling times.

The first step in duplicating the LLW calculation was to create a set of ORIGEN2 files representing the needed initial reactor-discharge inventories. These were created by using ORIGEN2 "PCH" commands to write files of gram-atoms. DKPRO has a subroutine, RDORIG that directly reads these ORIGEN2 files after an identifying line is added to the beginning of the file. The ORIGEN2 input file is orig96b.inp and is given in Appendix B. The "PCH" file which ORIGEN2 writes to FORTRAN Unit 7 was then edited to create the following set of files:

SP000.ORG - Initial single-pass inventories.

SP800.ORG - Single-pass inventories for natural uranium with 800 MWd/MTU burnup.
NR0000.ORG - Initial N reactor inventories
NR1000.ORG - N reactor inventories for enriched uranium with 1000 MWd/MTU burnup.
NR2000.ORG - N reactor inventories for enriched uranium with 2000 MWd/MTU burnup.

Editing involves splitting the PCH (Unit 7) file into individual files such that each file represents the output from a single ORIGEN2 PCH command and then adding the required heading record to each file.

The second step was creation of a representative history. The burnup history for the previous LLW calculation was modeled within the ORIGEN2 calculation as a histogram of four-year burnup intervals based on TRAC data (Jungfleisch (1992). Here the same power/burnup history was modeled by first reformatting the data to the archive.dat format and then preprocessing it to collapse it to one-year intervals. The resulting archive file is rheeb1.

The input for the verification calculation was completed with the directive files given in Appendix C.

4.1 Results

The results of the DKPRO calculation are compared to the LLW values in Table I for the composite values that include both the single-pass and N reactor values as well as the thorium campaign. (Note from the SUMMARY.DIR file that the thorium contribution is included in the single-pass reactor results.)

Table I: Comparison of DKPRO results with LLW results for composite calculation. (file: cmpr.all, units: curies)

Nuclide	DKPRO	LLW Results	% diff.	Nuclide	DKPRO	LLW Results	% diff.
BE10	1.801e-02	1.803e-02	-0.11	TC99	2.721e+04	2.724e+04	-0.12
C14	7.738e+02	7.748e+02	-0.13	RU106	9.267e+05	6.361e+05	45.68
SI32	6.080e-06	6.085e-06	-0.08	RH102	2.461e+00	2.204e+00	11.65
P32	6.080e-06	6.086e-06	-0.10	RH106	9.267e+05	6.361e+05	45.68
AR39	9.234e-17	9.265e-17	-0.33	PD107	1.020e+02	1.022e+02	-0.14
AR42	1.322e-15	1.306e-15	1.23	AG108	1.262e-03	1.261e-03	0.05
K42	2.018e-16	1.306e-15	-84.55	AG108*	1.418e-02	1.417e-02	0.06
CA45	1.118e-04	3.297e-05	239.10	AG109*	1.679e-01	1.274e-01	31.78
V50	7.440e-12	7.466e-12	-0.34	AG110	2.507e+00	1.306e+00	91.96
MN54	1.122e+02	6.993e+01	60.45	AG110*	1.885e+02	9.820e+01	91.96
FE55	2.126e+04	1.894e+04	12.25	CD109	1.679e-01	1.274e-01	31.78
CO60	9.947e+03	9.240e+03	7.65	CD113*	2.647e+04	2.608e+04	1.50
NI59	1.858e+02	1.861e+02	-0.13	IN115	1.218e-07	1.219e-07	-0.04
NI63	1.907e+04	1.904e+04	0.16	SN119*	1.332e+03	6.808e+02	95.65
ZN65	3.833e-02	1.951e-02	96.46	SN121*	2.792e+02	2.778e+02	0.50
SE79	1.028e+03	1.029e+03	-0.13	SN126	1.580e+03	1.582e+03	-0.11
KR81	1.731e-04	1.734e-04	-0.16	SB125	3.771e+05	3.392e+05	11.17
KR85	5.127e+06	5.033e+06	1.87	SB126	2.211e+02	2.214e+02	-0.14
RB87	6.109e-02	6.115e-02	-0.10	SB126*	1.580e+03	1.582e+03	-0.11
SR90	1.129e+08	1.122e+08	0.62	TE123	3.902e-11	3.911e-11	-0.23
Y90	1.129e+08	1.122e+08	0.62	TE125*	9.200e+04	8.278e+04	11.13
ZR93	4.862e+03	4.867e+03	-0.10	I129	6.607e+01	6.615e+01	-0.12
NB93*	3.440e+03	3.461e+03	-0.63	CS134	2.959e+05	2.538e+05	16.58
NB94	1.250e-01	1.252e-01	-0.14	CS135	1.085e+03	1.086e+03	-0.11
MO93	1.401e-01	1.405e-01	-0.28	CS137	1.308e+08	1.300e+08	0.60
TC98	5.246e-04	5.254e-04	-0.15	BA137*	1.238e+08	1.230e+08	0.63
				LA138	4.385e-07	4.391e-07	-0.13

CE142	6.596e-02	6.604e-02	-0.12
CE144	1.421e+06	8.272e+05	71.78
PR144	1.421e+06	8.272e+05	71.78
PR144*	1.706e+04	9.926e+03	71.87
ND144	3.045e-06	3.048e-06	-0.12
PM146	4.660e+01	4.408e+01	5.72
PM147	6.109e+06	5.480e+06	11.48
SM146	2.123e-05	2.133e-05	-0.49
SM147	2.398e-02	2.402e-02	-0.20
SM148	1.623e-08	1.626e-08	-0.16
SM149	1.938e-08	1.940e-08	-0.07
SM151	3.691e+06	3.686e+06	0.13
EU150	3.568e-03	3.544e-03	0.68
EU152	2.620e+03	2.567e+03	2.06
EU154	2.397e+05	2.316e+05	3.50
EU155	2.071e+05	1.985e+05	4.33
GD152	5.395e-10	5.425e-10	-0.55
GD153	2.191e+00	1.107e+00	97.92
HO166*	1.019e-01	1.021e-01	-0.16
TM171	6.473e-06	5.475e-06	18.23
LU176	3.998e-09	4.011e-09	-0.32
HF182	7.826e-05	7.853e-05	-0.34
TA182	3.262e-02	4.409e-03	639.85
RE187	8.573e-06	8.602e-06	-0.34
OS194	4.174e-15	3.904e-15	6.92
IR192	5.112e-11	4.932e-11	3.65
IR192*	4.917e-11	4.923e-11	-0.12
IR194	3.261e-15	3.905e-15	-16.49
PT193	1.558e-11	1.562e-11	-0.26
TL206	6.841e-12	6.865e-12	-0.35
TL207	7.680e+01	7.497e+01	2.44
TL208	4.311e+01	4.347e+01	-0.83
TL209	2.083e-02	2.014e-02	3.43
PB204	5.837e-12	5.857e-12	-0.34
PB205	8.062e-06	8.090e-06	-0.35
PB209	9.643e-01	9.326e-01	3.40
PB210	9.044e-04	8.850e-04	2.20
PB211	7.701e+01	7.518e+01	2.43
PB212	1.200e+02	1.210e+02	-0.83
PB214	2.671e-03	2.612e-03	2.27
BI208	1.043e-11	1.047e-11	-0.38
BI210	9.034e-04	8.850e-04	2.08
BI210*	6.869e-12	6.892e-12	-0.33
BI211	7.701e+01	7.518e+01	2.43
BI212	1.200e+02	1.210e+02	-0.83
BI213	9.643e-01	9.326e-01	3.40
BI214	2.671e-03	2.612e-03	2.27
PO210	8.739e-04	8.850e-04	-1.26
PO211	2.156e-01	2.105e-01	2.42
PO212	7.686e+01	7.751e+01	-0.84
PO213	9.434e-01	9.124e-01	3.40
PO214	2.671e-03	2.612e-03	2.27
PO215	7.701e+01	7.518e+01	2.43
PO216	1.200e+02	1.210e+02	-0.83
PO218	2.672e-03	2.613e-03	2.27
AT217	9.643e-01	9.326e-01	3.40
RN219	7.701e+01	7.518e+01	2.43
RN220	1.200e+02	1.210e+02	-0.83
RN222	2.672e-03	2.613e-03	2.27
FR221	9.643e-01	9.326e-01	3.40
FR223	1.066e+00	1.037e+00	2.80
RA223	7.701e+01	7.518e+01	2.43
RA224	1.200e+02	1.210e+02	-0.83
RA225	9.659e-01	9.326e-01	3.57
RA226	2.673e-03	2.613e-03	2.31
RA228	3.246e+00	3.298e+00	-1.58
AC225	9.643e-01	9.326e-01	3.40
AC227	7.727e+01	7.516e+01	2.81
AC228	3.246e+00	3.298e+00	-1.58
TH227	7.604e+01	7.414e+01	2.56
TH228	1.199e+02	1.210e+02	-0.91
TH229	9.683e-01	9.326e-01	3.83
TH230	2.489e-01	2.428e-01	2.50
TH231	1.224e+01	1.226e+01	-0.10
TH232	2.683e+00	2.684e+00	-0.04
TH234	2.957e+02	2.960e+02	-0.12
PA231	1.451e+02	1.452e+02	-0.07
PA233	7.440e+01	7.452e+01	-0.16
PA234	3.844e-01	3.847e-01	-0.10
PA234*	2.957e+02	2.960e+02	-0.12
U232	1.134e+02	1.145e+02	-0.96
U233	4.299e+02	4.301e+02	-0.05
U234	2.984e+02	2.988e+02	-0.13
U235	1.224e+01	1.226e+01	-0.10
U236	7.368e+00	7.380e+00	-0.16
U237	3.722e+00	3.637e+00	2.34
U238	2.957e+02	2.960e+02	-0.12
U240	9.666e-09	9.697e-09	-0.32
NP235	8.717e-04	6.201e-04	40.57
NP236	2.315e-04	2.320e-04	-0.22
NP237	7.440e+01	7.452e+01	-0.16
NP238	9.283e-01	9.283e-01	0.00
NP239	3.378e+01	3.388e+01	-0.30
NP240*	9.666e-09	9.697e-09	-0.32
PU236	1.590e-02	1.420e-02	12.00
PU238	2.226e+03	2.252e+03	-1.17
PU239	3.707e+04	3.712e+04	-0.12
PU240	7.183e+03	7.194e+03	-0.15
PU241	1.517e+05	1.483e+05	2.35
PU242	6.006e-01	6.023e-01	-0.28
PU243	7.191e-10	7.216e-10	-0.35
PU244	9.667e-09	9.710e-09	-0.44
AM241	5.333e+04	5.180e+04	2.95
AM242	1.848e+02	1.848e+02	0.01
AM242*	1.857e+02	1.856e+02	0.01
AM243	3.378e+01	3.388e+01	-0.30
AM245	5.271e-15	3.336e-15	58.00
CM242	1.902e+02	1.638e+02	16.09
CM243	1.584e+01	1.562e+01	1.42
CM244	4.141e+03	4.044e+03	2.40
CM245	1.026e-01	1.029e-01	-0.29
CM246	2.239e-03	2.247e-03	-0.36
CM247	7.191e-10	7.216e-10	-0.35
CM248	1.643e-10	1.797e-10	-8.57
BK249	3.635e-10	2.300e-10	58.04
CF249	2.932e-10	2.942e-10	-0.34
CF250	1.764e-10	1.706e-10	3.40
CF251	5.781e-13	5.797e-13	-0.28
CF252	6.542e-13	5.659e-13	15.60

No. compared: 172
No. with difference < 1 pct: 100
Average percent difference: 13.7

Generally the agreement is excellent with nearly 60% of the compared nuclides within 1% of one another. The observed differences are typically for shorter-lived nuclides that are sensitive to small differences in decay time. The four-year intervals used in the LLW calculation limits the precision of the decay time. In order to obtain a better comparison, the single-pass results were compared with the final decay time slightly adjusted. It was found by trial and error that the best agreement was obtained when the final decay time was backshifted two months to 11/90. The revised comparison is given in Table II.

Table II: Comparison of DKPRO results with LLW results for single-pass reactors with the final decay time backshifted by two months. (file: cmpr.sp)

Nuclide	DKPRO	LLW Results	% diff.
BE10	1.549e-02	1.550e-02	-0.06
C14	6.005e+02	6.009e+02	-0.07
SI32	4.992e-06	4.993e-06	-0.02
P32	4.992e-06	4.994e-06	-0.04
CA45	3.164e-24	2.929e-24	8.02
V50	1.124e-13	1.125e-13	-0.09
MN54	6.892e-04	7.197e-04	-4.24
FE55	1.558e+03	1.480e+03	5.27
CO60	2.949e+01	2.833e+01	4.09
NI59	1.449e+02	1.450e+02	-0.07
NI63	1.458e+04	1.454e+04	0.28
ZN65	1.856e-09	1.961e-09	-5.35
SE79	8.994e+02	9.002e+02	-0.09
KR81	1.210e-04	1.211e-04	-0.08
KR85	4.013e+06	3.922e+06	2.32
RB87	5.405e-02	5.409e-02	-0.07
SR90	9.678e+07	9.592e+07	0.90
Y90	9.680e+07	9.595e+07	0.89
ZR93	4.266e+03	4.269e+03	-0.07
NB93*	3.107e+03	3.127e+03	-0.64
NB94	9.550e-02	9.558e-02	-0.08
TC98	3.687e-04	3.690e-04	-0.08
TC99	2.380e+04	2.382e+04	-0.08
RU106	3.995e+01	4.086e+01	-2.23
RH102	8.256e-02	7.842e-02	5.28
RH106	3.995e+01	4.086e+01	-2.23
PD107	8.068e+01	8.074e+01	-0.07
AG108	8.603e-04	8.591e-04	0.14
AG108*	9.667e-03	9.652e-03	0.16
AG109*	1.054e-04	1.045e-04	0.86
AG110	1.404e-07	1.486e-07	-5.52
AG110*	1.056e-05	1.117e-05	-5.46
CD109	1.054e-04	1.045e-04	0.86
CD113*	2.021e+04	1.986e+04	1.76
IN115	1.067e-07	1.067e-07	0.00
SN119*	2.545e-05	2.695e-05	-5.57
SN121*	1.551e+02	1.543e+02	0.52
SN126	1.348e+03	1.349e+03	-0.07
SB125	4.241e+04	4.030e+04	5.24
SB126	1.887e+02	1.889e+02	-0.11
SB126*	1.348e+03	1.349e+03	-0.07
TE123	1.552e-11	1.553e-11	-0.06
TE125*	1.035e+04	9.833e+03	5.26
I129	5.685e+01	5.690e+01	-0.09
CS134	3.234e+03	3.087e+03	4.76
CS135	9.599e+02	9.607e+02	-0.08
CS137	1.105e+08	1.095e+08	0.91
BA137*	1.045e+08	1.036e+08	0.87
LA138	3.904e-07	3.908e-07	-0.10
CE142	5.784e-02	5.789e-02	-0.09
CE144	3.620e+00	3.822e+00	-5.29
PR144	3.620e+00	3.822e+00	-5.29
PR144*	4.344e-02	4.587e-02	-5.30
ND144	2.666e-06	2.668e-06	-0.07
PM146	1.371e+01	1.319e+01	3.94
PM147	7.647e+05	7.265e+05	5.26
SM146	1.417e-05	1.419e-05	-0.14
SM147	2.140e-02	2.142e-02	-0.09
SM148	1.158e-08	1.159e-08	-0.09
SM149	1.832e-08	1.833e-08	-0.05
SM151	3.324e+06	3.315e+06	0.27
EU150	2.072e-03	2.057e-03	0.73
EU152	1.347e+03	1.322e+03	1.89
EU154	1.068e+05	1.039e+05	2.79
EU155	1.238e+05	1.187e+05	4.30
GD152	3.677e-10	3.689e-10	-0.33
GD153	3.182e-08	3.365e-08	-5.44
HO166*	6.164e-02	6.167e-02	-0.05
TM171	8.924e-10	8.537e-10	4.53
TL206	2.879e-16	4.530e-16	-36.45
TL207	7.643e+01	7.497e+01	1.95
TL208	4.317e+01	4.346e+01	-0.67
TL209	2.068e-02	2.014e-02	2.68
PB209	9.575e-01	9.326e-01	2.67
PB210	8.368e-04	8.218e-04	1.83
PB211	7.665e+01	7.518e+01	1.96
PB212	1.202e+02	1.210e+02	-0.66
PB214	2.418e-03	2.366e-03	2.20
BI208	6.906e-16	6.909e-16	-0.04
BI210	8.358e-04	8.218e-04	1.70
BI210*	4.546e-16	4.548e-16	-0.04
BI211	7.665e+01	7.518e+01	1.96
BI212	1.202e+02	1.210e+02	-0.66
BI213	9.575e-01	9.326e-01	2.67
BI214	2.418e-03	2.366e-03	2.20
PO210	8.094e-04	8.218e-04	-1.51
PO211	2.146e-01	2.105e-01	1.95
PO212	7.698e+01	7.750e+01	-0.67
PO213	9.368e-01	9.124e-01	2.67
PO214	2.418e-03	2.366e-03	2.20
PO215	7.665e+01	7.518e+01	1.96
PO216	1.202e+02	1.210e+02	-0.66
PO218	2.419e-03	2.367e-03	2.20
AT217	9.575e-01	9.326e-01	2.67
RN219	7.665e+01	7.518e+01	1.96
RN220	1.202e+02	1.210e+02	-0.66
RN222	2.419e-03	2.367e-03	2.20
FR221	9.575e-01	9.326e-01	2.67
FR223	1.061e+00	1.037e+00	2.31
RA223	7.665e+01	7.518e+01	1.96
RA224	1.202e+02	1.210e+02	-0.66
RA225	9.591e-01	9.326e-01	2.84
RA226	2.420e-03	2.367e-03	2.24
RA228	3.256e+00	3.298e+00	-1.27
AC225	9.575e-01	9.326e-01	2.67
AC227	7.691e+01	7.516e+01	2.33
AC228	3.256e+00	3.298e+00	-1.27

TH227	7.569e+01	7.414e+01	2.09
TH228	1.201e+02	1.210e+02	-0.74
TH229	9.615e-01	9.326e-01	3.10
TH230	2.154e-01	2.100e-01	2.57
TH231	1.144e+01	1.145e+01	-0.09
TH232	2.683e+00	2.684e+00	-0.04
TH234	2.796e+02	2.799e+02	-0.11
PA231	1.451e+02	1.452e+02	-0.07
PA233	5.303e+01	5.307e+01	-0.08
PA234	3.635e-01	3.638e-01	-0.08
PA234*	2.796e+02	2.799e+02	-0.11
U232	1.136e+02	1.145e+02	-0.79
U233	4.299e+02	4.301e+02	-0.05
U234	2.756e+02	2.759e+02	-0.11
U235	1.144e+01	1.145e+01	-0.09
U236	5.060e+00	5.064e+00	-0.08
U237	1.321e+00	1.298e+00	1.77
U238	2.796e+02	2.799e+02	-0.11
U240	5.237e-10	5.241e-10	-0.08
NP235	1.706e-08	1.727e-08	-1.22
NP236	1.096e-04	1.097e-04	-0.09
NP237	5.303e+01	5.307e+01	-0.08
NP238	1.034e-01	1.033e-01	0.10
NP239	4.165e+00	4.168e+00	-0.07
NP240*	5.237e-10	5.241e-10	-0.08
PU236	3.356e-04	3.193e-04	5.10
PU238	7.899e+02	7.943e+02	-0.55
PU239	3.269e+04	3.272e+04	-0.09
PU240	5.252e+03	5.256e+03	-0.08
PU241	5.385e+04	5.290e+04	1.80
PU242	1.434e-01	1.435e-01	-0.07
PU243	1.151e-12	1.152e-12	-0.09
PU244	5.238e-10	5.248e-10	-0.19
AM241	1.650e+04	1.567e+04	5.30
AM242	2.057e+01	2.055e+01	0.10
AM242*	2.067e+01	2.065e+01	0.10
AM243	4.165e+00	4.168e+00	-0.07
CM242	1.706e+01	1.699e+01	0.41
CM243	4.466e-01	4.425e-01	0.93
CM244	1.136e+02	1.120e+02	1.43
CM245	1.517e-03	1.518e-03	-0.07
CM246	1.081e-05	1.082e-05	-0.09
CM247	1.151e-12	1.152e-12	-0.09
CM248	8.683e-14	9.472e-14	-8.33
BK249	1.085e-19	1.130e-19	-3.98
CF249	5.295e-14	5.296e-14	-0.02
CF250	6.586e-15	6.448e-15	2.14
CF251	1.227e-17	1.228e-17	-0.08

No. compared: 155
No. with difference < 1 pct: 106
Average percent difference: 1.8

The agreement is now within 1% for over two thirds of the compared nuclides. More importantly, with the slight shift in decay time, nearly all nuclides agree to within 5%. The largest discrepancy is 36% and occurs for ^{206}Tl which has a very small absolute value less than 10^{-15}.

4.2 Burnup Interpolation

DKPRO interpolates with respect to burnup for values that do not match the specific burnup on the ORIGEN2 source files. A one, two, or three-point Lagrange interpolating polynomial is used depending on the number of available ORIGEN2 source files. (One point interpolation selects the single available value). Interpolation is carried out on the number of gram-atoms per base unit (normally one metric ton of uranium or heavy metal). For many radionuclides such as ^{137}Cs, a slightly better interpolating value would be gram-atoms per specific burnup, a value that is nearly independent of burnup. However, for nuclides with non-zero initial amounts such as ^{235}U, this choice is not practical since the amount divided by the burnup becomes infinite at a burnup of zero.

The burnup interpolation is carried out by the POLY function called by the GETORIG subroutine. The interpolation was verified by creating a small archive file with records having a sequence of burnups from 100 MWd/MTU to 2500 MWd/MTU and including intermediate values not explicitly represented by the base ORIGEN2 inventory files. DKPRO was run using the standard archive file format where the amount of fuel is specified by the total burnup. A common total exposure of 10^4 MWd was specified for all records. To maintain this common exposure, the uranium mass must be inversely proportional to the specific burnup, a comparison that was easily checked by looking at ^{238}U amounts.

A second check was made for ^{137}Cs which, unlike ^{238}U, has a constant yield per unit exposure independent of the specific burnup. Adjusting the decay times in a manner to compensate for the variable irradiation intervals gave a set of ^{137}Cs values constant to within 0.1% completing the verification.

5.0 REFERENCES

1. Croff, A. G., 1980, "ORIGEN2- A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, ORNL-5621, Oak Ridge National Laboratory, Oak Ridge Tennessee.

2. Wittekind, W. D., 1994, "Software Certification Package for the ORIGEN2 Code", WHC-SD-NR-SWD-006 REV.0-A, Westinghouse Hanford Company, Richland, WA.

3. Schwarz, R. A., 1995, "Certification of RADNUC", WHC-SD-HWV-SWD-001, Westinghouse Hanford Company, Richland, WA.

4. Schmittroth, F., 1995a, "ISOCALC: A Decay and Transmutation Code", WHC-SD-ER-CSWD-0008, Westinghouse Hanford Company, Richland, WA.

5. Schmittroth, F., et al., 1995b, "Inventories for Low-Level Waste Tank Waste", WHC-SD-WM-RPT-164, Westinghouse Hanford Company, Richland, WA.

6. Jungfleisch, F. M., 1984, "Preliminary Estimation of the Waste Inventories in Hanford Tanks Through 1980, RHO-SD-WM-TI-057, Rockwell Hanford Operations, Richland, Washington.

APPENDIX A: ARCHIVE FILE FORMAT

DKPRO calls the function GetRcrd to read records from the archive file. The present version supports three formats, a default standard format, a standard HAPO format, and a LANL format used to support work at Los Alamos National Laboratory on estimating radionuclide inventories in Hanford waste tanks.

The non-default formats are used when a FORMAT keyword appears in the standard input file. (see Section 3.1)

Standard format (default)

For the first format, archive records consist of the following fields and are read with the indicated format statement:

Fields: IMON, IYR, TYPE, BU, PLANT, XMWD

Format: (2I6, 3X, A8, F6.0, 3X, A6, E11.3),

where

IMON	= Discharge month
IYR	= Discharge year
TYPE	= Fuel type
BU	= Specific burnup, MWd/MTU
PLANT	= Process plant or reactor identifier
XMWD	= Amount of discharged fuel, MWD.

(Note that the amount of fuel could be in other units such as metric tons of uranium as long as the normalized ORIGEN2 inventories are computed on a consistent basis.)

An alternative format, identified as a HAPO format, consists of the following fields and is read with the indicated format statement:

Fields: IHAPO, TYPE, PLANT, BU, XMTU

Format: (I6, 1X, A8, A8, F10.1, E12.4),

where

IHAPO	= No. of days from 9/26/44 to discharge date
XMTU	= Amount of discharged fuel, MTU,

and the remaining fields have the same meaning. Note that the amount of discharged fuel is expressed in MTU instead of total MWd as with the default format.

LANL format

Archive records in the LANL format consist of the following fields and are read with the indicated format statement:

Fields: KEY, TYPE, XMTU, PCT240, BU, PLANT,
IMON, IYR, SEPKEY, TCOOL, FTH, FNP, FU, FPU

Format: (F12.0, 1X, A8, 3F11.0, 1X, A8, 2I4, F10.0,
F9.0, 43X, 4F7.0)

where

KEY	= Not currently used
TYPE	= Fuel type
XMTU	= Amount of discharged fuel, MTU
PCT240	= % ^{240}Pu
BU	= Specific burnup, MWd/MTU
PLANT	= Process plant or reactor identifier
IMON	= Discharge month
IYR	= Discharge year
SEPKEY	= Not currently used
TCOOL	= Cooling time, days
FTH	= Thorium fractional recovery
FNP	= Neptunium fractional recovery
FU	= Uranium fractional recovery
FPU	= Plutonium fractional recovery.

The cooling time is used for decay by the "DECAY GIVEN" command. The fractional recovery coefficients are used by the "REPRO GIVEN" command.

APPENDIX B: ORIGEN2 INPUT FILE Orig96b.inp

```
 90   4  0.949
 92   4  0.952
 94   4  0.0
-1
-1
-1
RDA  ----------------------------------------------------------------
RDA  Set #4 repro. coef. for part of Th calc.
RDA  ----------------------------------------------------------------
TIT     Hanford Radionuclide Production Calculations
LIP     0 0 0
RDA     Assume MK IV Inner cross sections
RDA     Increase U235 Sigf to 100.0 barns
RDA     Set U238 n2n cross section to 0.0025
LPU     922350  922380 -1
LIB     0 1 2 3 411 -412 413 9 3 0 1  0
RDA
RDA     1 Metric ton Natural uranium
INP     -1  1  -1  -1  1  1
RDA     1 Metric ton 0.95 % enriched uranium
INP     -2  1  -1  -1  1 1
RDA     Trace impurities for 1 metric ton on uranium
INP     -3  1  -1  -1  1 1
RDA     1 metric ton zircaloy
INP     -4  1  -1  -1  1 1
RDA     1 metric ton aluminum
INP     -6  1  -1  -1  1 1
RDA     <<vectors have an inverted order here>>
RDA     1 Metric ton Natural thorium
INP     -5  1  -1  -1  1  1
RDA
RDA         << SINGLE PASS PRODUCTION >>
RDA     Create a vector with 1 metric ton of natural uranium
BAS     One metric ton of natural uranium
MOV     -1  1  0  1.0        URANIUM VECTOR
RDA     Add uranium trace impurities
ADD     -3  1  0  1.0
RDA     Add 5.0 wt% aluminum cladding
ADD     -6  1  0  0.05
RDA
RDA     Assume burnup of 800 MWd/MTU with a spec. power of 10 MW/MTU.
BUP
IRP     80.0    10.0   1 2 4 2
BUP
RDA     Decay for 10 days to reduce short-lived nuclides
DEC     10.0           2 3 4 1
DEC     100.0          3 4 4 0
RDA
RDA     The 100 day result is for check against prior calc.
MOV     3  5  0  1.0
RDA
RDA     ---------- Preliminary actinide output -------------
CUT       5  1.0E-10      -1
OPTA     8 8 8 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTL     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT     5 1 -1  0
RDA    Save Initial values on Unit 7
PCH     1 1 1
RDA     Save 800 MW/MTU results on unit 7
PCH     5 5 5
RDA     ----------------------------------------------------------
STP     2
5  920000  1.0E+6           0  0.0
0
2  922350  0.00950E+6  922380  0.99002E+6    0 0.0
2  922340  0.00008E+6  922360  0.00040E+6    0 0.0
0
4 400000  19.0  290000  18.0      480000    0.19  40000    1.0
4 130000 790.0   10000   1.3      140000    93.0  280000   56.0
4 250000   9.2  120000   3.0      260000   330.0  240000   22.0
4  50000   0.14  70000   8.0       60000   520.0       0    0.0
0
```

```
4 130000  75.0  500000 1.45E+4   260000 1350.0  240000 1000.0
4 280000 550.0   60000 275.0     920000    2.5  400000 0.9814E+6
4  50000    0.5 480000   0.5     270000   10.0  290000   50.0
4 720000 200.0   10000  25.0     820000  100.0  120000   20.0
4 250000  50.0  420000  50.0      70000   80.0  140000  100.0
4 110000  20.0  220000  50.0     740000   50.0  230000   50.0
0
4 130000  1.0E+6     0   0.0
0
5 900000  1.0E+6     0   0.0
0
RDA     << N-REACTOR PRODUCTION >>
RDA
RDA     Assume MK IV Inner cross sections
RDA     Set U235 Sigf cross section to 55.0 barns
RDA     Set U238 n2n cross section to 0.0025
LPU     922350  922380 -1
LIB     0 1 2 3 411 -412 413 9 4 0 1  0
RDA
RDA     Create a vector with 1 metric ton of 0.95% enriched uranium
BAS     One metric ton of 0.95% enriched uranium
MOV     -2  1  0  1.0         URANIUM VECTOR
RDA     Add uranium trace impurities
ADD     -3  1  0  1.0
RDA     Add 7.0 wt% zircaloy cladding
ADD     -4  1  0  0.07
RDA
RDA     Assume burnup of 2000 MWd/MTU with a spec. power of 10 MW/MTU.
BUP
IRP     100.0    10.0   1 2 4 2        100 day irrad.
DEC     120.0           2 3 4 0         20 day decay
IRP     220.0    10.0   3 4 4 0        100 day irrad.
BUP
RDA     Decay for 10 days to reduce short-lived nuclides
DEC     10.0            4 5 4 1
DEC     300.0           5 6 4 0
RDA
RDA     The 300 day result is for check against prior calc.
MOV     5  7  0  1.0
RDA
RDA     Decay 100-day values for 10 days to reduce short-lived nuclides
DEC     10.0            2 8 4 1
RDA
MOV     8  9  0  1.0
RDA
RDA     --------------- Preliminary actinide output --------------
CUT       5  1.0E-10      -1
OPTA     8 8 8 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTL     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT     7 1 -1  0
RDA   Save Initial values on Unit 7
PCH     1 1 1
RDA   Save 1000 MW/MTU values on Unit 7
PCH     9 9 9
RDA   Save 2000 MW/MTU on Unit 7
PCH     7 7 7
STP   2
RDA    ------------------------------------------------
RDA     Assume MK IV Inner cross sections
RDA     Set U235 Sigf cross section to 100.0 barns
RDA     Set U238 n2n cross section to 0.0025
RDA     Set Th232 capture cross section to 1.50 barns
LPU     902320  922350  922380  -1
LIB     0 1 2 3 411 -412 413 9 30 0 3  0
RDA
RDA         << SINGLE PASS U233 PRODUCTION >>
RDA     Create a vector with 1 metric ton of natural thorium
BAS     One metric ton of natural thorium
MOV     -5  1  0  1.0         THORIUM VECTOR
RDA
RDA     Strategy is to irradiate a single MT and then decay and
RDA     accumulate it to model the operating histogram.
RDA
RDA     Assume burnup of 100 days at average flux of 1.527e14 n/cm2-s
RDA     obtained from the single-pass irradiation.
```

```
BUP
IRF     100.0    1.527E+14   1 2 4 2
BUP
RDA     Decay for 10 days.
DEC     10.0           2 3 4 1
DEC     500.0          3 4 4 0
PCH     3 3 3
RDA
RDA     Following is to provide a check with earlier calc.
RDA     Decay for 500 days. Then extract 94.9% of Th and  95.2% of U
RDA      (unrecovered to vector 6)
PRO     4  5  6   4
RDA
RDA     -------------- Preliminary output --------------
CUT       5  1.0E-10      -1
OPTA     8 8 8 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTL     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF     8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OUT     6 1 -1  0
STP 4
```

APPENDIX C: VERIFICATION FILES

Archive file: rheeb1

```
     1    66   THORIUM     1.   TH      1.750E+02
     1    68   THORIUM     1.   TH      3.057E+02
     7    45   NAT-U     800.   R1      8.295E+04
     1    45   NAT-U     800.   R2      0.000E+00
     7    45   NAT-U     800.   R3      8.983E+04
     1    45   NAT-U     800.   R4      0.000E+00
     8    45   NAT-U     800.   R5      7.055E+04
     1    45   NAT-U     800.   R6      0.000E+00
     1    45   NAT-U     800.   R7      0.000E+00
     1    45   NAT-U     800.   R8      0.000E+00
     1    45   ENR-U    2000.   R9      0.000E+00
     3    46   NAT-U     800.   R1      1.514E+04
     ..........
     8    86   NAT-U     800.   R8      0.000E+00
     8    86   ENR-U    2000.   R9      6.534E+05
```

ORIGDICT file

```
'NAT-U'     0  'SP000.ORG'
'NAT-U'   800  'SP800.ORG'
'ENR-U'     0  'NR0000.ORG'
'ENR-U'  1000  'NR1000.ORG'
'ENR-U'  2000  'NR2000.ORG'
'THORIUM'   1  'TH1MT.ORG'
```

PROCESS.DIR file

```
FINAL 1/91 #End of 1990.  Change to 11/90 for test1
           #              backshifted calculation

PROCESS TH
   DECAY 500 d
   REPRO  TH 0.051
           U 0.048

PROCESS R1
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R2
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R3
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R4
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R5
   DECAY  100 d
```

```
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R6
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R7
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R8
   DECAY  100 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
PROCESS R9
   DECAY  300 d
   REPRO  PU 0.01
           U 0.01
          TC 0.80
          NP 0.30
```

SUMMARY.DIR file

```
SUMMARY  Single-pass
   PLANT  R1 R2 R3 R4 R5 R6 R7 R8 TH

SUMMARY   N-Reac
   PLANT R9                  # R9 denotes N-reactor
   TIME  (1/44, 1/76) (1/84, 1/90)

SUMMARY  K-basin
   PLANT R9
   TIME  (1/76, 1/84)

SUMMARY   Thorium
   PLANT  TH
```

Input file: test1.inp

```
FILE rheeb1
```

Output file: test1.out

```
<============================================================>
 *** DKPRO ***    Version 1.0 (4/12/96)
Input File: rheeb1
No. of records:   10000
No. of selected nuclides:   0
Output units: CUR

<<Open>>       DECAY LIBRARY: ACTIVATION PRODUCTS
        Single-pass N-Reac      K-basin     Thorium     Total
H03     2.157E+05   6.627E+04   4.562E+04   1.776E+02   3.278E+05
BE10    1.549E-02   2.518E-03   1.286E-03   2.863E-06   1.929E-02
C14     6.005E+02   1.734E+02   8.862E+01   1.152E-04   8.625E+02
SI32    4.992E-06   1.089E-06   5.601E-07   0.000E+00   6.641E-06
P32     4.992E-06   1.089E-06   5.602E-07   0.000E+00   6.641E-06
AR39    0.000E+00   9.238E-17   4.798E-17   0.000E+00   1.404E-16
```

AR42	0.000E+00	1.327E-15	7.707E-16	0.000E+00	2.098E-15
K42	0.000E+00	2.025E-16	0.000E+00	0.000E+00	2.025E-16
CA45	3.164E-24	1.449E-04	1.175E-06	0.000E+00	1.460E-04
SC46	0.000E+00	4.196E-05	2.252E-09	0.000E+00	4.196E-05
V50	1.124E-13	7.328E-12	3.743E-12	0.000E+00	1.118E-11
CR51	0.000E+00	1.034E-12	2.916E-26	0.000E+00	1.034E-12
MN54	6.892E-04	1.285E+02	1.195E+01	0.000E+00	1.404E+02
FE55	1.558E+03	2.067E+04	1.294E+04	0.000E+00	3.517E+04
FE59	0.000E+00	7.908E-08	4.777E-16	0.000E+00	7.908E-08
CO58	6.126E-28	2.941E-03	2.280E-08	0.000E+00	2.941E-03
CO60	2.949E+01	1.014E+04	8.162E+03	0.000E+00	1.833E+04
NI59	1.449E+02	4.092E+01	2.090E+01	0.000E+00	2.067E+02
NI63	1.458E+04	4.518E+03	2.422E+03	0.000E+00	2.152E+04
ZN65	1.856E-09	4.559E-02	2.009E-03	0.000E+00	4.759E-02
SE79	8.994E+02	1.281E+02	6.544E+01	9.422E-01	1.094E+03
KR81	1.210E-04	5.214E-05	2.663E-05	6.427E-08	1.998E-04
KR85	4.013E+06	1.170E+06	8.314E+05	6.280E+03	6.021E+06
RB86	0.000E+00	1.370E-21	0.000E+00	0.000E+00	1.370E-21
RB87	5.405E-02	7.037E-03	3.594E-03	5.666E-05	6.474E-02
SR89	0.000E+00	4.440E-02	2.282E-09	0.000E+00	4.440E-02
SR90	9.678E+07	1.655E+07	9.766E+06	7.198E+04	1.232E+08
Y90	9.680E+07	1.656E+07	9.769E+06	7.200E+04	1.232E+08
Y91	2.559E-30	1.028E+00	5.811E-07	0.000E+00	1.028E+00
ZR93	4.266E+03	5.960E+02	3.044E+02	2.436E+00	5.169E+03
ZR95	5.139E-27	6.073E+00	1.251E-05	0.000E+00	6.073E+00
NB93*	3.107E+03	3.226E+02	1.250E+02	1.623E+00	3.556E+03
NB94	9.550E-02	2.948E-02	1.506E-02	3.658E-04	1.404E-01
NB95	1.141E-26	1.348E+01	2.778E-05	0.000E+00	1.348E+01
NB95*	3.726E-29	4.506E-02	9.284E-08	0.000E+00	4.506E-02
MO93	0.000E+00	1.401E-01	7.164E-02	0.000E+00	2.117E-01
TC98	3.687E-04	1.559E-04	7.962E-05	1.312E-07	6.044E-04
TC99	2.380E+04	3.406E+03	1.740E+03	1.012E+01	2.896E+04
RU103	0.000E+00	1.166E-04	4.021E-14	0.000E+00	1.166E-04
RU106	3.995E+01	1.039E+06	1.457E+05	1.004E-02	1.185E+06
RH102	8.256E-02	2.479E+00	1.688E+00	1.743E-05	4.249E+00
RH103*	0.000E+00	1.051E-04	3.625E-14	0.000E+00	1.051E-04
RH106	3.995E+01	1.039E+06	1.457E+05	1.004E-02	1.185E+06
PD107	8.068E+01	2.135E+01	1.091E+01	8.159E-03	1.129E+02
AG108	8.603E-04	4.028E-04	2.131E-04	1.562E-09	1.476E-03
AG108*	9.667E-03	4.526E-03	2.394E-03	1.756E-08	1.659E-02
AG109*	1.054E-04	1.838E-01	4.214E-02	1.564E-12	2.260E-01
AG110	1.404E-07	2.969E+00	1.420E-01	3.488E-11	3.111E+00
AG110*	1.056E-05	2.233E+02	1.068E+01	2.622E-09	2.339E+02
CD109	1.054E-04	1.838E-01	4.214E-02	1.564E-12	2.260E-01
CD113*	2.021E+04	6.457E+03	4.287E+03	6.206E+00	3.096E+04
CD115*	0.000E+00	4.172E-06	2.108E-14	0.000E+00	4.172E-06
IN113*	0.000E+00	3.524E+00	3.226E-03	0.000E+00	3.528E+00
IN114	0.000E+00	1.556E-07	5.646E-15	0.000E+00	1.556E-07
IN114*	0.000E+00	1.626E-07	5.900E-15	0.000E+00	1.626E-07
IN115	1.067E-07	1.512E-08	7.722E-09	4.412E-11	1.295E-07
IN115*	0.000E+00	2.932E-10	1.481E-18	0.000E+00	2.932E-10
SN113	0.000E+00	3.522E+00	3.224E-03	0.000E+00	3.526E+00
SN117*	0.000E+00	7.740E-29	0.000E+00	0.000E+00	7.740E-29
SN119*	2.545E-05	1.583E+03	7.088E+01	1.367E-08	1.654E+03
SN121*	1.551E+02	1.247E+02	6.947E+01	1.884E-01	3.494E+02
SN123	2.782E-12	5.934E+01	1.228E-01	2.276E-16	5.947E+01
SN126	1.348E+03	2.317E+02	1.183E+02	8.657E-01	1.699E+03
SB124	0.000E+00	1.574E-04	1.360E-10	0.000E+00	1.574E-04
SB125	4.241E+04	3.507E+05	2.311E+05	5.004E+01	6.242E+05
SB126	1.887E+02	3.244E+01	1.657E+01	1.212E-01	2.378E+02
SB126*	1.348E+03	2.317E+02	1.183E+02	8.657E-01	1.699E+03
TE123	1.552E-11	2.350E-11	1.200E-11	6.272E-15	5.103E-11
TE123*	4.636E-19	1.322E-03	1.612E-06	2.994E-23	1.323E-03
TE125*	1.035E+04	8.557E+04	5.637E+04	1.221E+01	1.523E+05
TE127	5.520E-15	4.108E+01	2.466E-02	5.644E-19	4.110E+01
TE127*	5.635E-15	4.194E+01	2.518E-02	5.762E-19	4.196E+01
TE129	0.000E+00	2.408E-08	1.838E-19	0.000E+00	2.408E-08
TE129*	0.000E+00	3.699E-08	2.823E-19	0.000E+00	3.699E-08
I129	5.685E+01	9.223E+00	4.711E+00	3.701E-02	7.082E+01
XE127	0.000E+00	4.087E-15	2.386E-25	0.000E+00	4.087E-15

CS134	3.234E+03	3.097E+05	1.525E+05	2.642E+00	4.654E+05
CS135	9.599E+02	1.250E+02	6.383E+01	4.134E-01	1.149E+03
CS136	0.000E+00	1.760E-30	0.000E+00	0.000E+00	1.760E-30
CS137	1.105E+08	2.091E+07	1.229E+07	6.601E+04	1.437E+08
BA137*	1.045E+08	1.978E+07	1.163E+07	6.244E+04	1.360E+08
BA140	0.000E+00	2.617E-29	0.000E+00	0.000E+00	2.617E-29
LA138	3.904E-07	4.809E-08	2.456E-08	2.794E-10	4.634E-07
LA140	0.000E+00	3.012E-29	0.000E+00	0.000E+00	3.012E-29
CE141	0.000E+00	4.936E-07	1.560E-18	0.000E+00	4.936E-07
CE142	5.784E-02	8.119E-03	4.147E-03	3.086E-05	7.014E-02
CE144	3.620E+00	1.649E+06	1.177E+05	3.567E-03	1.767E+06
PR143	0.000E+00	3.289E-27	0.000E+00	0.000E+00	3.289E-27
PR144	3.620E+00	1.649E+06	1.177E+05	3.567E-03	1.767E+06
PR144*	4.344E-02	1.979E+04	1.413E+03	4.280E-05	2.120E+04
ND144	2.666E-06	3.786E-07	1.936E-07	1.472E-09	3.240E-06
PM146	1.371E+01	3.389E+01	2.722E+01	1.161E-02	7.483E+01
PM147	7.647E+05	5.620E+06	3.546E+06	8.566E+02	9.931E+06
PM148	0.000E+00	3.258E-07	3.372E-16	0.000E+00	3.258E-07
PM148*	0.000E+00	5.784E-06	5.987E-15	0.000E+00	5.784E-06
SM146	1.417E-05	7.028E-06	3.302E-06	7.080E-09	2.450E-05
SM147	2.140E-02	2.570E-03	1.296E-03	1.052E-05	2.528E-02
SM148	1.158E-08	4.650E-09	2.375E-09	5.783E-12	1.861E-08
SM149	1.832E-08	1.062E-09	5.423E-10	8.911E-12	1.994E-08
SM151	3.324E+06	3.726E+05	1.999E+05	9.432E+02	3.897E+06
EU150	2.072E-03	1.508E-03	8.669E-04	4.063E-07	4.447E-03
EU152	1.347E+03	1.296E+03	8.737E+02	3.074E-01	3.517E+03
EU154	1.068E+05	1.361E+05	1.017E+05	2.329E+01	3.446E+05
EU155	1.238E+05	8.820E+04	7.106E+04	3.370E+01	2.830E+05
EU156	0.000E+00	3.901E-25	0.000E+00	0.000E+00	3.901E-25
G0152	3.677E-10	1.710E-10	7.992E-11	6.350E-14	6.186E-10
G0153	3.182E-08	2.609E+00	1.121E-01	8.054E-12	2.721E+00
TB160	2.577E-28	1.259E-03	1.270E-08	0.000E+00	1.259E-03
HO166*	6.164E-02	4.027E-02	2.065E-02	2.694E-06	1.226E-01
TM170	1.308E-21	1.646E-06	3.306E-09	1.689E-27	1.650E-06
TM171	8.924E-10	6.874E-06	3.090E-06	1.598E-14	9.965E-06
LU176	0.000E+00	3.998E-09	2.042E-09	0.000E+00	6.039E-09
LU177	0.000E+00	2.177E-06	1.353E-08	0.000E+00	2.190E-06
LU177*	0.000E+00	9.466E-06	5.883E-08	0.000E+00	9.525E-06
HF175	0.000E+00	7.163E-04	4.837E-09	0.000E+00	7.163E-04
HF181	0.000E+00	3.889E-07	7.018E-16	0.000E+00	3.889E-07
HF182	0.000E+00	7.826E-05	3.997E-05	0.000E+00	1.182E-04
TA182	0.000E+00	4.708E-02	8.270E-05	0.000E+00	4.717E-02
W181	0.000E+00	1.098E-02	1.465E-05	0.000E+00	1.100E-02
W185	0.000E+00	1.177E-03	1.871E-08	0.000E+00	1.177E-03
W188	0.000E+00	1.608E-05	9.737E-11	0.000E+00	1.609E-05
RE187	0.000E+00	8.573E-06	4.379E-06	0.000E+00	1.295E-05
RE188	0.000E+00	1.625E-05	9.837E-11	0.000E+00	1.625E-05
OS194	0.000E+00	4.255E-15	3.392E-15	0.000E+00	7.647E-15
IR192	0.000E+00	5.261E-11	2.562E-11	0.000E+00	7.823E-11
IR192*	0.000E+00	4.919E-11	2.560E-11	0.000E+00	7.479E-11
IR194	0.000E+00	3.324E-15	3.393E-15	0.000E+00	6.717E-15
PT193	0.000E+00	1.558E-11	8.031E-12	0.000E+00	2.361E-11
TL206	2.879E-16	6.841E-12	3.494E-12	2.879E-16	1.034E-11
TL207	7.643E+01	1.483E-03	5.206E-04	7.642E+01	1.529E+02
TL208	4.317E+01	6.814E-03	3.337E-03	4.316E+01	8.635E+01
TL209	2.068E-02	7.461E-08	2.724E-08	2.068E-02	4.136E-02
PB204	0.000E+00	5.837E-12	2.981E-12	0.000E+00	8.818E-12
PB205	0.000E+00	8.062E-06	4.118E-06	0.000E+00	1.218E-05
PB209	9.575E-01	3.454E-06	1.261E-06	9.575E-01	1.915E+00
PB210	8.368E-04	5.853E-05	1.128E-05	1.758E-04	1.082E-03
PB211	7.665E+01	1.487E-03	5.220E-04	7.664E+01	1.533E+02
PB212	1.202E+02	1.897E-02	9.286E-03	1.201E+02	2.403E+02
PB214	2.418E-03	2.358E-04	7.297E-05	3.839E-04	3.111E-03
BI208	6.906E-16	1.043E-11	5.330E-12	6.905E-16	1.577E-11
BI210	8.358E-04	5.842E-05	1.124E-05	1.757E-04	1.081E-03
BI210*	4.546E-16	6.869E-12	3.508E-12	4.546E-16	1.038E-11
BI211	7.665E+01	1.487E-03	5.220E-04	7.664E+01	1.533E+02
BI212	1.202E+02	1.897E-02	9.286E-03	1.201E+02	2.403E+02
BI213	9.575E-01	3.454E-06	1.261E-06	9.575E-01	1.915E+00
BI214	2.418E-03	2.358E-04	7.297E-05	3.839E-04	3.111E-03

PO210	8.094E-04	5.549E-05	1.024E-05	1.721E-04	1.047E-03
PO211	2.146E-01	4.163E-06	1.462E-06	2.146E-01	4.292E-01
PO212	7.698E+01	1.215E-02	5.950E-03	7.697E+01	1.540E+02
PO213	9.368E-01	3.380E-06	1.234E-06	9.368E-01	1.874E+00
PO214	2.418E-03	2.358E-04	7.295E-05	3.838E-04	3.110E-03
PO215	7.665E+01	1.487E-03	5.220E-04	7.664E+01	1.533E+02
PO216	1.202E+02	1.896E-02	9.285E-03	1.201E+02	2.403E+02
PO218	2.419E-03	2.359E-04	7.299E-05	3.840E-04	3.111E-03
AT217	9.575E-01	3.454E-06	1.261E-06	9.575E-01	1.915E+00
RN219	7.665E+01	1.487E-03	5.220E-04	7.664E+01	1.533E+02
RN220	1.202E+02	1.896E-02	9.285E-03	1.201E+02	2.403E+02
RN222	2.419E-03	2.359E-04	7.299E-05	3.840E-04	3.111E-03
FR221	9.575E-01	3.454E-06	1.261E-06	9.575E-01	1.915E+00
FR223	1.061E+00	2.063E-05	7.273E-06	1.061E+00	2.122E+00
RA223	7.665E+01	1.487E-03	5.220E-04	7.664E+01	1.533E+02
RA224	1.202E+02	1.896E-02	9.285E-03	1.201E+02	2.403E+02
RA225	9.591E-01	3.460E-06	1.263E-06	9.591E-01	1.918E+00
RA226	2.420E-03	2.361E-04	7.309E-05	3.841E-04	3.113E-03
RA228	3.256E+00	1.277E-08	5.305E-09	3.256E+00	6.512E+00
AC225	9.575E-01	3.454E-06	1.261E-06	9.575E-01	1.915E+00
AC227	7.691E+01	1.495E-03	5.270E-04	7.690E+01	1.538E+02
AC228	3.256E+00	1.277E-08	5.305E-09	3.256E+00	6.512E+00
TH227	7.569E+01	1.469E-03	5.167E-04	7.568E+01	1.514E+02
TH228	1.201E+02	1.893E-02	9.270E-03	1.201E+02	2.403E+02
TH229	9.615E-01	3.469E-06	1.266E-06	9.615E-01	1.923E+00
TH230	2.154E-01	3.306E-02	1.620E-02	1.758E-02	2.823E-01
TH231	1.144E+01	8.040E-01	4.106E-01	9.292E-06	1.265E+01
TH232	2.683E+00	1.693E-08	8.267E-09	2.683E+00	5.366E+00
TH234	2.796E+02	1.606E+01	8.201E+00	7.595E-14	3.039E+02
PA231	1.451E+02	3.740E-03	1.853E-03	1.451E+02	2.902E+02
PA233	5.303E+01	2.136E+01	1.087E+01	8.744E-07	8.526E+01
PA234	3.635E-01	2.087E-02	1.066E-02	0.000E+00	3.951E-01
PA234*	2.796E+02	1.606E+01	8.201E+00	7.595E-14	3.039E+02
U232	1.136E+02	1.217E-02	6.523E-03	1.136E+02	2.272E+02
U233	4.299E+02	1.629E-03	5.195E-04	4.299E+02	8.598E+02
U234	2.756E+02	2.283E+01	1.165E+01	3.002E+00	3.131E+02
U235	1.144E+01	8.040E-01	4.106E-01	9.292E-06	1.265E+01
U236	5.060E+00	2.308E+00	1.179E+00	1.297E-06	8.547E+00
U237	1.321E+00	2.431E+00	1.619E+00	2.471E-14	5.371E+00
U238	2.796E+02	1.606E+01	8.201E+00	7.595E-14	3.039E+02
U240	5.237E-10	9.142E-09	4.669E-09	0.000E+00	1.434E-08
NP235	1.706E-08	9.699E-04	1.604E-04	2.370E-16	1.130E-03
NP236	1.096E-04	1.219E-04	6.227E-05	6.424E-13	2.938E-04
NP237	5.303E+01	2.137E+01	1.087E+01	8.744E-07	8.527E+01
NP238	1.034E-01	8.257E-01	4.343E-01	0.000E+00	1.363E+00
NP239	4.165E+00	2.961E+01	1.513E+01	0.000E+00	4.890E+01
NP240*	5.237E-10	9.142E-09	4.669E-09	0.000E+00	1.434E-08
PU236	3.356E-04	1.622E-02	1.091E-02	1.296E-10	2.747E-02
PU237	0.000E+00	1.606E-12	1.256E-20	0.000E+00	1.606E-12
PU238	7.899E+02	1.439E+03	7.693E+02	1.241E-04	2.998E+03
PU239	3.269E+04	4.381E+03	2.238E+03	3.399E-09	3.931E+04
PU240	5.252E+03	1.931E+03	9.855E+02	1.823E-10	8.169E+03
PU241	5.385E+04	9.912E+04	6.599E+04	1.007E-09	2.190E+05
PU242	1.434E-01	4.572E-01	2.333E-01	1.055E-15	8.339E-01
PU243	1.151E-12	7.179E-10	3.667E-10	0.000E+00	1.086E-09
PU244	5.238E-10	9.143E-09	4.670E-09	1.534E-24	1.434E-08
AM241	1.650E+04	3.681E+04	1.849E+04	6.936E-11	7.180E+04
AM242	2.057E+01	1.643E+02	8.643E+01	9.278E-16	2.713E+02
AM242*	2.067E+01	1.651E+02	8.686E+01	9.324E-16	2.727E+02
AM243	4.165E+00	2.961E+01	1.513E+01	1.896E-16	4.890E+01
AM244	5.186E-14	9.150E-13	4.673E-13	0.000E+00	1.434E-12
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