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Designing a Nuclear Data Base Prototype Using Oracle and Prolog

R. Paviotti-Corcuera
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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04; Microfiche A01

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ORNL/TM-10984

Instrumentation and Controls Division

DESIGNING A NUCLEAR DATA BASE PROTOTYPE USING ORACLE AND PROLOG

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Date Published: November 1988

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

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ABSTRACT

An ever-increasing demand exists for easily accessible nuclear data base systems. The purpose of this work is to analyze the feasibility of using artificial intelligence methods as tools to provide the necessary functionality to extract information from nuclear data files in a user-friendly manner. For the prototype of this work, a sample of data that can be later enlarged to a complete, evaluated nuclear data base has been used. To implement this prototype, two approaches have been followed:

1. a conventional approach using the commercially available Oracle relational data base management system, and
2. an artificial intelligence approach using the Prolog programming language.

This prototypic work shows the feasibility of applying artificial intelligence methods to data bases and represents a first step toward development of intelligent nuclear data base systems.

The characteristics of the query language from both approaches make the second one preferable from a user's point of view.

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1. INTRODUCTION

Demands for an organized and easily accessible set of neutron cross sections and nuclear parameters information, commonly referred to as "nuclear data," have increased during the last 20 years.

Some of the most important organized collections of nuclear data are the so-called "evaluated nuclear data libraries."

Evaluated nuclear data libraries include, for example, neutron cross sections, resonance parameters, angular distributions of secondary neutrons, energy distributions of secondary neutrons, radioactive decay and fission product yield, energy distribution of photons, and covariance matrices.

Some of the widely used evaluated nuclear data libraries are Evaluated Nuclear Data Files (ENDF/B) from Brookhaven such as ENDF/B-V Fission Products, ENDF/B-V Standards, and ENDF/B-V Dosimetry; ENDL from Lawrence Livermore Laboratory; JNDL from the Japanese Atomic Energy Commission; KEDAK from Kernforschungszentrum Karlsruhe; INDL from the International Atomic Energy Agency; SOCRATOR from Obsninsk, Soviet Union; and JEF from the NEA Data Bank in France.

Usually this information is distributed by the nuclear data centers, which will, among many other tasks, compile and distribute data and exchange information under international agreements.[1,2]

The evaluated data contained in these libraries are the initial data needed to begin the design of a nuclear reactor, and they are also used whenever a change occurs in the fuel composition, as, for example, in burnup calculations.

At the start of the design process, the reactor designer needs answers to questions such as, Do we have all the nuclear data we need for this application? What amount of data are we going to process? With what detail are the cross sections given? These questions are now answered by a specialist in nuclear data, who will go through catalogs[3,4] or will load the nuclear data file tapes on a computer and retrieve the information needed with the help of Fortran programs.

Recently, artificial intelligence methodologies have been applied to the development of expert systems for nuclear data evaluation[5] and for the generation of uncertainties for the EXFOR files.[6,7] The purpose of this work is to initiate a detailed study of these methodologies as potential tools to provide the necessary functionality to extract information from nuclear data files in a user-friendly manner.

For the development of the prototype of this work, a subset of data from ENDF/B, which can be later extended to cover a complete, evaluated nuclear data base, has been used. To implement this prototype, two approaches have been followed:

1. a conventional approach using the commercially available Oracle relational data base management system, and
2. an artificial intelligence approach using the Prolog programming language.

Oracle[8] is a relational data base management system commercially available. Prolog[9] in this report refers to the Prolog implementation of Arity Corporation for the IBM-PC/AT.

The prototype developed in this work was implemented on an IBM AT with MS-DOS, but the tools used, Oracle and Prolog, are also available on many other computers and operating systems.

In Sects. 2 and 3, the Oracle and Prolog implementations are explained. In Sect. 4, the differences between both implementations are discussed, and their main advantages and disadvantages are pointed out. Finally, the conclusions are given in Sect. 5.

2. IMPLEMENTING THE DATA BASE WITH ORACLE

Several relational data base management systems were analyzed[10,11] from which Oracle V.4.1.4 was selected for its combination of features, transportability, and price. Oracle for the IBM-PC consists of

- a "kernel," that is, the low-level data base management software as well as the files composing the relational data base itself; and

- several utility programs, including a report writer (RPT and RPF), a C-language interface preprocessor and runtime library, an import/export facility (IMP and EXP), an external data loader (ODL), an interactive application facility (IAG and IAP), and a query language command interpreter (UFI).

All data in Oracle are stored in tables that are logically made up of rows and columns. The efficiency and usefulness of Oracle result from

- the simplicity, power, and flexibility of its ANSI-standard query language, "Structured Query Language" (SQL);

- the convenience of the IAG: fully functional data manipulation programs with attractive screen presentations can be designed and implemented, often without any traditional programming.

To illustrate the type of information actually stored in the data base, a sample extracted from the ENDF/B files is given in Tables 1, 2, and 3. These tables represent the conceptual definition of our data base.

Table 1 gives information on the available libraries, Table 2 shows which nuclides are in each library, and Table 3 describes which data are available for each nuclide. The column "No. records" gives an idea of the volume of the information [for cross sections, one record contains three points of the function cross section (energy)]. Other tables, which contain the data themselves—for example, the cross sections as functions of energy—could be easily defined and added at a later stage.

With all of this information stored in an appropriate data base, the user can request information by means of the following questions.

- Which libraries are available?
- Which nuclides are in each library?
- What type of information is given for each nuclide in the specified library?

To store this information in our data base, four Oracle tables were created (see Table 4). The first Oracle table, "library," contains information about the available libraries and the country of origin. The second, "source," contains information about the nuclides available in each library; the third table, "section," contains the Mat, Mf, and Mt numbers; and the fourth, "numeric_code," contains the description (or translation) of those numbers as defined in ENDF/B Data Formats and Procedures.[12]

To answer some of the questions typically asked by users, two Oracle views were also created and are in Table 4. A sample of the commands used to store the information in the data base is shown in Table 5.

The appearance of the Oracle tables on the screen is displayed in Table 6. The relevant commands used to retrieve the information are also shown.*

One of the main features of Oracle is the ability to create fully functioning screens via the IAG. When the data are accessed through these applications, managing the information becomes straightforward. By using the IAG, a screen appropriate for our type of data was created. Figure 1 shows the Oracle table that appears on the screen. With IAG, some 30 different data operations can be performed using function keys and the Control, Shift, and Alt keys. Some of these operations are: execute a particular query, abort a query, clear a record, delete a record, clear a field, commit all changes, roll back all changes, show all key bindings, and help to explain the field where the cursor is. A partial list of the operations performed by the function keys is given at the bottom of Fig. 1.

For our simplified example, Oracle seems to be an appropriate and effective system for the storage and retrieval of nuclear data.

*Sometimes, when a text field must be split over several lines, Oracle seems to have made a bad choice of breakpoints. Nothing can be done about this problem because the Oracle report writer facility is not a word processor.

3. IMPLEMENTING THE DATA BASE WITH PROLOG

Prolog is a programming language based on logic that was originated and developed by the artificial intelligence community.[13-15] Its ability to traverse the search space efficiently and automatically has already been proven.[16] Furthermore, several researchers have recognized the close and fundamental relationship that exists between Prolog and relational data bases.[17-20]

In an analysis[21] of 14 commercially available Prolog implementations, Arity/Prolog was considered to be powerful and robust, with syntax and predicates very similar to the Edinburgh standard.

Arity/Prolog has another interesting feature, namely, its SQL package, Arity/SQL, suitable for data base applications. The query language used is SQL, essentially the same as the one in Oracle. The commands to create the tables and insert the information are very similar to those shown in Tables 4 through 6. A nuclear data base prototype was implemented using Arity/SQL and a subset from ENDF/B. (Because of the similarity with the Oracle tables, the data are not shown).

In addition to that implementation, we have also made a first attempt to describe in Prolog the format of ENDF/B as documented in ref. 12. Taking advantage of the similarity between Prolog and a relational data base, we have attempted to implement our nuclear data base directly in Prolog.

In this case, we have gone one step further by implementing not only information about the data—as we did for the two cases above (Oracle, Arity/SQL)—but the data themselves. That is, we have also stored the cross sections as a function of, for example, the energy and the angular distributions.

As a data subset for our prototype, we chose the data of B-10 (Boron 10) that we took from ENDF/B-V Standards and stored in a file: B10B.DAT.

The problem of storing and retrieving the information was solved in three steps. At each step a program is run. These programs are stored in the following files:

1. File READFILE.ARI

   This file contains the program that transforms the card-image format data into Prolog data. Throughout the execution, the data are put in the form of Prolog clauses that look like

```
source (Tape,Library,Mat,Nuclide,Affiliation,Evaluator),
data(Mat,Mf,Mt,Text),
section(Mat,Mf,Mt), etc.
```

   See ref. 12 for definitions.

2. File CODE.ARI

   This file contains the Prolog clauses that represent the conventions and procedures of ENDF/B Data Formats and Procedures[12] that are independent of the nuclide loaded in the data base.

3. File REPORT.ARI

   The predicates in this file combine the information of the file CODE.ARI with particular nuclide data from the data base. This combination makes it possible to retrieve the information. See examples of queries in Table 7.

Queries 10 and 11 are similar to the kind of output that can be obtained by running LIFTC.[22]

The Prolog program can be extended to answer questions related to the type of information given in ref. 23. That is, for example: Is it a fissionable material? Is it stable? Are resonance data given? Which is the formalism used for the resonance parameters? Are unresolved data given? Are the data temperature-dependent? For the angular distribution, are the data given as Legendre coefficients or as a probability distribution? Which law is used to describe the energy distribution of fission neutrons?

4. COMPARISON BETWEEN ORACLE AND PROLOG IMPLEMENTATIONS

In the preceding chapters, four methods to retrieve information were described. They are as follows:

in Oracle,
1. using SQL language, and
2. using IAG (this is the screen of page 1);

in Prolog,
3. using SQL language, and
4. using a Prolog program.

From the point of view of a nonspecialized user, the easiest way to retrieve information from the data base is through method 2; method 4 comes next, and methods 1 and 3 are essentially equivalent.

The main advantage of method 4 is that because Prolog is a logic language especially appropriate for artificial intelligence techniques, it will be easier in a later stage to use our data base in an expert system for a particular application.

Let us now compare some SQL and Prolog queries (see Tables 6 and 7).

```
Data needed:  Which nuclides are in ENDF/B-V, and what is their Mat
               number?.
SQL:          select * from numeric_code where code_type like 'mat';
Prolog:       code(mat,Mat.Nuclide).

Data needed:  What are the possible values and meaning for Mf?.
SQL:          select * from numeric_code where code_type like 'mf';
Prolog:       code(mat,Mat,Data_type).

Data needed:  Which nuclide has the Mat number = 1305?.
SQL:          select * from numeric_code where code_type like 'mat' and
               code = 1305;
Prolog:       explain(mat,1305,Nuclide).

Data needed:  What is the Mat number for B-10?.
SQL:          select * from numeric_code where code_type like 'mat' and
               translation like 'B-10';
Prolog:       explain(mat,Mat,$B-10$).

Data needed:  What data_type is coded with Mf = 3?.
SQL:          select * from numeric_code where code_type like 'mf' and
               code = 3;
Prolog:       explain(mf,3,Data_type).

Data needed:  What is the value of Mf for Neutron Cross Sections?.
SQL:          select * from numeric_code where numeric code_type like
               'mf' and translation like 'Neutron Cross Section';
Prolog:       explain(mf,Mf,$Neutron Cross Section$).
```

Data needed: What are the data available for B-10?.
SQL: select * from nuclide_info where nuclide like 'B-10' order by mf,mt;
Prolog: table of contents('file_name').

In general, for the questions above, the syntax of the Prolog queries is much easier than that of SQL queries.

Because of the prototypic nature of this work, not much attention was paid to issues of efficiency, such as data base sizes, code sizes, compile times, and execution times. Nonetheless, since the raw input files approached 1 Mbyte in size, these concepts could not be completely ignored. With Prolog, we used the easiest method of storing and retrieving the data, namely the "assert" and (sometimes implicit) "call" predicates. With Arity/Prolog, other alternatives were available that would certainly have significantly reduced the time to record and retrieve the data; these techniques involve "B-tree" indexes, hash tables, "data world(s)," etc. In any event, the time required to parse an entire data file and store the data as Prolog clauses never exceeded a few minutes. As is often the situation, we experienced dramatic improvement in retrieval speed by creating (B-tree) indexes for the Oracle data base; in fact, response times for some of the complex multitable queries listed earlier in this paper were reduced from 30 min to a few seconds simply by creating relevant indexes. Interestingly, when using SQL data base management systems like Oracle, neither the user nor the programmer needs to remember which, if any, indexes have been defined; it is the responsibility of the underlying kernel software to determine the appropriate index(es) to achieve the most efficient processing.

As stated previously, Oracle is a very popular package; its query language and programming interfaces meet the ANSI standards for SQL, which makes it very transportable to and compatible with other systems. With its other utility packages and its C interface, Oracle is a powerful component in any such system.

The main disadvantage of Prolog is probably that it is not widely known and accepted in the programmer and user community, especially in the United States. Apart from that, Arity/Prolog together with Arity/SQL and Arity/Expert, its expert system building package, could also serve as an advanced tool for the management and analysis of nuclear data.

Certainly, neither Oracle nor Arity/Prolog was specially designed to handle "scientific data" (i.e., vast quantities of numeric data) such as this. However, both systems seemed to provide all the functionality necessary to process evaluated nuclear data.

5. CONCLUSIONS

We have shown, through this prototypic example, that artificial intelligence methodologies and data base management systems now available provide the necessary functionality to extract information from nuclear data files.

A first attempt was made to codify in Prolog the ENDF/B Data Formats and Procedures. Although this codification was restricted to Mat, Mf, Mt, and some Head, Send, Fend, and Tend records, the extension of this work to cover all records and "flags" contained in the ENDF/B files should be straightforward.

This work represents a modest first step towards the development of intelligent data base systems, which by combining nuclear data sets with experimental data files would provide automatized input sets for reactor calculations.

The limited expressive power of SQL compared to the power of Prolog, which has been used both as a programming language and as a query language, makes the second approach preferable to the first.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the help and guidance of Dr. P. J. Otaduy and Dr. G. de Saussure, both of the Oak Ridge National Laboratory Engineering Physics and Mathematics Division.

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Table 1. Some internationally available evaluated nuclear data libraries

Library name	Country of origin
ENDF/B-IV - Standards	U.S.A.
ENDF/B-IV - Dosimetry	U.S.A.
ENDF/B-IV - Fission Products	U.S.A.
ENDF/B-V - Standards	U.S.A.
ENDF/B-V - Dosimetry	U.S.A.
ENDF/B-V - Fission Products	U.S.A.
ENDF/B-V - Actinides	U.S.A.
JENDL-2	Japan
ENDL-84	U.S.A.
KEDAK	Germany
SOCRATOR	U.S.S.R.
FRENDL	France
INDL	I.A.E.A.

Table 2. Nuclides present in the ENDF/B-V Standards library

Nuclide	Material number	Evaluator - Laboratory
He-3	1146	Leona Stewart - LASL[a]
H-1	1301	L. Stewart et al. - LASL
Li-6	1303	G. Hale et al. - LASL
B-10	1305	G. Hale et al. - LASL
C-12	1306	C. Y. Fu et al. - ORNL[b]
Au-196	1379	S. F. Mughabghab - BNL[c]
U-235	1395	M. R. Bhat - BNL

[a]Los Alamos National Laboratory.
[b]Oak Ridge National Laboratory.
[c]Brookhaven National Laboratory.

Table 3. Type of information given for the nuclide H-1 in the ENDF/B-V Standards library

Nuclide	Code	File	Section	Information given	No. of Records
H-1	1301	1	451	General description	142
		2	151	Res. parameters	5
		3	1	Total cross section	48
		2		Elastic cross section	48
			102	(n,gamma)	48
			251		8
			252		8
			253		8
		4	2	Elastic cross section	163
		12	102	(n,gamma)	5
		14	102	(n,gamma)	2
		33	1	Covariance for total	5
			2	Covariance for elastic	25
			102	Covariance for (n,gamma)	9

Table 4. Tables and views for the data base

```
UFI> START CRRSIC

UFI> create table library (
  2          library char(66),
  3          origin char(17)
  4  );

Table created.

UFI> create table source (
  2              mat number(4),
  3              nuclide char(6),
  4              tape char(4),
  5              library char(66),
  6              affiliation char(4),
  7              evaluators char(33)
  8  );

Table created.

UFI> create table section (
  2              mat number(4),
  3              mf number(2),
  4              mt number(3),
  5              number_of_records number(5)
  6  );

Table created.

UFI> create table numeric_code (
  2              code_type char(3),
  3              code number(4),
  4              translation char(68)
  5  );

Table created.

UFI> create view mf_in_section as
  2              select mat,mf from section group by mat,mf;

View created.
```

Table 4 (contined)

```
UFI> create view nuclide_info as select nuclide,source.mat,mf,
  2  n1.translation mf_info,mt,n2.translation mt_info,number_of_records
  3  from source,section,numeric_code n1,numeric_code n2
  4  where source.mat = section.mat
  5  and n1.code_type ='mf' and n1.code = section.mf
  6  and n2.code_type ='mt' and n2.code = section.mt;

View created.


UFI> create index source_index on source(mat);

Index created.


UFI> create index section_index on section(mat,mf,mt);

Index created.


UFI> create index numeric_code_index on numeric_code(code_type,code);

Index created.


UFI> create index source_index on source(mat);

Index created.


UFI> create index section_index on section(mat,mf,mt);

Index created.


UFI> create index numeric_code_index on numeric_code(code_type,code);

Index created.


UFI> EXIT
Logged off from ORACLE.
```

Table 5. Some of the commands used to insert the information

```
UFI> START B10
UFI> insert into source values(1305,'B - 10','563',
  2     'ENDF/B-V STANDARDS',
  3     'LASL','G.HALE, L.STEWART, P.YOUNG');

1 record created.

UFI>
UFI> insert into section values(1305,1,451,390);

1 record created.

...(many similar data "insert" commands)

UFI> insert into section values(1305,33,781,21);

1 record created.


UFI> START U235
UFI> insert into source values(1395,'U -235','563',
  2     'ENDF/B-V STANDARS',
  3     'BNL ','M.R.BHAT');

1 record created.

UFI>
UFI> insert into section values(1395,1,451,330);

1 record created.

...(many similar data "insert" commands)

UFI> insert into section values(1395,33,102,42);

1 record created.

UFI> START CODE
UFI> insert into numeric_code values('mat',1305,'B-10');

1 record created.

UFI> insert into numeric_code values('mat',1395,'U-235');

1 record created.

...(many similar data "insert" commands)
```

Table 5 (continued)

```
UFI> insert into numeric_code values('mat',1379,'Au-197');

1 record created.


UFI> insert into numeric_code values('mf',1,'General Information');

1 record created.

...(many similar data "insert" commands)

UFI> insert into numeric_code values('mf',33,'Data Covariance Matrices
for Neutron Cross Sections');

1 record created.

UFI> insert into numeric_code values('mt',1,'Total Cross Section');

1 record created.

...(many similar data "insert" commands)

UFI> insert into numeric_code values('mt',781,'(n,al) Cross Section for
1st excited state');

1 record created.
```

Table 6. Example of possible queries to the data base

```
UFI> column library format a20 wrap heading 'Library'
UFI> select * from library;
```

Library	Origin
ENDF/B-V - STANDARDS	U.S.A.
ENDF/B-V - DOSIMETRY	U.S.A.
ENDF/B-V - FIS. PROD.	U.S.A.
ENDF/B-V - ACTINIDES	U.S.A.
JENDL-2	JAPAN
ENDL-84	U.S.A.
KEDAK	GERMANY
JEF-1	FRANCE
SOCRATOR	U.S.S.R.
INDL	I.A.E.A.

```
10 records selected.

UFI> exit
Logged off from ORACLE.
```

Table 6 (continued)

```
UFI> select * from source;

MAT   Nuclide Tape Library                    Aff. Evaluator(s)
-1305  B - 10  563 ENDF/B-V STANDARDS LASL G. HALE, L. STEWART, P. YOUNG

1395  U -235  563  ENDF/B-V STANDARDS  BNL  M. R. BHAT
```

```
UFI> break on mat skip 1 on mf skip 1
UFI> select * from section;

                  Number
  MAT  MF   MT   Recs.
----- --- ---- -------
 1305   1  451     390

        2  151       4

        3    1     132
             2     126
 ...

       12  102      40
           781       4

       13    4     368
           103      88

       14    4       1
           102       1
           103       1
           781       1

       33    1       5
             2      87
           107       9
           780      54
           781      21
```

Table 6 (continued)

```
                          Number
 MAT   MF  MT              Recs.
----- ---- ------         -------
 1395   1  451              330
           452                7
           455                8
           456                6
           458                5

        2  151              973

        3    1              470
             2              470
             4              128
            16               26
            17                9
            18              300
...
       31  452               56

       33   18               78
           102               42
191 records selected.

UFI> select * from mf_in_section;

  MAT  MF
----- ---
 1305   1
        2
        3
        4
       12
       13
       14
       33

 1395   1
        2
        3
        4
        5
        8
       12
       13
       14
       15
       31
       33
20 records selected.
```

Table 6 (continued)

```
UFI> break on code_type skip 1
UFI> select * from numeric_code order by code_type,code;

Code
Type  Code Translation
---- ----- ------------------------------------------------------------
mat   1146 He-3
      1301 H-1
      1303 Li-6
      1305 B-10
      1306 C-12
      1379 Au-197
      1395 U-235
Code
Type  Code Translation
---- ----- ------------------------------------------------------------

mf       1 General Information
         2 Resonance Parameter Data
         3 Neutron Cross Sections
         4 Angular Distributions of Secondary Neutrons
        12 Multiplicities for Photons (from neutron reactions)
        13 Cross Sections for Photons (from neutron reactions)
        14 Angular Distributions for Photons (from neutron reactions)
        33 Data Covariance Matrices for Neutron Cross Sections

Code
Type  Code Translation
---- ----- ------------------------------------------------------------
mt       1 Total Cross Section
         2 Elastic Scattering Cross Section
         3 Non-Elastic Cross Section
         4 Total Inelastic Cross Section
        51 (n,n ) to the 1st excited state
        52 (n,n ) to the 2nd excited state
        53 (n,n ) to the 3rd excited state
        54 (n,n ) to the 4th excited state
        55 (n,n ) to the 5th excited state
        56 (n,n ) to the 6th excited state
        57 (n,n ) to the 7th excited state
        58 (n,n ) to the 8th excited state
        59 (n,n ) to the 9th excited state
       102 (n,g) Radiative Capture Cross Section
       103 (n,p) Cross Section
       104 (n,d) Cross Section
       107 (n,a) Cross Section
       113 (n,t2a) Cross Section
       151 Resonance Information
       251 MuL, average cosine of the scattering angle
       252 Psi, average logarithmic energy decrement
       253 Gamma, avg of the square of the log. energy dec.
44 records selected.
```

Table 6 (continued)

```
UFI> select * from nuclide_info
  2  where nuclide = 'U -235'
  3  order by mf,mt;
```

Nuclide	MAT	MF	MF description	MT	MT description	Number Recs.
U -235	1395	1	General Information	451	Heading or Title information	330
U -235	1395	2	Resonance Parameter Data	151	Resonance Information	973
U -235	1395	3	Neutron Cross Sections	1	Total Cross Section	470
U -235	1395	3	Neutron Cross Sections	2	Elastic Scattering Cross Section	470
U -235	1395	3	Neutron Cross Sections	4	Total Inelastic Cross Section	128
U -235	1395	3	Neutron Cross Sections	51	(n,n) to the 1st excited state	11
U -235	1395	3	Neutron Cross Sections	52	(n,n) to the 2nd excited state	15
U -235	1395	3	Neutron Cross Sections	53	(n,n) to the 3rd excited state	14
U -235	1395	3	Neutron Cross Sections	54	(n,n) to the 4th excited state	14
U -235	1395	3	Neutron Cross Sections	55	(n,n) to the 5th excited state	13
U -235	1395	3	Neutron Cross Sections	56	(n,n) to the 6th excited state	13
U -235	1395	3	Neutron Cross Sections	57	(n,n) to the 7th excited state	12

Table 6 (continued)

Nuclide	MAT	MF	MF description	MT	MT description	Number Recs.
U -235	1395	3	Neutron Cross Sectio ns	58	(n,n) to the 8th ex cited state	12
U -235	1395	3	Neutron Cross Sectio ns	59	(n,n) to the 9th excited state	11
U -235	1395	3	Neutron Cross Sectio ns	102	(n,g) Radiative Capt ure Cross Section	371
U -235	1395	3	Neutron Cross Sectio ns	251	MuL, average cosine of the scattering an gle	10
U -235	1395	3	Neutron Cross Sectio ns	252	Psi, average logarit hmic energy decremen t	10
U -235	1395	3	Neutron Cross Sectio ns	253	Gamma, avg of the sq uare of the log. ene rgy dec.	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	2	Elastic Scattering C ross Section	146
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	51	(n,n) to the 1st ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	52	(n,n) to the 2nd ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	53	(n,n) to the 3rd ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	54	(n,n) to the 4th ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	55	(n,n) to the 5th ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	56	(n,n) to the 6th ex cited state	10

Table 6 (continued)

Nuclide	MAT	MF	MF description	MT	MT description	Number Recs.
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	57	(n,n) to the 7th ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	58	(n,n) to the 8th ex cited state	10
U -235	1395	4	Angular Distribution s of Secondary Neutr ons	59	(n,n) to the 9th ex cited state	10
U -235	1395	12	Multiplicities for P hotons (from neutron reactions)	4	Total Inelastic Cros s Section	253
U -235	1395	12	Multiplicities for P hotons (from neutron reactions)	102	(n,g) Radiative Capt ure Cross Section	5
U -235	1395	13	Cross Sections for P Photons (from neutron reactions)	3	Non-Elastic Cross Se ction	8
U -235	1395	14	Angular Distribution s for Photons (from neutron reactions)	3	Non-Elastic Cross Se ction	1
U -235	1395	14	Angular Distribution s for Photons (from neutron reactions)	4	Total Inelastic Cros s Section	1
U -235	1395	14	Angular Distribution s for Photons (from neutron reactions)	102	(n,g) Radiative Capt ure Cross Section	1
U -235	1395	33	Data Covariance Matr ices for Neutron Cro ss Sections	102	(n,g) Radiative Capt ure Cross Section	42

35 records selected.

UFI> exit
Logged off from ORACLE.

Table 7. Prolog predicates to retrieve information

```
% Which nuclides are on ENDF/B-V, and what is their Mat number?

?- code(mat,Mat,Nuclide).

Mat = 1305
Nuclide = $B-10$ ->;
Mat = 1395
Nuclide = $U-235$ ->;
Mat = 1146
Nuclide  = $He-3$ ->;
Mat = 1301
Nuclide = $H-1$ ->;
Mat = 1303
Nuclide = $Li-6$ ->;
Mat = 1306
Nuclide = $C-12$ ->;
Mat = 1379
Nuclide = $Au-197$
yes
```

```
% What are the possible values and meaning for Mf?

?- code(mf,Mf,Data_type).

Mf = 1
Data_type = $General Information$ ->;

Mf = 2
Data_type = $Resonance Parameter Data$ ->;

Mf = 3
Data_type = $Neutron Cross Sections$ ->;

Mf = 4
Data_type = $Angular Distributions of Secondary Neutrons$ ->;

Mf = 12
Data_type = $Multiplicities for Photons (from neutron reactions)$ ->;

Mf = 13
Data_type = $Cross Sections for Photons (from neutron reactions)$ ->;

Mf = 14
Data_type = $Angular Distributions for Photons (from neutron reactions)$
->
continue .
          .
          .
```

Table 7 (continued)

```
% What are the possible values and meanning for Mt?

?- code(mt,Mt,Reaction).

Mt = 1
Reaction = $Total Cross Section$ ->;

Mt = 2
Reaction = $Elastic Scattering Cross Section$ ->;

Mt = 3
Reaction = $Non-Elastic Cross Section$ ->;

Mt = 4
Reaction = $Total Inelastic Cross Section$ ->;

Mt = 51
Reaction = $(n,n ) to the 1st excited state$ ->

continue .
         .
         .
```

```
% Which nuclide has the  Mat number = 1305?

?- explain(mat,1305,Nuclide).

Nuclide = $B-10$ ->
yes
-----------------------------------------
% What is the Mat number for B-10 ?

?- explain(mat,Mat,$B-10$).

Mat = 1305 ->
yes
-------------------------------------------------------
% What data_type is coded whith Mf =3?

?- explain(mf,3,Data_type).

Data_type = $Neutron Cross Sections$ ->
yes
-----------------------------------------
% What is the value of Mf for Neutron Cross Sections?

?- explain(mf,Mf,$Neutron Cross Sections$).

Mf = 3 ->
yes
```

Table 7 (continued)

```
% What reaction is coded with Mt = 102?

?- explain(mt,102,Reaction).

Reaction = $(n,g) Radiative Capture Cross Section$ ->
yes

-----------------------------------------------------------------


% What are the data available for B- 10?

?- table_of_contents('borontoc.tex').

TABLE_OF_CONTENTS output on file borontoc.tex

TABLE_OF_CONTENTS Exit.

yes
% See output on file 'borontoc.tex' in the following pages.

-------------------------------------------------


% Make an interpreted listing for boron and store it in the file
% boron.tex.

?- report('boron.tex').

REPORT output on file boron.tex
REPORT Exit.

yes
% See output on file 'boron.tex' in following pages.

 -------------------------------------------------------------


% Make an interpreted listing for Mf = 33, Mt = 1.

?- report('covar.tex',33,1).

REPORT output on file covar.tex
REPORT Exit.
yes
% See ouput on file 'covar.tex' in following pages

-------------------------------------------------------
```

Table 7 (continued)

```
% Retrieve all the data.

?- data(Mat,Mf,Mt,Seq,Text).

Mat = 563
Mf = 0
Mt = 0
Seq = 0
Text = $ENDF/B-V AMPX MOD NO. 3 OCTOBER 83
     $->;
Mat = 1305
Mf = 1
Mt = 451
Seq = 1
Text = $ 5.01000+ 3 9.92690+ 0          0          0        0 1$->;


Mat = 1305
Mf = 1
Mt = 451
Seq = 2
Text = $ 0.0    + 0 0.0    + 0          0          0        0 0$->

...
continue .
         .
         .
-------------------------------------------------------------------

% Retrieve the data for Mf = 33, Mt = 1.

?- data(1305,33,1,_,Text).

Text = $ 5.01000+ 3 9.92690+ 0          0          0        0 1$->;


Text = $ 0.0    + 0 0.0    + 0          0          1        1 0$->;


Text = $ 0.0    + 0 0.0    + 0          0          0        0 0$->;


Text = $ 1.00000- 5 2.00000+ 7          0          0        6 13$->;


Text = $ 1.00000+ 0 2.00000+ 0 1.00000+ 0 7.80000+ 2 1.00000+ 0
7.81000+ 2$->;

no
```

Table 7 (continued)

```
08-Jul-1988 13:40:09     File : covar.tex

Tape No. : 563
Library  : ENDF/B-V AMPX MOD NO. 3 OCTOBER 83

Material : B - 10 [1305]

File     : Data Covariance Matrices for Neutron Cross Sections [33]

Type     : Total Cross Section [1]

3357       5.01000+ 3 9.92690+ 0          0          0        0   1
3357       5.01000+ 3 9.92690+ 0          0          0        0   1
3358       0.0    + 0 0.0    + 0          0          1        1   0
3358       0.0    + 0 0.0    + 0          0          1        1   0
3359       0.0    + 0 0.0    + 0          0          0        0   0
3359       0.0    + 0 0.0    + 0          0          0        0   0
3360       1.00000- 5 2.00000+ 7          0          0        6   3
3360       1.00000- 5 2.00000+ 7          0          0        6   3
3361       1.00000+ 0 2.00000+ 0 1.00000+ 0 7.80000+ 2 1.00000+ 0
7.81000+ 2
3361       1.00000+ 0 2.00000+ 0 1.00000+ 0 7.80000+ 2 1.00000+ 0
7.81000+ 2
.
.
.
```

Table 7 (continued)

11-Jul-1988 11:10:04 Table of Contents

Tape No. : 563
Library : ENDF/B-V AMPX MOD NO. 3 OCTOBER 83

Material : B - 10 [1305]
Affiliation : LASL
Evaluators : G.HALE, L.STEWART, P.YOUNG

MF	MT		Recs
1 :		General Information	
	451 -	Heading or Title information	6
2 :		Resonance Parameter Data	
	151 -	Resonance Information	4
3 :		Neutron Cross Sections	
	1 -	Total Cross Section	6
	2 -	Elastic Scattering Cross Section	4
	4 -	Total Inelastic Cross Section	6
	51 -	(n,n) to the 1st excited state	6
	52 -	(n,n) to the 2nd excited state	5
	53 -	(n,n) to the 3rd excited state	5
	54 -	(n,n) to the 4th excited state	6
	55 -	(n,n) to the 5th excited state	6
	56 -	(n,n) to the 6th excited state	7
	57 -	(n,n) to the 7th excited state	9
	58 -	(n,n) to the 8th excited state	7
	59 -	(n,n) to the 9th excited state	1
	102 -	(n,g) Radiative Capture Cross Section	5
	103 -	(n,p) Cross Section	6
	104 -	(n,d) Cross Section	6
	107 -	(n,a) Cross Section	7
	113 -	(n,t2a) Cross Section	8
	251 -	MuL, average cosine of the scattering angle	7
	252 -	Psi, average logarithmic energy decrement	6
	253 -	Gamma, avg of the square of the log. energy dec.	8
	700 -	(n,p0) Cross Section	6
	701 -	(n,p1) Cross Section for 1st excited state	6
	702 -	(n,p2) Cross Section for 2nd excited state	6
	703 -	(n,p3) Cross Section for 3rd excited state	6
	780 -	(n,a0) Cross Section for ground state	7
	781 -	(n,a1) Cross Section for 1st excited state	5
4 :		Angular Distributions of Secondary Neutrons	
	2 -	Elastic Scattering Cross Section	5
	51 -	(n,n) to the 1st excited state	5
	52 -	(n,n) to the 2nd excited state	6
	53 -	(n,n) to the 3rd excited state	3

Table 7 (continued)

12 :	Multiplicities for Photons (from neutron reactions)	
	102 - (n,g) Radiative Capture Cross Section	9
	cont. table 7.	
	781 - (n,al) Cross Section for 1st excited state	4
13 :	Cross Sections for Photons (from neutron reactions)	
	4 - Total Inelastic Cross Section	7
	103 - (n,p) Cross Section	8
14 :	Angular Distributions for Photons (from neutron reactions)	
	4 - Total Inelastic Cross Section	1
	102 - (n,g) Radiative Capture Cross Section	1
	103 - (n,p) Cross Section	1
	781 - (n,al) Cross Section for 1st excited state	1
33 :	Data Covariance Matrices for Neutron Cross Sections	
	1 - Total Cross Section	5
	2 - Elastic Scattering Cross Section	7
	107 - (n,a) Cross Section	5
	780 - (n,a0) Cross Section for ground state	5
	781 - (n,al) Cross Section for 1st excited state	5

Table 7 (continued)

```
08-Jul-1988 12:43:22      File : boron.tex

Tape No. : 563
Library  : ENDF/B-V AMPX MOD NO. 3 OCTOBER 83

Material : B - 10 [1305]

   : General Information [1]
Type     : Heading or Title information [451]

1          5.01000+ 3 9.92690+ 0          0          0          0          1
1          5.01000+ 3 9.92690+ 0          0          0          0          1
2          0.0    + 0 0.0    + 0          0          0          0          0
2          0.0    + 0 0.0    + 0          0          0          0          0
3          0.0    + 0 0.0    + 0          0          0        284        103
3          0.0    + 0 0.0    + 0          0          0        284        103
4           5-B - 100LASL       EVAL-DEC76 G.HALE, L.STEWART, P.YOUNG
4           5-B - 100LASL       EVAL-DEC76 G.HALE, L.STEWART, P.YOUNG
5                               DIST-MAY79 REV1-JAN77            790518
5                               DIST-MAY79 REV1-JAN77            790518
6                                                                      cont.
     .
     .

File     : Resonance Parameter Data [2]
Type     : Resonance Information [151]

393        5.01000+ 3 9.92690+ 0          0          0          1          0
393        5.01000+ 3 9.92690+ 0          0          0          1          0
394        5.01000+ 3 1.00000+ 0          0          0          1          0
394        5.01000+ 3 1.00000+ 0          0          0          1          0
395        1.00000- 5 1.00000+ 4          0          0          0          0
395        1.00000- 5 1.00000+ 4          0          0          0          0
396        3.00000+ 0 4.02380- 1          0          0          0          0
cont.
     .
     .

File     : Neutron Cross Sections [3]
Type     : Total Cross Section [1]

399        5.01000+ 3 9.92690+ 0          0          0          0          0
399        5.01000+ 3 9.92690+ 0          0          0          0          0
400        0.0    + 0 0.0    + 0          0          0          2        386
400        0.0    + 0 0.0    + 0          0          0          2        386
.
.
.
```

Table 7 (continued)

```
File      : Neutron Cross Sections [3]
Type      : Elastic Scattering Cross Section [2]

532         5.01000+ 3 9.92690+ 0          0          0          0          0
532         5.01000+ 3 9.92690+ 0          0          0          0          0
533         0.0     + 0 0.0     + 0        0          0          1        368
533         0.0     + 0 0.0     + 0        0          0          1        368
534                368          2                                                ...
File      : Neutron Cross Sections [3]
Type      : Total Inelastic Cross Section [4]

659         5.01000+ 3 9.92690+ 0          0         99          0          0
659         5.01000+ 3 9.92690+ 0          0         99          0          0
660         0.0     + 0-7.17000+ 5         0          0          1        185
660         0.0     + 0-7.17000+ 5         0          0          1        185
...
File      : Angular Distributions of Secondary Neutrons [4]
Type      : Elastic Scattering Cross Section [2]

2322        5.01000+ 3 9.92690+ 0          1          1          0          0
2322        5.01000+ 3 9.92690+ 0          1          1          0          0
2323        0.0     + 0 9.92690+ 0         0          2        121         10
2323        0.0     + 0 9.92690+ 0         0          2        121         10
.
.
.
File      : Multiplicities for Photons (from neutron reactions) [12]
Type      : (n,g) Radiative Capture Cross Section [102]

2842        5.01000+ 3 9.92690+ 0          1          0         12          0
2842        5.01000+ 3 9.92690+ 0          1          0         12          0
2843        0.0     + 0 0.0     + 0        0          0          1          2
2843        0.0     + 0 0.0     + 0        0          0          1          2
2844                 2          2                                                ...

File      : Multiplicities for Photons (from neutron reactions) [12]
Type      : (n,al) Cross Section for 1st excited state [781]

2883        5.01000+ 3 9.92690+ 0          1          0          1       2883
 5.01000+ 3 9.92690+ 0          1          0          1          ...
.
.
.

File      : Cross Sections for Photons (from neutron reactions) [13]
Type      : Total Inelastic Cross Section [4]

2893        1.10000+ 6 5.50540- 4 1.20000+ 6 1.10000- 3 1.30000+ 6 1.79380- ...
.
.
.
```

Table 7 (continued)

```
File      : Angular Distributions for Photons (from neutron reactions) [14]
Type      : Total Inelastic Cross Section [4]

3348        5.01000+ 3 9.92690+ 0          1          0          13          0
3348        5.01000+ 3 9.92690+ 0          1          0          13          0
 cont table 7.
File      : Angular Distributions for Photons (from neutron reactions) [14]
Type      : (n,g) Radiative Capture Cross Section [102]

3350        5.01000+ 3 9.92690+ 0          1          0          12          0
3350        5.01000+ 3 9.92690+ 0          1          0          12          0

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

File      : Angular Distributions for Photons (from neutron reactions) [14]
Type      : (n,p) Cross Section [103]

3352        5.01000+ 3 9.92690+ 0          1          0           4          0
3352        5.01000+ 3 9.92690+ 0          1          0           4          0
.
.
.

File      : Angular Distributions for Photons (from neutron reactions) [14]
Type      : (n,al) Cross Section for 1st excited state [781]

3354        5.01000+ 3 9.92690+ 0          1          0           1          0
3354        5.01000+ 3 9.92690+ 0          1          0           1          0

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

File      : Data Covariance Matrices for Neutron Cross Sections [33]
Type      : Total Cross Section [1]

3357        5.01000+ 3 9.92690+ 0          0          0           0          1
3357        5.01000+ 3 9.92690+ 0          0          0           0          1
3358        0.0    + 0 0.0    + 0          0          1           1          0
3358        0.0    + 0 0.0    + 0          0          1           1          0
3359        0.0    + 0 0.0    + 0          0          0           0          0
3359        0.0    + 0 0.0    + 0          0          0           0          0
3360        1.00000- 5 2.00000+ 7          0          0           6          3
3360        1.00000- 5 2.00000+ 7          0          0           6          3
3361        1.00000+ 0 2.00000+ 0 1.00000+ 0 7.80000+ 2 1.00000+ 0 7.81000+
.
.
.
File      : Data Covariance Matrices for Neutron Cross Sections [33]
Type      : Elastic Scattering Cross Section [2]

3363        5.01000+ 3 9.92690+ 0          0          0           0          3
.
```

```
                                  R S I C   D A T A
MAT : 1305 NUCLIDE : B - 10          TAPE : 563
           LIBRARY : ENDF/B-V AMPX MOD NO. 3 OCTOBER 83
       AFFILIATION : LASL  EVALUATOR(S) : G.HALE, L.STEWART, P

 MF : 3     NEUTRON CROSS SECTIONS

        MT   SECTION                                          NO. OF RECORDS

        1     TOTAL CROSS SECTION                                  132
        2     ELASTIC SCATTERING CROSS SECTION                     126
        4     TOTAL INELASTIC CROSS SECTION                         65
        51    (N,N ) TO THE 1ST EXCITED STATE                       65
        52    (N,N ) TO THE 2ND EXCITED STATE                       59
        53    (N,N ) TO THE 3RD EXCITED STATE                       56
        54    (N,N ) TO THE 4TH EXCITED STATE                       51
        55    (N,N ) TO THE 5TH EXCITED STATE                       48

  F1:SHOW KEYS          F2:HELP          F7:ENTER QUERY        F8:EXEC.QUERY
S-F1:EXPLAIN ERROR     F10:COMMIT      S-F7:ROLLBACK        CTRL-Z:EXIT

     V  CHAR MODE: REPLACE  PAGE 1                          COUNT: *52
```

```
                                  R S I C   D A T A
MAT : 1305 NUCLIDE : B - 10          TAPE : 563
           LIBRARY : ENDF/B-V AMPX MOD NO. 3 OCTOBER 83
       AFFILIATION : LASL  EVALUATOR(S) : G.HALE, L.STEWART, P

 MF : 3     NEUTRON CROSS SECTIONS

        MT   SECTION                                          NO. OF RECORDS

        252   PSI, AVERAGE LOGARITHMIC ENERGY DECREMEN             30
        253   GAMMA, AVG OF THE SQUARE OF THE LOG. ENE             30
        700   (N,P0) CROSS SECTION                                 34
        701   (N,P1) CROSS SECTION FOR 1ST EXCITED STA             25
        702   (N,P2) CROSS SECTION FOR 2ND EXCITED STA             19
        703   (N,P3) CROSS SECTION FOR 3RD EXCITED STA             18
        780   (N,A0) CROSS SECTION FOR GROUND STATE                61
        781   (N,A1) CROSS SECTION FOR 1ST EXCITED STA             61

  F1:SHOW KEYS          F2:HELP          F7:ENTER QUERY        F8:EXEC.QUERY
S-F1:EXPLAIN ERROR     F10:COMMIT      S-F7:ROLLBACK        CTRL-Z:EXIT

     ^    CHAR MODE: REPLACE  PAGE 1                          COUNT: *52
```

Fig. 1. Two examples of Oracle tables as seen on the screen generated by the IAG.

INTERNAL DISTRIBUTION

1. S. J. Ball
2. H. R. Brashear
3. B. G. Eads
4-7. C. E. Ford
8. D. N. Fry
9. W. R. Hamel
10. N. A. Hatmaker
11. F. C. Maienschein
12. B. F. Maskewitz
13. D. W. McDonald
14. D. R. Miller
15. O. B. Morgan
16. C. A. Mossman
17. L. C. Oakes
18. P. J. Otaduy
19-23. R. Paviotti-Corcuera
24-27. R. B. Perez
28. G. de Saussure
29. D. K. Trubey
30. R. E. Uhrig
31. J. D. White
32. B. A. Worley
33. J. B. Ball, Advisor
34. P. F. McCrea, Advisor
35-36. Central Research Library
37. Y-12 Technical Reference Section
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