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NESSY, a relational PC database for nuclear structure and decay data

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Abstract: The universal relational database NESSY (New ENSDF Search SYstem) based on the international ENSDF system (Evaluated Nuclear Structure Data File) is described. NESSY, which was developed for IBM compatible PC, provides high efficiency processing of ENSDF information for searches and retrievals of nuclear physics data. The principle of the database development and examples of applications are presented.

Introduction

The Evaluated Nuclear Structure Data File (ENSDF) /1/ is now apparently one of the most complete nuclear structure and decay data bank. It contains the data for all known nuclides. Being produced and supported by the IAEA international cooperation with the main responsibility of the USA BNL National Nuclear Data Center, the ENSDF is permanently updated. The main accent in ENSDF preparation is on the experimental information, the only well known and reliable systematics or theoretical predictions are used for data evaluation. The contents and principles of preparation of ENSDF are described in details in /1-3/.

The most important characteristics from ENSDF are the following: for levels - excitation energy, spin, parity, half-life time (or total width), decay branching ratio, electric and magnetic moment; for gamma-transitions - energy, intensity, multipolarity, mixing ratio, for alpha- and beta-decays - energy and intensity. These data are published regularly in Nuclear Data Sheets and (for A $<$ 45) in Nuclear Physics compilations /4/.

Nevertheless there exists and being developed the software for data base kind operation with ENSDF. This one has an obvious advantages: fast search, the preparation of data files for future application in special software, the possibilities for networks etc. There are several directions of special ENSDF software development. The programs giving to one the possibility for obtaining the output information from the ENSDF in the form analogous to that of the Nuclear from the ENSDF in the form analogous to that of the Nuclear Data Sheets have been developed in the USA BNL NNDC. The NNDC On-Line Retrieval system is in operation from 1986. The special programs MEDLIST and RADLIST /1,2/ for medical applications are well known. The plans for 1994 on development of the Electronic Table of Isotopes for personal computer were announced /5/. The nuclear radioactive decay gamma-radiation characteristics data base was developed /6/ in Lund University and Institute of Technology (Sweden). The data library /7/ on the base of the ENSDF is known to be used as the bank of initial data for nuclear reaction model calculations. In /8/ we proposed the method for "fast developing" of specialized programs for the ENSDF operation. More than 15 programs were developed which gave the possibility to use the ENSDF for various fields of application including both basic research such as investigation of photonuclear reactions /9/ and applied research such as, for example, gamma-activational analysis /10/. Any of these programs were used for analysis of large number of data on spins, parities, and spectroscopic factors of nuclear levels from the ENSDF which gave us the possibility to predict several previously unknown spin values and evaluate the one-particle structure parameters for several nuclei /11,12/.

The cited list of works though not being complete illustrates one general feature of them. Each of programs mentioned above is intended for search only one kind information from ENSDF data bank. The appearing of new kind information needs means the necessity of new program developing. This software organization method can not be appreciated when the new needs appear relatively frequently.

The situation changed noticeably at last time. The high frequency personal computers (PC) dissemination, the development of data base management systems (DBMS) with advanced interface and convenient and power request languages allows to put the problem of creation of the universal data base (DB) on the base of the ENSDF. At bottom the point is in the ENSDF data adaptation to such DBMS in such manner that all possible requests to the ENSDF set were completely exceeded by the standard resources of DBMS.

This problem naturally is spread into several questions unstudied till now. Is it possible to transform the ENSDF initial tree structure to new one which is do for using under DBMS guidance on PC? What part of physically significant information would be lost after such transformation? What is the efficiency of modern DBMS working with such large (about 100 Mb) data volumes? For what degree the discussed system would be ready to future modifications and improvements?

The first experience of mentioned problems solving and discussed DB developing is described in present work.

The Brief ENSDF Description

Historically the ENSDF was developed as computerized "twin" of the Nuclear Data Sheets publications. This defined its structure certainly /1/.

So called "data set" corresponding to one scheme (or table) of levels and transitions from named edition is the basic structure unity of the file. Several data sets can exist for each nucleus, and each data set contains information on levels and radiations in this nucleus obtained from definite reaction or decay experiment with this nucleus as a final. Besides, there are the special data sets "Adopted Levels, Gammas" (one data set for one nucleus) in the ENSDF, and they may be considered as the "best" or evaluated properties of the nuclear levels or radiations.

The ENSDF is organized as a sequence of data sets for different nuclei and experiments, ordering by mass numbers A and charges Z increasing.

The inner organization of data set corresponds to the scheme of levels and transitions organization. Each data set consists of the individual ordered records. The first - "I" record - identifies the whole data set and corresponds to the scheme (table) headline. Each from following records consists of information on individual physical object - element of general scheme of nuclear states and transitions: "L" records contain ground and excited state characteristics, "G", "B", "E", "A" records - characteristics of the gamma-, beta-transitions, electron capture and alpha transitions correspondingly, "P" records - parent nucleus properties (if data set describes any decay), "Q" record - energy characteristics of the nucleus, "N" - normalization coefficient values.

Each of these records have own strictly keep format. For example, level energy value is placed in the fields from 10 to 19 from left in "L" record, energy uncertainty value is placed in the fields from 20 to 21, and so on for all values.

All records within any data set are in definite connections each to other in accordance with that ones between the individual physical objects - elements of nuclear levels and transitions scheme. For example, if any gamma-transitions can discharge some definite excited states, it means that corresponding "G" records are strictly connected with definite "L" records. The same situation is in records for transitions populating definite levels - "A", "B", "E" records. At the same time, "N", "Q", "P" records are concerned to the whole data set directly.

Therefore the different type records form an hierarchical structure in the ENSDF. This fact is reflected on Fig.1. The first level of the hierarchy consists of "I" records - data set headlines. The next level - of "N", "Q", "P" and "L" records. Also "G", "B", "E", "A" records are on

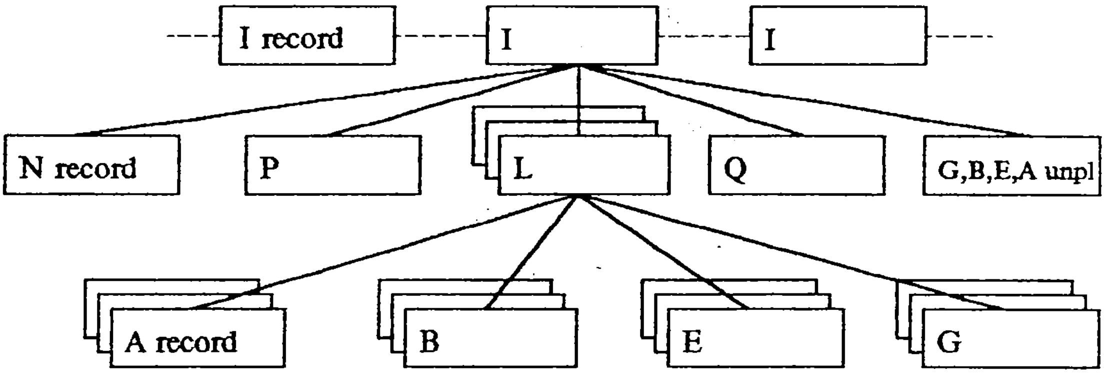

Fig.1. The ENSDF records hierarchy.

this level if they describe transitions unplaced in scheme. The "G", "B", "E", "A" records for transitions from definite nuclear states or on these ones form the third level of the hierarchy.

It must be noted that this hierarchical structure of the ENSDF is realized by ordering of the different types records in the file. The fact that the ENSDF has sequential organization plays important role here. For instance, "G" record must follow the "L" record for the level from which the gamma-transition occurs. Therefore the position of any record in the ENSDF namely carries quite important information. In this connection under any ENSDF transformation one must solve the problem of the conservation of the hierarchical connections between different records.

The information on the some record types is omitted in this description: text comments, continuation and references decoding records, and so on. The reason is that these type records are not included to the system which will be described below at the present time; it's planed to do in the further stage.

Data Base Management System PARADOX

The data base management system PARADOX (trade mark registered by Borland International) was chosen as a program tool for new universal data base on decay and structure of nuclei. This choice was determined by two principal factors. At first, this DBMS is known to be quite fast for great data volumes (at present time the version 4.0 is declared to be the most fast in this class). At second, the PARADOX has an advanced interface and a powerful query language named QBE (Query By Example).

Like a majority of DBMS intended for PC with similar characteristics, the PARADOX realizes the relation data model, according to which the same-type-data are organized as same- type-tables. To construct the query in the PARADOX one should enter to the screen representation of the corresponding table that value that is to be founded. The operations +, -, *, /, <, >, = are proper for numerical fields, the context searching - for character ones, and the logical constructions - for all types of fields. The constructed query can be saved as the file with the name, and new queries can be constructed on the base of old ones by means of the redactor.

The Constructing of the Relation Data Base Using the ENSDF Information

To construct the universal relation data base on structure and decays of the nuclei one must combine relation data base management system (in considered case - the

PARADOX) and the ENSDF information. For this one must transform the original file to the management system adaptable presentation. The preservation of the hierarchical relations in the original file is an important condition of this transformation. Because of a table is the structure unit of any relation DB, and the ENSDF data set is an ensemble of ordered different kinds records, the task of constructing of the necessary data tables on the base of the existing data sets become the main.

To solve this task the whole original file ENSDF (the complete set of information for all nuclei) was decomposed on the groups of the records of the same kind, i.e. "I", "L", "G", "Q" records and others. Because of having the same format, such records being placed "each under other" compose the corresponding table automatically. The fragment of the "L" table obtained via all "L" records extracting is shown on the Fig. 2. After this decomposing the information from the ENSDF appears as set of tables "I", "L", "G", "Q" etc. It is clear that without special actions the information on the places of records in the original file which is responsible for hierarchical connections may be lost.

To conserve this hierarchy the special key system was developed. All records of each table were numbered. For each record the number assigned was declared as "own" record key. Besides the "senior" keys were introduced for each record - one or several. The "senior" key of any record is the own key value of the hierarchically higher level corresponding to this record. For example, "L" record has own L-key. At the same time, this record has I-key to be equal to own key value (the number) of the "I" record identified the data set contained this "L" record (generally, all records of the same data set have the same I-key values). Any gamma-decays from this level (i.e. any "G" records correspond to this "L" record) have assigned L-keys equal to L-key of this "L" record (together with own G-key). The record hierarchy recovered in this way is illustrated on Fig. 3.

It must be pointed out that the original ENSDF records of several types were not included in new system on the present stage of job: comments "C", continuations, references decoders "R", delayed particles "D". The problems arise because of considerable complexity and large size of the commentary records at first, and, at second, of absence of hard format for the continuation records.

The Work of the Universal Relation Nuclear Structure and Decay Data Base

The ideas stated above were applied in the MSU INP CDFE (the Centre for Photonuclear Experiments Data of the Institute of Nuclear Physics of the Moscow State University) for the constructing of the NESSY (New ENSDF Search System) - the relation nuclear structure and decay data base

Mass	Symb	Energy	D(E)	Spin & parity	Half-life	D(H-l)	Ang m	S s	D(S s)	Fl	Isom	S?
44	SC	0.00		2+	3.927 H	8						
44	SC	67.85	.04	1-	153 NS	2						
44	SC	146.25	.05	0-	49 US	2						
44	SC	234.70	.20	2-	6.1 NS	2						
44	SC	271.13	.11	6+	2.442 D	4					M	
44	SC	349.84	.09	4+	3.1 NS	2						
44	SC	424.77	.08	3-	0.38 NS	4						
44	SC	531.50	.20	3	35 NS	LT						
44	SC	630.94	.13	4-	0.40 NS	3						
44	SC	666.70	.40	1+	49 FS	14						
44	SC	763.10	.40	3+	0.22 PS	4						
44	SC	829.00	2.00									?
44	SC	968.20	.30	(5,6,7)+	3.5 PS	LT						
44	SC	986.70	.40		1.4 PS	6						
44	SC	1006.30	.40	(3,4-)	35 NS	LT						
44	SC	1050.00	2.00	(3,4,5)+	0.17 PS	6						
44	SC	1142.00	5.00									?
44	SC	1185.80	.60	3+	39 FS	13						
44	SC	1197.44	.12	(4+,5-)	35 NS	LT						

Fig. 2. Fragment of "L" table, composed from "L" records of ENSDF.

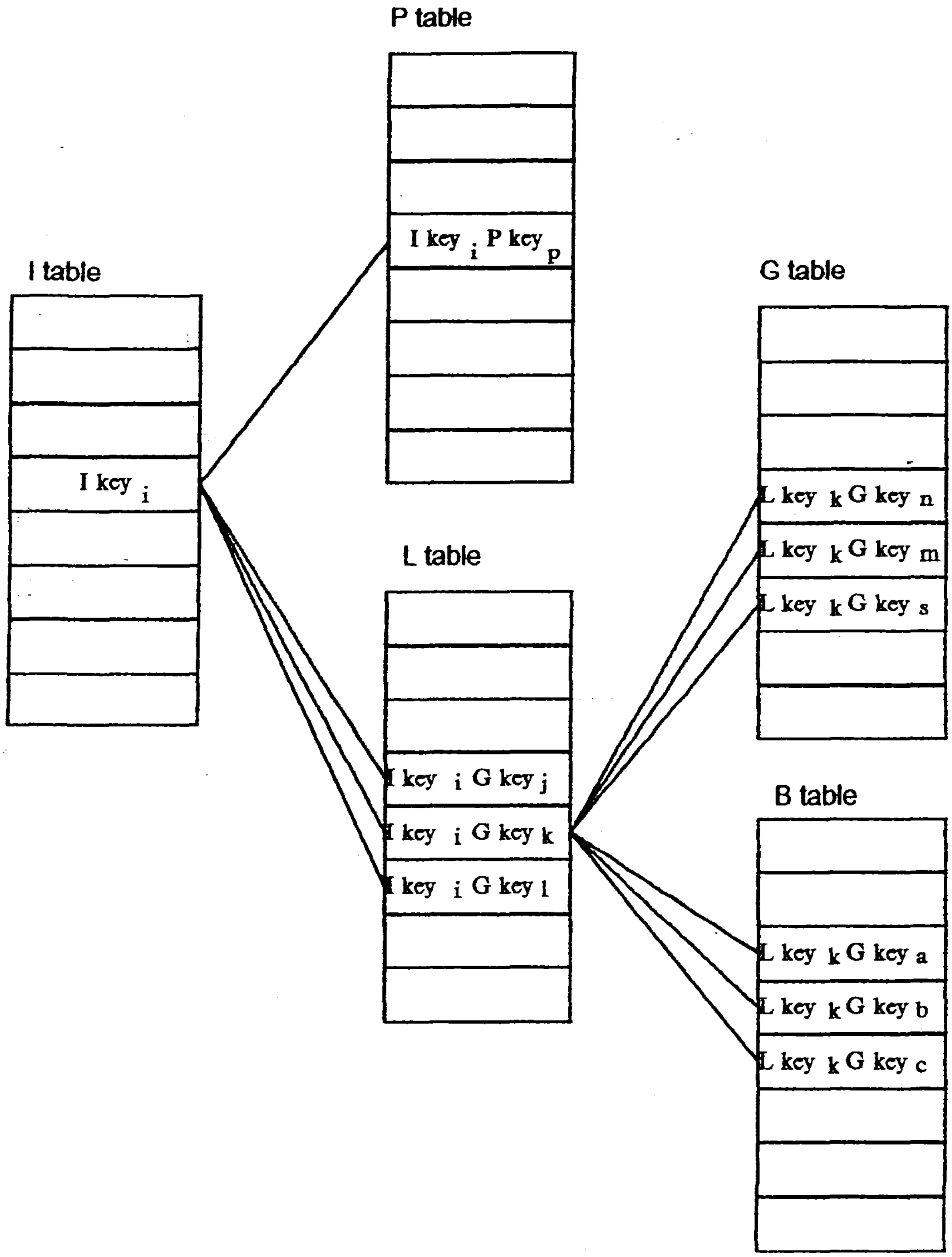

Fig.3. Relations between the tables.

intended for IBM/PC based on the ENSDF and the PARADOX combination. The special codes were developed for the original file information reorganization and the data import to the PARADOX system.

The data search in the PARADOX may be carried out for contents of any table fields presented in the system. This means that any physical values presented in the ENSDF can be the object of searching, and any demands can be specified for these values.

Like this, any of the table fields from information substance satisfied to the search conditions can be given out at the system exit. This means the possibility of the giving out the any data from ENSDF corresponding to query criteria.

THE QUERY FOR SINGLE TABLE. The most simple kind of query is that for single table, because in this case both query demands and leaded out values correspond to the same physical object - i.e. levels, gamma-rays etc.

For example, for the following query:

" Nuclear levels must be found with:

- positive parity;
- excitation energy more than 10 MeV;

and the following output information must be given:

- the nucleus (Z,A) which has such levels;
- excitation energy values of each of such levels;
- spin and parity values of each of such levels"

the result is presented on Fig. 4. The time of operating this query is about 40 sec. on the PHILIPS P3370 (IBM/PC 386, 33 MHz).

THE QUERY FOR SEVERAL TABLES. The system of keys described above is used to specify the query on information from several tables: in this case the demands of the identity of the corresponding keys are stated. For example, having any characteristics of parent states (P table) as entry we can obtain the characteristics of levels and gamma-rays observed in decays of these states (L and G tables) or decay modes (I table) as exit. In particular, the possibilities of this system allow to restore the full scheme of levels and transitions for any nucleus and data set, i.e. restore the initial original ENSDF structure for individual data set (Fig. 5). This means that adopted conception of keys really preserves all connections between the individual ENSDF records, and hence, the whole information contained in the ordering of the ENSDF records is preserved.

The powerful possibilities of the NESSY can be illustrated by examples of it's application in the MSU INP CDFE to the solving of two data search tasks related with concrete nuclear physics problems.

CONCRETE NUCLEAR PHYSICS PROBLEMS. NUCLEAR ECOLOGY. It was necessary to follow the decay chains of every

Mass	Symb	Energy	Spin & parity
36	AR	10319	2+
36	AR	10439	2+
36	AR	10558	2+
36	AR	10593	2+
36	AR	10613	1+,2+,3+
36	AR	10858	0+
36	AR	11027	3+
36	AR	11050	2+
36	AR	11222	1+,2+,3+
36	AR	11639	1+,2+;3+_
39	AR	11312	1/2+
40	CA	10271	(3,4,5)+
40	CA	10321	1+
40	CA	10544	2+
40	CA	11418	4+
40	CA	11974	0+
41	K	10190	1/2+
42	CA	14700	0+
43	CA	10485	1/2+
46	TI	12460	0+
46	TI	14153	0+
47	CA	10056	3/2+,5/2+
47	CA	10056	5/2+
47	CA	10182	3/2+,5/2+
47	CA	10182	5/2+
47	CA	10302	3/2+,5/2+
47	CA	10302	5/2+
47	CA	10358	3/2+,5/2+
47	CA	10358	5/2+
47	CA	10431	3/2+,5/2+
47	CA	10431	5/2+
47	CA	10485	3/2+,5/2+
47	CA	10485	5/2+
47	CA	10581	3/2+,5/2+
47	CA	10581	5/2+
47	CA	10640	3/2+,5/2+
47	CA	10640	5/2+
47	CA	10680	3/2+,5/2+
47	CA	10680	5/2+
47	CA	10765	1/2+
47	CA	11003	3/2+,5/2+
47	CA	11003	5/2+
47	CA	12730	1/2+
47	CA	12737	1/2+

Fig. 4. Fragment of the NESSY answer; see the text for query.

Levels and Gamma Rays of 44 SC from ADOPTED LEVELS, GAMMAS
Page 1

Energy	D(E)	Spin & parity	Half-life	Isom	S?	Energy-G	D(E)-G	Rel intens	D(R i)	Multipol	Mix ratio	Coin p	Coin f	Energy - Energy-G
829.00	2.00				?	479.20								349.80
						829.00								0.00
763.10	.40	3+	0.22 PS			528.40		7.5	22E-1					234.70
						763.10		100.0	22E-1	M1(+E2)	+0.06			0.00
666.70	.40	1+	49 FS			666.70		100.0		M1(+E2)	+0.09			0.00
630.94	.13	4-	0.40 NS			206.17		18.8	21E-1					424.77
						281.10		100	5	E1(+M2)	+0.02			349.84
						396.24		90	5	E2(+M3)	-0.02			234.70
531.50	.20	3	35 NS			181.66		4.1	21E-1					349.84
						296.80		100	4	D(+Q)	+0.02			234.70
						463.65		20	4	Q(+O)	-0.02			67.85
						531.50		80	4	D(+Q)	+0.04			0.00
424.77	.08	3-	0.38 NS			190.07		45	4	M1(+E2)	-0.02			234.70
						356.92		100	4	E2(+M3)	0.00			67.85
						424.77		28	4	E1(+M2)	-0.03			0.00
349.84	.09	4+	3.1 NS			349.84		100.0		E2(+M3)	+0.01			0.00
271.13	.11	6+	2.442 D	M		271.24	10E-3	100.0		(E4)				-.11
234.70	.20	2-	6.1 NS			88.45		2.9						146.25
						166.85		45	3	M1(+E2)	-0.02			67.85
						234.70		100	3	E1(+M2)	0.00			0.00
146.25	.05	0-	49 US			78.38	4E-2	100.00	3E-2	(M1)				67.87
						146.23	6E-2	0.10	3E-2					.02
67.85	.04	1-	153 NS			67.85	4E-2	100.0		E1(+M2)	0.01			0.00
0.00		2+	3.927 H											

Fig. 5. The tables obtained by means of the NESSY to be analogous the scheme of the levels and gamma transitions. The left part describes levels properties, the right - transitions ones. The last column corresponds to levels populated by which transition.

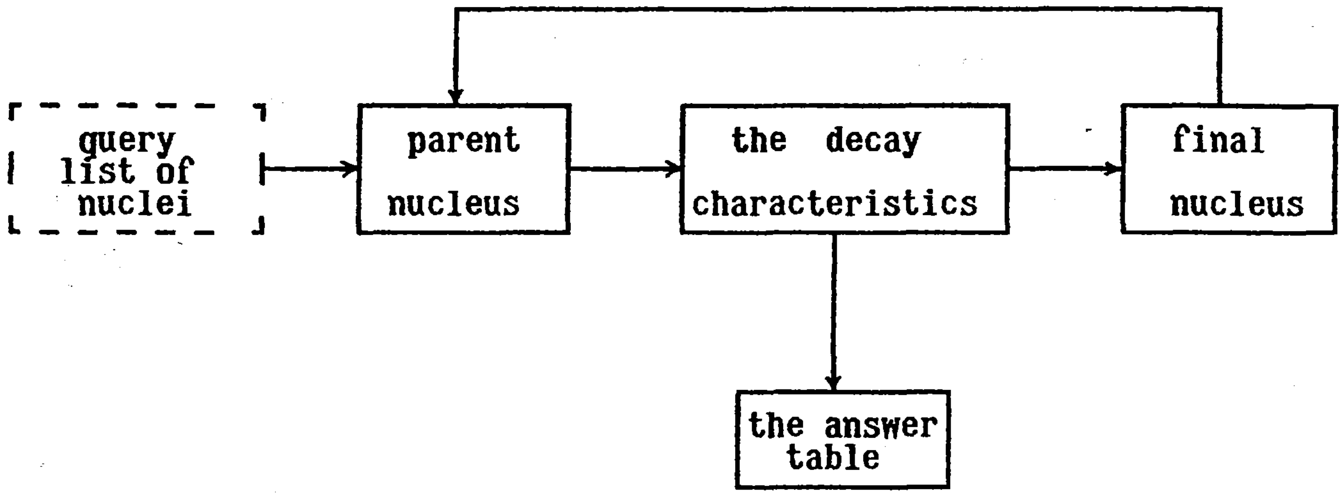

Fig. 6. The NESSY query system for the obtaining
the nuclear decay full chains.

radioactive isotope pointed out (about 250 nuclides) and indicate decay mode and final nucleus and half-life time and branching ratio values for every decay. Since the final nucleus of the majority of decays can be the parent one for next decay, the "query chain" scheme was realized. The appearance of any stable isotope as a final means a stop point for every query chain. The "query chain" scheme is presented on Fig. 6. The result table for the case described contained information on about 500 elementary decays.

ATOMIC POWER STATION WASTE UTILIZATION. For the mathematical modelling in this field the data on specific nuclei was required and the following demands were specified:
- to indicate all levels with known gamma-decays so that the sum of intensities for every level to be equal to 1;
- to find and to indicate all metastable states;
- to determine if radioactive decays of the nucleus exist (both for ground and excited states), and if that do, indicate their modes, half-life times and the average excitation energy of the final nuclei;
- to give up the most complete listing of such states. To solve this task the special sequence of the elementary queries for the NESSY was developed and the information requested was obtained for large number of nuclides.

Moreover, the NESSY allows as particular cases to solve the tasks for which the specialized systems were developed earlier. So for example, "The ENSDF Radioactivity Data Base" /6/ mentioned above ensures the realizations of following tasks: (i) to give out the radioactive decay gamma-lines with energies closest to pointed out ones; (ii) to give out the full listing of the gamma-lines observed at the decay pointed out. It is clear that the NESSY ensures these possibilities by operating of two ordinary query tasks for G and I tables with condition of the connection between them by means of I-key.

In general, the first experience of the NESSY using testifies that it is certainly the very powerful and convenient tool for both fundamental and applied research in wide range of science and technology.

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