21 June 1991

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From: H.D. Lemmel

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Data Centers Network which I presented at the Nuclear Data Conference in
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THE NETWORK OF THE NUCLEAR REACTION DATA CENTRES

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Abstract: Nine Nuclear Reaction Data Centers co-operate in the maintenance of international databases of experimental and evaluated nuclear reaction data for incident neutrons, charged particles and photons in order to satisfy the nuclear data needs in various fields of science and technology. The status of these databases is reviewed, and the services that scientists may obtain from the data centers are described. Emphasis is given to the current problems confronted by the data centers.

For more than 20 years national and regional nuclear data centers co-operate in the compilation of internationally available nuclear data libraries, to the effect that

- data obtained in a given country are made available speedily to data users in all countries;

- data are available world-wide in uniform computerized formats for which data-processing computer codes are also provided;

- data handbooks are produced from the international data files for the convenience of data users;

- for some more important nuclear data, international standard reference values have been established with high precision.

This has been achieved by a joint effort of nine nuclear reaction data centers co-ordinated by the IAEA Nuclear Data Section under the guidance of the International Nuclear Data Committee.

For the existing nuclear data centers and their acronyms see table 1.

The nuclear data centers provide an essential service required for pure and applied nuclear science and technology. The co-operation of the nuclear data centers can be considered as a model for various other scientific disciplines (such as materials properties data) for which similar international databases do not yet exist.

Unfortunately, the continuing high quality of the data center services is now seriously endangered due to repeated budget cuts or changing work priorities of the data centers involved. This has the consequence that

- the updating of some of the databases will be less complete and less speedy than it used to be;

- there are new data requirements which cannot be taken care of by the staff available at the existing data centers (such as medium energy nuclear reaction data for research on actinide burning in accelerators and for medical applications and radiation damage in space technology; or nuclear activation reactions for a large number of isotopes occurring in nuclear waste or in fusion technology; or charged particle reaction data for various scientific and industrial applications);

- database software maintenance and development will become increasingly inadequate, thus reducing the speed and efficiency of retrievals; notably there is only slow progress at most centres in the development of an effective system of on-line access.

Complete, speedy and reliable nuclear data center services can be continued only,

- if the gradual decrease in data center support is reversed,

- and if additional data center manpower is granted either by additional staff at the existing centers or by the creation of new specialized data centers within the co-ordinated data center network.

Table 1. List of Cooperating Nuclear Reaction Data Centers

Code	Address	Type of Data Compiled
CJD	USSR Nuclear Data Center, Fiziko Energeticheskij Institut, Obninsk, Kaluga Region, USSR	Neutron reaction data
NDS	IAEA Nuclear Data Section P.O. Box 100, A-1400 Vienna, Austria DATEX-P 2322 Host ID 6221047 TYMNET 2329 Host ID 11507701 EARN/BITNET: "RNDS@IAEA1"	Neutron reaction data and others
NEADB	NEA Data Bank, F-91191 Gif-Sur-Yvette, France EARN/BITNET: "DBMAIL@FRNEAB51" TRANSPAC (PSN): (0)208 - (0)or(1)91040946 (Username: NEADB) PHYSNET/HEPNET: Decnet node address 32.9	Neutron reaction data
NNDC	US National Nuclear Data Center, Brookhaven National Laboratory, Upton, N.Y., U.S.A. 11973 BITNET "NNDC@BNL"	Neutron and charged particle reaction data
CAJaD	Center for Nuclear Structure and Reaction Data of the USSR State Committee on the Utilization of Atomic Energy, I.V. Kurchatov Institute of Atomic Energy Moscow, USSR	Charged particle reaction data
CDFE	Center for Photonuclear Experimental Data Nauchno-Iss. Inst.Yad.Fiz., Moskovskiy Gos. Unviersitet Leninskiye Gory, Moscow, USSR	Photonuclear data
CNDC	Chinese Nuclear Data Center, Institute of Atomic Energy P.O. Box 275, Beijing, People's Republic of China	Neutron and charged particle reaction data
RIKEN	Nuclear Data Group, RIKEN Institute of Physics and Chemistry Research, Wako-Shi, Saitama, Japan 351-01	Charged particle reaction data for medical radioisotope production
Study Group	Japanese Nuclear Data Study Group, c/o Dr. M. Chiba, Hokkaido University, Computing Center Kita-11 Nishi-5, Kita-Ku Sapporo 060, Japan	Differential charged particle reaction data

The following center has made significant contributions in the past but was discontinued:

KaChaPaG	Karlsruhe Charged Particle Group Federal Republic of Germany	Charged particle reaction data

The following centers are not formal members of the network but contributed important comprehensive evaluated data files:

JAERI	Nuclear Data Center, Japan Atomic Energy Research Institute, Tokai-Mura, Naka-Gun, Ibaraki-Ken 319-11 Japan	Evaluated neutron reaction data
LLNL	Nuclear Data Group, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94550 U.S.A.	Evaluated neutron, photon and charged particle reaction data

and
others

1. Data center services:

The following centers should be contacted for data retrievals, copies of data libraries, related documents and data processing computer codes, depending on the geographical location:

CJD - USSR; (resp. CAJaD in case of charged particle and photonuclear data);
NEADB - OECD countries in Europe and Japan;
NNDC - USA and Canada;
CNDC - the People's Republic of China (services being developed);
NDS - all other countries.

Of these, NEADB and NNDC offer on-line computer services via telephone and computer networks such as HEPNET or INTERNET. Included are the CINDA, EXFOR, and evaluated nuclear data files. Additionally, the two centers also offer on-line access to the Nuclear Structure References and ENDSF data files. Contact the appropriate center for more information (see Table 1). At the other centers on-line services are so far only in a preparatory stage. The services of the centers are advertised by means of newsletters [1].

Whereas the dissemination of data to customers upon their request is concentrated at the above centers, the data compilation and the production of evaluated data files involve contributions from various additional centers and research groups.

2. Neutron reaction data:

CJD, NEADB, NNDC and NDS co-operate in the following projects.

2.1 WRENDA [2]

This is a computer produced periodical document which lists (mostly) neutron nuclear reactions for which adequate data are missing or where existing data have insufficient accuracy to meet the requirements in the physics of fission and fusion reactors and nuclear material safeguards. The requests included have been reviewed by official bodies such as national or international nuclear data committees.

2.2 CINDA

This is a bibliographic index to the literature and numerical databases on microscopic neutron data. The centers maintain a computer file from which selective retrievals are available. CINDA handbooks are published annually by IAEA [3]. The present file has 240 000 entries. The unique feature of CINDA compared to other bibliographies is that references referring to the same data set are blocked together, and that superseded references are either labelled as such or omitted from the published book, thus avoiding "noise" in retrievals.

2.3 EXFOR [4]

This is a world-wide comprehensive compilation of experimental neutron reaction data, containing about 50 000 data sets for 600 nuclides in 4 million records (=320 Megabytes). It includes not only the numerical values but also detailed information on the measurement method and data uncertainty analysis. In particular, EXFOR includes data
- that have not been published in numerical form,
- and data that supersede published values.

Reliability and accuracy are ensured as far as possible through a combination of measures: the soliciting of large files of experimental data either on tape or by electronic mail directly from the experimentalist, the use of rigorous checking programs, and where possible the approval by the author or experimentalist concerned of the EXFOR proof copy.

For a set of published handbooks on experimental neutron reaction data see [5].

The EXFOR database of experimental data is the basis for the development of evaluated data libraries with "best" values for all neutron nuclear reactions.

2.4 ENDF - evaluated data [6]

Except for selected standard reference data, there is not yet one universal file with recommended best neutron cross-section values. Different data libraries with often disagreeing numerical values are used in different countries. However, all these data libraries are now in the internationally recognized ENDF format [7]. The following comprehensive evaluated neutron data libraries exist at present, containing data for 411 elements or isotopes [8]:
- BROND (USSR), 94 elements/isotopes [9]; BROND-2, 163 elements/isotopes, being presented at this conference;
- ENDF/B-VI (USA), 320 elements/ isotopes [10];
- JEF-1 (NEA), 303 elements/isotopes [11]; JEF-2 has been prepared but its availability at present is restricted to users within the NEA Data Bank community;
- JENDL-3.1 (Japan), 324 elements/ isotopes [12].

Partly, these data libraries complement each other: an isotope not contained in the one library may be included in the other. In general, these data libraries satisfy most of the data needs. But continuing work is required in many areas:
- Discrepancies among the data libraries must be analyzed in order to decide, which data of which library may be the best choice for a given nuclear reaction.
- A large number of reactions, in particular neutron activation cross-sections required for applications in nuclear fusion, nuclear waste disposal, reactor decomissioning, etc., are not yet contained in any of the four major evaluated data libraries.

Data evaluation activities are reported in an international newsletter [13], and the

evaluation efforts in OECD countries are coordinated by a newly established working group on evaluation cooperation.

2.5 ENDF data processing codes

The ENDF-formatted data files are accompanied by data processing computer codes [14] by which the original ENDF formatted data files can be transformed to other formats, in particular multigroup formats required as input to application codes. This includes processes like interpolation, avaraging, graphical plotting, and specifically the reconstruction of cross-section data from the resonance-parameter data.

In some respects the complexity of the new data files presents problems, especially for the user with more modest computer resources at his disposal. For example, pointwise cross-section generation from parametric files containing many hundreds of resolved resonances will inevitably incur long run times and produce voluminous output files [15]. Clearly there is a need for improved and more user-friendly data handling codes, capable of sifting the vast amounts of data present in these original libraries and producing optimized files tailored to specific applications.

2.6 Standard reference data

So far, there are only a few neutron data areas where internationally recommended values exist. These are
- Standard cross-sections for nuclear measurements, i.e. the ENDF/B-VI standards file [16];
- IRDF-90, the international reactor dosimetry file containing recommended values of neutron activation cross-sections for selected materials used for reactor neutron dosimetry by foil activation [17];
- Actinide decay data [18];
- X-Ray and Gamma-ray standards for detector efficiency calibration [19].

2.7 Specialized neutron reaction data libraries

In addition to the ENDF-formatted evaluated data libraries for general application (see item 2.4 above), there are many specialized evaluated neutron data libraries [20] available from the nuclear data centers. Space limitations permit only a few examples to be quoted here:
- JEF-1 Thermal Neutron Scattering Law Library [21];
- Chinese Evaluated Fission Product Yield Library [22];
- UKFY2, new evaluated library of fission product yields from UK [23];
- JNDC-FP2, the fission product nuclear data library of the Japanese Nuclear Data Committee, including data for yields, decay data and neutron cross-sections of fission product nuclei [24];
- USSR Evaluated Nuclear Data Library for Neutron Activation Analysis [25].
- USSR Fast Neutron Activation Cross-section file ACTIV87 [26].

Data compilations for special applications are also issued as handbooks [27, 28, 29].

3. Charged-particle reaction data

Some of the data centers (see Table 1) are specialized in the compilation of charged-particle and heavy-ion reaction cross-sections or in photonuclear data in the international EXFOR format. For an index to the data already compiled see [30].

Due to lack of manpower, a systematic compilation to a similar degree of completeness as for neutron data has not yet been possible. Special emphasis is given to
- charged-particle induced neutron source reactions [31];
- cross-sections used as proton beam monitors [32], specifically for radioisotope production [33];
- cross-sections for the production of radioisotopes for medical applications [34];
- (α,n) reactions for selected materials [35];
and others. The existing data compilations are still incomplete and evaluated data files with recommended values are seriously lacking for many applications. The creation of additional specialized data centers embedded in the international data center network is required in order to be able to provide the scientific community with reliable nuclear data for applications. This is particularly needed for intermediate energy data and for medical application data.

The ENDF format originally developed for neutron reaction data has been widened to include also evaluated data of charged-particle induced reactions. A first demonstration file has been produced for neutron and proton reaction data up to 1 GeV for Fe-56 [36].

4. Photonuclear and photo-atomic reaction data

For photonuclear data a report series [37] is issued by the USSR Photonuclear Data Center in Russian and English, containing partly bibliographic compilations, partly data compilations on selected topics such as photofission.

Numerical photoneutron data and selected other photonuclear reaction data have been compiled in EXFOR [4, 30]. For photo-atomic interaction data see
- the ENDF/B-VI Photon Interaction Data Library [38],
- XCOM, a PC database for various photon cross-sections in any element or chemical compound [39].

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The Network of the

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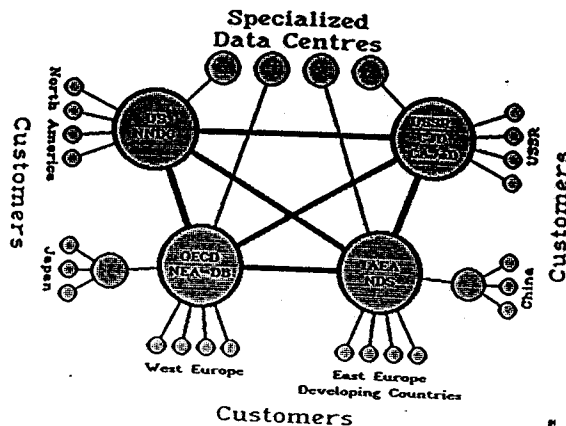IAEA NUCLEAR DATA SECTION, P.O. BOX 100, A-1400 VIENNA

	NEUTRON DATA	C.P. DATA
DATA NEEDS	WRENDA	(meeting proceedings)
DATA INVENTORY	CINDA	(CP-BB discontinued) (NSR)
EXPERIMENTAL DATA	EXFOR (complete)	EXFOR (incomplete)
EVALUATED DATA	general: ENDF/B-6 JEF-2 JENDL-3.1 BROND-2 CENDL	special: many libraries more are needed	few special libraries N-source ECPL
INTER-NATIONALLY RECOMMENDED DATA	—	EG Stand. IRDF-90 Actinides γ standards	—

The main Nuclear Data Centres

" E X F O R   a g r e e m e n t "

NNDC   USA, Canada

NEA-DB   OECD countries in Europe
              and Japan

CJD/CAJaD   USSR

IAEA NDS   all other countries

CNDC   China

Specialized Nuclear Data Centres

KaChaPaG   (discontinued)
              charged particle data

RIKEN   charged particle
              reaction data for
              medical radioisotope
              production

Study   differential charged
Group   particle reaction data

CDFE   photonuclear data

Achievements

* worldwide co-ordination of compilation and evaluation of nuclear data

* general availability of nuclear data files as an essential service for pure and applied nuclear science and technology

* uniform data file formats: EXFOR for experimental data ENDF for evaluated data

* data processing computer codes

* international standard reference data with high precision

* nuclear data handbooks

Manpower shortage

* updating of databases will be less complete

* improvements needed in
  - database software development
  - user-friendly on-line access

* new data needs not adequately covered:
  medium energy data for
  - actinide burning
  - medical applications
  - space technology
  nuclear activation reactions
  - in nuclear waste
  - in fusion technology

>>> additional staff required in
  - existing data centers
  - new specialized data centers

The Products

W R E N D A
lists data with insufficient accuracy for applications

C I N D A
bibliography and index to numerical databases

E X F O R
comprehensive compilation of experimental nuclear data
  - neutron reaction data
  - fission product yield data
  - charged particle reaction data
  - heavy ion reaction data
  - photonuclear data

Products (cont'd)

E N D F
comprehensive evaluated data files
  - neutron reaction data
    - photon production data
    - double differential data
    - uncertainty/covariance data
  - thermal neutron scattering law
  - fission product yield data
  - nuclear decay data
  - photon interaction data
started:
  - charged particle reaction data
  - medium energy data

      B R O N D - 2
      C E N D L - 2
      E N D F / B - VI
      J E F - 2
      J E N D L - 3.1

ENDF data processing codes

Products (cont'd)

Standard reference data
  - ENDF/B-VI standards
  - IRDF-90 international reactor dosimetry file
  - actinide decay data
  - X-ray and gamma-ray standards for detector efficiency calibration

Specialized nuclear data libraries
  - fission-product data for decay heat calculations
    - JNDC-FP2
    - UKFY2
    - Chinese FP library
  - neutron activation cross-section
    - several data libraries
  - activation analysis
    - USSR NAA library
  - charged particle induced neutron source reactions
    - DROSG
>>>many more are needed!!!

Handbooks