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Proprietary, Standard, and Government-Supported Nuclear Data Bases

by

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PROPRIETARY, STANDARD, AND GOVERNMENT-SUPPORTED NUCLEAR DATA BASES

by

C. G. Poncelet, Odelli Ozer, and D. R. Harris

ABSTRACT

This study presents an assessment of the complex situation surrounding nuclear data bases for nuclear power technology. Requirements for nuclear data bases are identified as regards engineering functions and system applications for the many and various user groups that rely on nuclear data bases. Current practices in the development and generation of nuclear data sets are described, and the competitive aspect of design nuclear data set development is noted. The past and current role of the federal government in nuclear data base development is reviewed, and the relative merits of continued government involvement are explored. National policies of the United States and other industrial countries regarding the availability of nationally supported nuclear data information are reviewed. Current proprietary policies of reactor vendors regarding design library data sets are discussed along with the basis for such proprietary policies. The legal aspects of protective policies are explored as are their impacts on the nuclear power industry as a whole. The effect of the regulatory process on the availability and documentation of nuclear data bases is examined. Current nuclear data standard developments are reviewed, including a discussion of the standard preparation process. Standards currently proposed or in preparation that directly relate to nuclear data bases are discussed in some detail. Obstacles to achieving standard nuclear data bases are reviewed, particularly the technical difficulties encountered in developing soundly based data sets that perform well when compared with integral observations. The benefits accruing from the establishment of nuclear standards are discussed, as are the probable impacts on user groups of the adoption of nuclear data base standards. Issues raised in the context of the study are highlighted, and some recommendations are made regarding the roles of government and industry, regarding data protection and availability, and regarding standards in relation to nuclear data bases. In particular, it is recommended that National Standard nuclear data sets, including both basic evaluated nuclear data and design multigroup data sets, be developed and made available for use by all segments of the nuclear power effort.

I. INTRODUCTION

A. Objective

Any large technological program, such as the U. S. nuclear power program, requires for its successful development and implementation the establishment and general acceptance of adequate data bases. Ideally, these data bases should be as comprehensive and accurate as are required to provide reliable foundations for the engineering and scientific disciplines relevant to the program. In practice, however, the data bases at any particular time are imperfect, and these imperfections can have important consequences to the development of the program. Strategems devised to accomodate known or suspected imperfections in the data bases also can affect hardware design as well as the planning methods that are devised to achieve the technology. Because of the considerable benefits resulting from use of adequate data bases it is not surprising that substantial efforts have been directed to data base development. It is also not surprising that the expenditure of these efforts has been paralleled by the growth of policies, such as proprietary and classification policies, and of procedures, such as quality assurance procedures and the definition and use of standards, that are intended to increase benefits from the data base development.

It is the objective of this study to provide a description and an assessment of policies and procedures relevant to the development and utilization of nuclear data bases for the U. S. nuclear power program. Nuclear data bases for the fission reactor and related industries will be discussed most fully, but because of the impact of government-supported activities on nuclear data base development and utilization it is necessary to consider nuclear data base development for the nuclear weapons program and for the embryonic fusion reactor area as well. The aim of the study is to be primarily descriptive and informative in nature, while providing a general overview, or synthesis, of the situation. However, issues are identified and tentative recommendations are made here on the basis of the overall assessment.

B. Data Bases for the Nuclear Power-Related Industries

Nuclear power technology consists of a highly complex and sophisticated mix of many disciplines, some traditional and some relatively new and unique. Important data bases that support nuclear power technology can be identified as follows, where the list is not meant to be complete, but merely representative:

-- nuclear data
-- materials properties and behavior
-- coolant and fluid chemistry data
-- thermodynamic and thermofluid properties
-- component failure rates
-- geological, socio-economic and related impact data

The relative state of development and importance of each of these data bases to the technology varies from one to another, and has changed in time since the early development of the nuclear field. For example, development of a reasonable nuclear data base was of overwhelming importance to the early demonstration of fission reactor feasibility. In the current state of the art, other data bases, such as those related to materials and to coolant and fluid chemistry, are probably at a more critical state of development than the nuclear data base for the safe, reliable, and economic implementation of nuclear power technology.

The present study is limited to the nuclear data base. Such a limitation in scope is obviously dictated by the vastness of the subject. However, there are additional reasons for focusing on this particular data base. The nuclear data base is unique to nuclear power technology. The nuclear data field is well documented and has reached a state of relatively high sophistication, partly as a result of the large amount of government funds that have been expended in the field. In addition, the nuclear data area is relatively nonsensitive, at least in the sense that the nuclear data base has only an indirect connection with manufacturing and fabrication processes. While limiting ourselves to the nuclear data base, however, we wish to call attention to a need for similar assessments of other data bases that are relevant to nuclear power technology.

C. Nuclear Data Bases

A data base in the most general sense consists of those data or parameters that are associated with the analytical description or modeling of a process. Uncertainty data may be required as well as mean or expected values. The base includes not only the basic data that parameterize the description of a process, but also includes results from tests or "integral" measurements on the overall process itself. Such integral data often are of paramount importance for modeling purposes, both for testing and for adjusting the models and data base and, in some cases, for direct incorporation into the model. In this sense, the nuclear data base for nuclear power technology may be thought of as consisting of:

-- basic, usually differential, evaluated and processed nuclear data
-- integral data from critical or special experiments
-- integral operational data from power reactors and other nuclear devices

Basic nuclear data are those nuclear physics data that are required for the modeling of particle transport or reactor physics processes. They include, for example, nuclear interaction cross sections and yields, fission reaction data, and nuclear decay and branching data, and are based to a large extent on directly measured information. The frequently discrepant and incomplete measured basic data are analyzed and, in some cases, fitted and extended by application of nuclear theory to yield "evaluated" data sets. Evaluated basic nuclear data sets usually are complete both in the sense that all relevant reaction and decay types are described and in the sense that the data are uniquely defined over all ranges of importance, e.g., a fission yield is evaluated as a unique function of continuous incident neutron energy. These evaluated data sets then are "processed" (for example, averaged over energy bands referred to as "multigroups") into formats for direct use by nuclear design codes.

Integral data from critical or special experiments may consist, for example, of critical loadings, activation measurements, and reactivity measurements. Such data are relied on in the development of nuclear design methods. These data play an important role in the development of computational models for the design of reactor plants. Examples are the WRE experiments[1,2] for the Yankee Rowe PWR demonstration plant, the TRX[3,4] critical experiments, and the ZPR experiments[5] for the LMFBR demonstration plant.

Integral operational data are obtained during startup physics testing, operational testing, or post-irradiation testing on operating power plants. They may consist, for example, of critical soluble boron concentrations, control rod configurations, reactivity coefficients, power distributions, irradiated fuel isotopic compositions, and shield performance observations. These are the data that are ultimately relied on for validation, improvement, and tuning of computational methods.

The total body of basic and integral nuclear data is very large, complex, and interactive in that many parts bear on other parts. For example, it frequently occurs that basic or integral data developed for one area of nuclear technology, e.g., nuclear weapons system design, has an important impact on other areas, e.g., fission and fusion reactor development.

Again for the sake of practicality, this study will emphasize the basic nuclear data, although frequent reference will, by necessity, be made to the integral parts of the data base. The basic nuclear data part of the base consists of the following types of data:

-- neutron, photon, and charged particle interaction cross sections for the many nuclides used in nuclear technology
-- fission data (yields and energies of neutrons, fission products, etc.)
-- transmutation and decay data for fission products, actinides, and other nuclides
-- fusion data (reaction yields, energies, etc.)

Interaction cross sections make up the bulk of the basic nuclear data base. Cross sections usually are specified as functions of incident particle energy, and in the case of particle and photon emission, as differential functions of energy and angle of the emitted particles and photons. Uncertainty information may be included, but currently these data often are absent. In discussing basic cross-section sets, it is important to distinguish between evaluated data sets, processed data sets, and design code library data sets. According to proposed ANSI Standard N411 for Nuclear Data Sets for Reactors Design Calculations,[6] an evaluated data set is a set which is completely and uniquely specified over the ranges of energy and angles important to reactor calculations. An evaluated data set is intended to be independent of specific reactor compositions, geometries, energy group structures, or spectra. The data are usually specified on an energy and angle grid which may contain thousands of points.

The evaluated basic data then are processed into formats for use by nuclear design codes. Almost all nuclear design is accomplished using multigroup methods, so when we refer to processed basic nuclear data we shall usually signify the data as averaged over each of a number of energy groups. However, the basic nuclear data also are processed into special forms for efficient use by continuous energy Monte Carlo codes.

Again according to ANSI N411, an "averaged" data set is a set prepared by averaging an evaluated data set with a specified weighting function over a specified energy group structure. Such a set is intended to be independent of a specific environment, composition, geometry, or spectrum, or dependent on these factors only through slowly varying and well-defined functions. The recommended ANSI N411 multigroup structure for an averaged data set between 0.00001 eV and 20 MeV contains about 700 groups. Previously employed data sets filling the same role have utilized about 100 to 200 groups. Although such data sets may have a role in the documentation and transmittal of evaluated data, they have no direct bearing on the subject at hand.

A code library data set is a multigroup set that is directly associated with a design code, such as a spectrum code used to generate few group constants. This is the basic data set that is actually used in the design process. Such a data set could be an averaged data set in the sense of ANSI N411, although it usually is more collapsed. Energy group structures depend on the specific application as well as on the code computational model itself, and usually include from a few tens to a few hundred groups in the energy range of interest to nuclear design. Multigroup code library data sets are normally selected or adjusted to be useful for a particular application, although they are frequently used for other applications as well.

D. Historical Background

The historical development of nuclear data bases has its root in early nuclear physics investigations such as led to the discovery of the neutron, the fission process, and the fusion processes. The development of nuclear data bases, including both basic and integral data, received major incentives from the initiation of the nuclear weapons program and the naval reactors program in the 1940's, and from the initiation of the commercial nuclear power program in the mid 1950's. The bulk of the resources expended in this effort were of government origin. Initially, applied nuclear data information emerged regularly from basic physics studies, but as scientific frontiers moved outward it became necessary to support specialized physics work for the nuclear data base. By the early 1960's, various nuclear code library data sets and other relevant nuclear data were in use by the national laboratories and by the various industrial reactor vendors, such sets having usually originated in a national laboratory, but with private industry taking an increasing role in adapting and modifying such sets and linking the data sets to nuclear design codes.

In the mid 1960's two events had a major impact on nuclear data base development. The first was the commercial acceptance of nuclear power with the sale of a large number of nuclear power plants to electric utility companies. The maturing of the nuclear power industry into a major multi-billion dollar industry had the dual effect of increasing substantially the number of user groups interested in nuclear data bases as well as intensifying proprietary policies of reactor vendors with regard to nuclear data bases. The second event was the formation of the Cross Section Evaluation Working Group under government sponsorship, charged with the coordination, development, and testing of evaluated and processed nuclear data sets.

Two recent developments have had added impact on nuclear data bases. One has been the increased regulatory activity surrounding nuclear power technology. The other has been the associated emphasis given to the development of standards. The interplay of these forces and factors is a central theme of this study.

E. Outline

In the next section, Sec. II, nuclear data base requirements for nuclear design are discussed in terms of functions and system applications, and the important user groups are identified. Current practices in the development and utilization of nuclear data bases are discussed, along with the impact of such practices on various segments of the nuclear power community.

In Sec. III, past and current federal government programs for the development of nuclear data bases are described, and the role of the U. S. government in the area of nuclear data bases for nuclear power technology is discussed.

In Sec. IV, national policies of several key countries regarding the protection of nuclear data bases are discussed. Current proprietary policies of U. S. reactor vendors regarding nuclear data bases for design purposes are discussed and the legal aspects and impacts of such policies are explored. Finally, the impact of regulatory activities on the protection and release of nuclear data bases is discussed.

In Sec. V, current standard development efforts related to nuclear data bases are described. The justifications and probable impacts of such standards are discussed.

Section VI includes a summary as well as a list of key issues identified in this study along with recommendations.

II. NUCLEAR DATA BASES FOR NUCLEAR DESIGN

A. Requirements

1. Engineering Functions. Nuclear data bases are required in a number of specific engineering functions related to nuclear power technology. Major engineering functions for which these bases are required can be classed as follows:

-- component design
-- fuel management and fuel cycle optimization
-- safety analysis and licensing
-- system operations and control
-- shielding and environmental effects
-- materials safeguards

Certain engineering functions, such as reactor design, fuel management, and selected safety and reactor operations analyses, require essentially the same types of nuclear data bases, and often the same basic code library set will be used for all functions. In other cases, such as emergency code cooling analyses and shielding analyses, additional nuclear data may be required to supplement the basic code library. In all cases, however, the engineer or analyst uses code library data sets as a starting point.

Accuracy requirements vary from function to function, and may vary within a given function depending on the particular task. It can be conjectured that the current state of knowledge of basic data constitutes in most cases an adequate initial base for nuclear power technology. It follows that projected improvements in the nuclear data base should be subjected to study of costs and benefits. Specific exceptions may include particularly important data as well as data which are important but discrepant. The pressing need for comprehensive quality assurance in the nuclear power field requires that improvements must be made in the nuclear data bases so that important uncertainties resulting from utilization of the nuclear data base are effectively eliminated.

2. Systems Applications. Major system applications related to the nuclear data base, at least in the United States, can be grouped as follows:

-- fission converter reactors (LWR, HTGR)
-- fission breeder reactors (LMFBR, GCFR, LWBR, MSBR)
-- controlled thermonuclear reactors (magnetic and inertial confinement systems)
-- nuclear explosives and effects

The types and contents of required nuclear data bases differ somewhat from system to system, but not as much as one might think. Nuclear designers recurrently examine a variety of nuclides for their applications even though fewer actually are used in the hardware. Moreover, the energy ranges that are important for various applications have large overlaps. Accuracy requirements for specific data, on the other hand, may vary greatly from system to system. Over the years code library data sets have been developed by national laboratories and reactor vendors for application to specific systems. All engineering functions listed in Section II.A.1, however, generally apply to all the systems listed above.

B. Users

There are many groups that use or require a nuclear data base. The major user groups can be identified as follows:

-- reactor vendors
-- fuel manufacturers
-- electric utilities
-- architect-engineers
-- consulting firms
-- universities
-- national laboratories
-- regulatory agencies

Not all functions listed in Section II.A.1 are performed by each group. Reactor vendors perform essentially all functions. Electric utilities are involved in fuel management, and reactor system planning and operation. Architect-engineers may concern themselves with one or more or all of the functions. Thus nuclear data base requirements vary among the user groups.

Evaluated and averaged nuclear data sets have been developed primarily by the national laboratories with contributions from reactor vendors and universities. A description of the federally-supported program is given in Sec. III. These sets are in the public domain and are generally available to all user groups in the United States. Code library data sets for engineering and design have been developed primarily by national laboratories and reactor vendors. Although data libraries developed by national laboratories are generally available to all user groups (for example through the Argonne Code Center, the National Neutron Cross Section Center, and other Centers), library sets developed and used by reactor vendors generally have not been available to other user groups or to other reactor vendors. This proprietary aspect of code library data sets is discussed further in Section IV.

C. Current Practices

This section will describe the current practices and procedures followed in the United States in the development and utilization of nuclear data bases. The practically universally adopted evaluated data set in this country is the ENDF/B system[7,8] (Evaluated Nuclear Data File / B Library). Other evaluated nuclear data systems, such as UKNDL and KEDAK, are used to some extent in other countries. However, the ENDF/B system is that primarily relied upon in the United States, and to a growing extent in other countries, and is the only one discussed here. The ENDF/B system has been and is being developed under the auspices of the Energy Research and Development Administration and other U. S. government agencies at national laboratories and industrial organizations.

The National Neutron Cross Section Center (NNCSC) at Brookhaven National Laboratory maintains an experimental data library, known as CSISRS (Cross Section Information Storage and Retrieval System), for experimentally measured cross section and associated nuclear data. Other organizations, such as Lawrence Livermore Laboratory, also maintain experimental data libraries. The Cross Section Evaluation Working Group (CSEWG), with secretariat at NNCSC is comprised of representatives from national laboratories, reactor vendors, and other organizations. It is charged with preparing evaluated data sets on the basis of experimental data, theoretical nuclear model studies, and feedback from appropriate integral data analyses. The ENDF/B file is developed by CSEWG to be the best possible evaluated data set consistent with the support available for the work. The ENDF/B files are prepared in a specified format, for use in a computer-oriented system which creates, stores, and retrieves evaluated data sets. Since the issurance of the first ENDF/B version in 1968, a new version replacing earlier ones has been released approximately once every two years, (labelled successively ENDF/B-I, ENDF/B-II, etc.) The present version, ENDF/B-IV has been issued in 1974 and is available from NNCSC at Brookhaven National Laboratory and from other organizations. The operation of the CSEWG and the development of the common evaluated data formats of ENDF/B have greatly increased the effectiveness of the applied nuclear program. The CSEWG operates both as a tool for focusing and coordinating effort, and also as a technical forum for resolving issues.

To produce an averaged data set or a code library data set requires the use of so-called processing codes which read the ENDF/B files as input and generate a secondary, or processed, data set. Since design codes that use processed library data sets differ greatly from one system application to the next, and have widely different energy grid structures, a series of supplementary processing codes have been developed which produce library data sets for specific design codes or for series of such codes.[9,10] These processing codes have been developed at national laboratories and by reactor vendors, largely under government support, and are generally available either from the Argonne Code Center or the Radiation Shielding Information Center at Holifield National Laboratory.

Code library data sets, because they are intimately connected with specific design codes or computational methods, are often considered to be part of the design codes themselves. As integral data accumulate both the design codes and the data sets are modified, so that it is often difficult to define whether the modification was made to the computational model or to the library data set itself. Some modifications to the data base are entirely arbitrary, while others are made with the intention of actually improving the basic data, as when it is felt that the integral data directly bear on, and are more accurate than, the basic data.

Integral data, and particularly clean integral data, are often used as a basis for adjustments of code library data sets and in some cases this has led to adjustments of the basic ENDF/B data. Programs for formal adjustments of code library data sets based on normalization to integral data from critical or special test facility experiments are ongoing among reactor vendors[11-13] and fuel manufacturers,[14] in many foreign organizations,[15-22] and, to a limited extent, in domestic laboratories.[23-25] A number of special codes, such as the PENICUIK series[22] in England have been developed for automatically generating optimum adjustments to cross-section data. The integral data used in these normalizations or adjustments often have been obtained from government-supported experimental programs, and are available in the open literature, together with descriptions of the experimental conditions.[1,3-5,26,27]

Reactor vendors increasingly have relied on integral operational power reactor data to validate, improve, and tune their design codes and library data sets. This is consistent with an objective of the vendor, which is to predict correctly the operational performance of his reactors. Operational power reactor integral data are not generally available, and a substantial amount of the existing power reactor data, in particular properly interpreted and processed data, has been available only to the reactor vendor that designed the particular reactor. Although the electric utility that owns and operates the reactor usually retains the bulk of the operational integral data, it is in the form of raw data, and of little use without proper reduction and interpretation, a capability oftentimes not available to the utility. Adjusted code library data sets usually are regarded by reactor vendors as proprietary.

Because of the need to model and calculate the integral measurements, adjusted cross section library sets are, to a certain degree, dependent on the associated transport code characteristics, on the characteristics of other codes utilized in the normalization, and on the quality of the integral data used in the normalization. In the case of relatively "clean" integral measurements, such as critical experiments performed under controlled and well-known conditions, the influence of extraneous factors often can be minimal, such that multigroup cross section adjustments can in fact be considered as approaching truth. In the case of operational power reactor data, the situation is much more muddied in that experimental or test conditions are oftentimes not precisely known. Moreover, the modeling of the experimental conditions is much more complex and sophisticated, and usually requires a combination of somewhat approximate computational tools and methods. Indeed, since a unique and consistent library data set, properly normalized to more than one type of integral data (e.g., criticality, depletion rate, reactivity coefficient, irradiated fuel isotopic data) or to more than one reactor plant, has not been obtained, design code library data sets also reflect judgement and company/institution policy factors. This has resulted in the practice among some reactor vendors to carry along a number of different library data sets with the same computer code, which are used for different functions, applications, or systems. It should also be pointed out that code library data set modifications resulting either from reevaluations of the basic nuclear data or from normalization to new integral data, occur over periods of time which are sometimes shorter than the overall time required to do a core design or fuel management analysis. Since economic considerations may preclude redoing all calculations with a new library set, the older data sets are retained and reliance on a series of code library data sets becomes a necessity.

D. Impact on Competitive Nature of Industry

The development and acquisition of appropriate design code library sets has been considered by industry as being part of the competitive aspect of the market, and reactor vendors increasingly have protected their in-house adjusted code library data sets. At the same time, government supported programs have made evaluated data sets and associated processing codes increasingly available to all segments of the nuclear field, with reactor vendors depending more and more on modestly adjusted ENDF/B data for their design purposes. Indeed, with a few glaring exceptions, the differences between a code library set generated with the most current ENDF/B file and appropriate processing code and a proprietary adjusted code library set utilized by a reactor vendor may be relatively small. However, small differences in multigroup cross sections can translate into million of dollars when evaluated in the context of a multibillion dollar reactor manufacturing and nuclear fuel cycle industry.

This competitive aspect of adjusted design code library sets probably has a beneficial effect in motivating continued improvements in such data sets. However, the fact that the data bases that actually are relied on for the design and safety analyses of reactor cores generally are not available, even to the reactor operators and to government licensing and regulatory bodies, may have a negative effect. For example, it tends to stifle efforts by other segments of the industry, such as electric utilities, to carry out certain functions related to fuel management, fuel cycle analysis, reactor operations, and safety.

III. GOVERNMENT-SUPPORTED NUCLEAR DATA BASE DEVELOPMENT

A. Federal Agency Programs

Government agencies have supported and directed portions of virtually all aspects of nuclear data base development, from support for accelerators and basic nuclear measurements to support for nuclear design code library preparation. In the United States the Atomic Energy Commission (AEC), Energy Research and Development Administration (ERDA), Nuclear Regulatory Commission (NRC) Department of Defense, National Bureau of Standards, National Science Foundation, and National Aeronautics and Space Administration have had particularly effective programs in these areas. Some of these government-supported nuclear data programs have been productive for a third of a century, and the existence of a useful data base would be unimaginable without this effort. In addition, many useful nuclear data bases have been developed in other countries, usually with foreign government support, and most of these have been incorporated into the United States data.

If it were felt that United States nuclear data bases were a unique asset to be protected in commercial and military relations with other countries, then one process for protection could be that of classification. In fact, however, nuclear data are not classified in the United States and in most other countries. Certain nuclear design code libraries may be classified, but in connection with protection of the code or of a result obtained with the code. There is another mechanism for protection, the limited data distribution agreement, such as that used by the ERDA Division of Naval Reactors, but this is the exception that demonstrates the rule that nuclear data usually move freely among governments and governmental agencies.

B. Role of the United States Government

The roots of U. S. government involvement in nuclear data base development are found in the mandates of the Atomic Energy Act. The substantial role of the government in the nuclear data area has had very beneficial impacts on the nuclear power program, by providing the needed support and resources for the development of what was a very large and new data base that would be required by the nuclear power-related industries. Much of the development process for nuclear data requires a long lead time, perhaps longer than private industry would countenance, and it is fortunate that the U. S. government had this foresight. The continued role of the government in nuclear data base development will depend to some extent on current and future energy legislation developments, and on the future organizational structure and responsibilities of energy-related federal agencies and departments.

It is probably safe to say that continued or increased federal support of nuclear data base development will be to a large extent determined by the requirements for such support for the successful development of nuclear energy programs, and/or for the protection of the health, safety, and well-being of the public. It might be argued that the industry ought to bear the burden of future nuclear data base development needs. However, the situation within the nuclear industry is a complex one and the identification of required or desirable industry support is not a simple matter. On the one hand reactor vendors, who design the nuclear power reactors, possess substantial capabilities related to nuclear data bases, and generally profess to the adequacy or excellency of their nuclear data bases. On the other hand, individual electric utilities, who own and operate the nuclear power plants, possess few or no capabilities related to nuclear data bases, and oftentimes have very limited access to existing nuclear design data bases. In addition, there are many other users, who are involved to a larger or smaller extent in various functions such as safety, licensing, operation, the nuclear fuel cycle, etc., and who require adequate data.

To place the role of the U. S. government in nuclear data base development in a larger context, the nature of the U. S. commercial nuclear power program should be noted. Here the government has served in limited areas as a major supplier, but there are other major suppliers, and the customer is not the government. This is opposed, for example, to the U. S. space program where the government is both supplier and customer. By way of contrast, in many other countries, the government is directly involved in companies and organizations which engage in all phases of nuclear power technology. Added to the complexity is the large transfer of technology that has occurred in the nuclear data base area from defense-related programs to commercial programs. Such issues are currently relevant to many other large technology programs in the U. S., and it is probable that the extent of the government role in specific areas of these large national programs, including that in the nuclear data base area, will be determined more by special circumstances than by clear directives.

IV. CLASSIFIED AND PROPRIETARY ASPECTS OF NUCLEAR DATA

A. National Policies

Nuclear data information developed under government support, such as the ENDF/B file, and defense-related nuclear data information which has been declassified, is available to all potential users in the United States, and has been generally available to most users outside of the U. S. One exception has been the information developed under the Naval Reactor Program, which at times carries distribution restrictions, particulary as regards foreign users. The distribution of nuclear data outside the United States has been controlled in general by the U. S. Department of Commerce, Bureau of International Commerce, and in particular by the U. S. Atomic Energy Commission and Energy Research and Development Administration according to federal regulation 10CFR 110. According to 10CFR 110 the export of information requires an export license or the equivalent unless the data have already been made publicly available. Many existing design library data sets have been generated in this country by reactor vendors and their general availability, including their availability for export to foreign countries, depends on company proprietary policies as discussed in Section IV.B.

National nuclear power programs in many developed countries, such as the United Kingdom, France, and the Scandinavian countries, are carried out in nationalized or near-nationalized circumstances, in the sense that the government and government laboratories play a major role in the design of nuclear reactors, with private industry assuming the major role in the fabrication and manufacturing aspects. Moreover, the relevant private industrial companies frequently are owned or controlled by the governments concerned. Nuclear data bases, including multigroup library data sets, have with a few exceptions been generally available outside of the originating country and often are of high quality. Some foreign multigroup nuclear library data sets, however, are of limited applicability because of the use of special nuclear design techniques and computer programs in the separate countries. On the other hand, foreign interest in U. S.-produced PWRs, BWRs, and HTGRs. elicits considerable foreign interest in U. S. design codes and data bases. Foreign companies who hold licenses from U. S. reactor vendors would be expected to be subject to proprietary conditions regarding their access to nuclear data bases obtained from United States firms.

Nuclear data bases used in design by truly private foreign firms, such as reactor vendors in Germany, usually fall under company proprietary policies similar to those of private United States firms.

Availability of nuclear data bases to and from the Union of Soviet Socialist Republics has been limited, with the exception of certain data sets for particular application or particular isotopic species.

B. Proprietary Policies of Reactor Vendors

Nuclear code library sets are usually considered, as are many computer programs, as proprietary information by nuclear reactor vendors. This trend is part of the overall effort by individual companies to protect and exploit company information and know-how. In this section, general policies of reactor vendors in protecting information are described first, followed by discussion of specific policies regarding computer programs and nuclear data sets.

Although specific procedures may vary from one reactor vendor to another, general policies regarding proprietary information and its protection are relatively uniform across the industry. These policies usually are set down in documents and are available to persons outside the company.[28]

By the term proprietary, it is meant here that information so classed may not be disclosed to knowledgeable persons or groups outside the company, and is protected from disclosure by company policies, directives, and control procedures.

1. General Policies Concerning Company Proprietary Information. For a company that deals in major technological products, knowledge and engineering know-how constitute a fundamental resource. This fund of knowledge leads to concrete information of various kinds which can form the basis for a competitive advantage over other companies dealing in the same product, for example, nuclear power reactors. This competitive advantage is necessary in a free-

enterprise system for the company to compete effectively in the market place and thereby recover operating costs and provide an adequate profit margin. It is therefore the policy of reactor vendors to protect company information which has been identified as valuable, sensitive, or critical in the sense that it provides the company with a competitive economic advantage over other companies. It should be noted that the information which is protected does not always constitute an advance in knowledge. In addition, information related to pathologies or potential problems may be safeguarded in order to obtain or maintain competitive advantage.

The general types of information that are protected by a company fall into two broad categories:

-- technological processes and engineering know-how
-- business and financial plans and strategies

We will be concerned only with the first category. This category includes information such as data, models, computational methods, computer programs, analyses and calculations, processes, and various information related to the design and manufacture of a product or component.

There are several sorts of technical information that may be classed as proprietary by a company. These include:

-- information related to a process, such as a design component or a design method, which, if protected, would prevent or inhibit a competitor from developing and utilizing the process
-- information, such as supporting data relative to a process, which, if protected, would enhance the competitive advantage of the company through optimization or improved marketability of the process
-- information, such as calculations and computer programs, which, if protected, would require the competitors to increase their expenditure of resources to acquire an equivalent competitive position
-- information on company- or customer-supported research and development programs which could lead to competitive advantages for the company
-- information concerning inventions, for which patent protection may be desirable

Information which the company is contractually bound to disclose, such as information and data generated under government contract, cannot be classed as proprietary.

These are incentives which can lead a company to disclose information which otherwise might be classed as proprietary. Such disclosures include:

-- information which can be easily duplicated by competitors
-- information which if disclosed would benefit the company more from its publication than from its protection

Although it is the company policy to safeguard as far as possible its proprietary information, there are many instances where reactor vendors, by necessity, routinely disclose some of the company proprietary information to selected groups or individuals. Such limited disclosures include:

-- disclosures to government agencies, usually in relation to licensing and regulatory activities
-- disclosures to customers or prospective customers
-- disclosures to suppliers, architect-engineers, and independent consultants
-- disclosures to foreign licensees and foreign governments
-- disclosures to interviewers

In all cases the company attempts to protect the information from further disclosure by legal clauses and contracts. Disclosures to competition are made only in the case of significant safety-related problems that can affect the entire nuclear power reactor industry.

Procedures utilized by reactor vendors in protecting company information generally consist of the following. New information, when it is first generated, is given proprietary status according to some classification procedures, and control procedures are put into effect. As noted earlier, incentives may exist for immediate disclosure of the information, in which case the information is classified as nonproprietary. Similar incentives would come into play in the decision to change at a later date the proprietary status of some given information.

Some information, such as fabrication and manufacturing processes, or material compositions or test data, may be considered by a reactor vendor so important to its competitive position, that the information is disclosed to no one outside the company, except on order or subpoena from a court or regulatory agency. Other information, such as calculational techniques and associated data bases usually are kept proprietary over long periods of time, then released.

Other information, such as broad design features, calculations, and generic analyses, often are disclosed over shorter periods of time.

2. Proprietary Policies Concerning Nuclear Data Sets. Nuclear design code library sets, although they are based ultimately on nuclear data which have been measured and/or evaluated in government-supported programs, do reflect to various extents adjustments and selections made by the reactor vendor on the basis of normalization to integral data. As such they are considered as part of the company knowledge base and are treated as proprietary information. It is evident that the bases for classifying nuclear library data sets as proprietary are the second and third points on page 10 of Sec. IV.B.1., concerning enhancement of the company's competitive advantage at the expense of competitors. For example, use of an improved nuclear data library can give a reactor vendor an economic advantage in that he may develop a more optimized fuel management scheme or a better plutonium recycle capability. At the same time, it must be recognized that a reactor vendor may expend a number of man-years per year, that is, some hundreds of thousands of dollars per year, along with substantial computer charges, in maintaining, updating, and adjusting nuclear data library sets. There is obviously no incentive for the company to make such information available to its competitors at no cost. There is little, if any, incentive for a nuclear vendor to disclose its code library data base on the basis that it would have a favorable public relations effect or that it would enhance the marketability of the nuclear reactor cores or fuel.

In relation to limited disclosures, it has been the practice of reactor vendors not to make their nuclear data library sets available to customers. Disclosures of nuclear data bases are not required under the current regulatory process (discussed in Sec. IV.E).

It has been mentioned earlier that it is often difficult to distinguish a library data set from the code with which it is associated. This is not only true conceptually and in documentation, but also physically, in that the library and source programs are usually on the same magnetic tape, or together in one or more computer card boxes, and are therefore inherent parts of the same physical source. This has the effect that the proprietary status of a computer program directly spills over to the status of the library data set.

Reactor vendors have over the years come increasingly to regard computer programs developed in-house, or modified and adjusted in-house, as part of the company knowledge base and therefore as candidates for proprietary status. Indeed, a substantial number of computer programs utilized by reactor vendors in design, safety, and analysis of reactors are company proprietary. There is a considerable cost associated with the development, validation, maintenance, and up-dating and adjusting of computer programs. This cost can vary from a few tens of thousands of dollars to millions of dollars per code, depending on the nature of the computer program. Reactor vendors have therefore come to consider computer programs as assets as well as resources. Computer program proprietary policies usually are such as to insure a proper return on the company's investment in the programs by establishing procedures whereby the reactor vendor will supply, for a price, such programs to customers, licensees, and other parties.

Proprietary computer programs utilized in the performance of a government contract can be, and usually are, protected by special contract provisions. Results obtained with the proprietary programs under the contract usually are classified as non-proprietary.

C. Legal Aspects of Proprietary Policies

1. Legal Basis for Proprietary Status of Nuclear Data Bases. The legal basis for a company to withold proprietary information from public disclosure is grounded in the United States Freedom of Information Act and related USAEC-ERDA-NRC regulations such as 10CFR2.790. The act provides a company legal recourse in enforcing its proprietary rights in a court of law, provided the company shows diligence in protecting its proprietary information.

Because of the special circumstances, discussed in Secs. II and III, surrounding the development of nuclear data bases, the legality of the proprietary nature of nuclear code library data sets is not a clear or readily assessed matter. A substantial amount of the information contained in proprietary data sets, as well as a substantial amount of the resources that went into the development of such sets, comes from government sources. A reactor vendor, however, through selection of appropriate data, through adjustments and normalization to integral data, and through other effort, modifies, using its own resources, the publicly available data sets, and many subsequently refer to the modified sets as proprietary. For example, a reactor vendor may develop a spectrum code library data set for design purposes based on an ENDF/B evaluated nuclear data file and on an averaged multigroup data set developed at a government laboratory such as the Bettis Atomic Power Laboratory, properly normalized to important critical experiment data and power reactor operating data. With such a large fraction of the information coming from government resources, it is not evident whether the reactor vendor, or any other party, has a legal right to protect the information.

A number of other considerations tend to further cloud the issue. First, could a data library be considered as part of a computer program, and therefore subject to restrictions imposed on the computer program? Recall that whereas basic evaluated data such as ENDF/B data are intended to be independent of computational method or program, a code library data set has a connection to the code methodology itself, as the selected energy group structure. Moreover the code, with its inherent computational assumptions, may have been used in the normalization of the nuclear data to integral observations.

Second, could adjustments to nuclear data bases be considered as modifications to the computational model itself, and thus be considered proprietary? That is, adjustments to nuclear data bases could be considered as part of the utilization of government-sponsored information. Again one could consider nuclear data bases in the same context as design drawings. Common company policy is to consider company-adjusted government drawings as proprietary, when these reflect modifications or advancements in design funded by the company. Finally, assuming the public availability of a number of evaluated data sets (such as the ENDF/B files) and of a number of averaged data sets, must a company reveal its choice or selection of data in arriving at a design data base?

As was discussed in Sec. IV.B.2, grounds for treating nuclear data bases as proprietary are that the design nuclear data sets provide a competitive economic advantage to a reactor vendor, and that they are an asset in that there was a company cost involved in determining the nuclear code library data sets. It might be difficult to justify the proprietary nature of nuclear data sets solely on the basis of economic advantage, in view of the large involvement of government support. A valid legal ground however might be the expenditure of resources in developing the data sets as components of design of the company's product.

There is a cost, as well as a capability requirement, in determining a design code library data set from publicly available evaluated and averaged data sets. One might justify the proprietary status of design code libraries on the fact that the company expended resources in generating the libraries, and therefore the code libraries become an asset. To rely on resources expenditures as a legal basis for proprietary status would require that company contributions to the data base be easily recognized, as separate from information based on government-sponsored work. This brings us to the concept of equity, which is probably the key issue in dealing with the proprietary nature of nuclear data bases.

In a court decision regarding the legality of the proprietary status of nuclear data bases, the question of equity would most likely be the important yardstick. That is, one would have to consider the cost incurred by the company in generating design data sets based on government-sponsored information versus the economic advantage accruing from using information. If there is a disproportionate difference between the cost incurred and the economic advantage accrued, the legality of the case is clear. A court of law therefore could decide the proprietary status of a nuclear data base on the basis of equity. The company would still have the right to protect from disclosure the methods used in the data adjustments or in arriving at the design data bases. Strictly speaking, a possible public interest in disclosing data so as to permit confirmation of vendor claims in the course of the regulatory process does not arise.

2. <u>Legal Trends in Proprietary Status of Technical Information</u>. Legal trends, as they manifest themselves in court decisions and federal regulations, are such that it may become more and more difficult for technical information related to major technological programs to acquire company proprietary status.

The trend in the law is that whenever public funds are involved, the information, no matter how modified or added on by private funds, must become part of the public domain.

Related to this trend is the problem of effective technology transfer, which has become more and more of an issue in government and political circles. In the United States, the government may develop or sponsor a process up to a point where it could be made into a commercial process. Then it is turned over to private industry for possible commercial development. If the process information is regarded as public property, then private industry may be slow to invest in the research and development required to remove the inevitable remaining technical problems.

More generalized in its impact on proprietary information is the trend to consider all technical information, no matter from what sources, that is related to important technological programs, as public information for the furtherance of the public good, particularly health and safety. Thus it might be argued that the national importance of safe, reliable, and economic nuclear power justifies the public disclosure of the requisite data bases. In particular it might be argued that optimized nuclear data sets should be made available on a consistent basis of equity to all concerned, including reactor manufacturers, fuel manufacturers, electric utilities, consultants, government agencies, regulatory bodies, and the general public. In this case, even if a data base did not include any government funding, a company might be required to release the information on the basis of the public interest.

3. Copyrights and Patents. It is possible to copyright a data base or a computer program and to assign a trademark to these. Protection afforded by a copyright is, however, limited, since the person or company owning the copyright is responsible for protecting the copyright. We are not aware of any copyrighted applied nuclear data bases.

Data bases cannot be patented at present. There have been, however, attempts to patent computer programs,[29,30] and it has been pointed out that the computer program might be treated as including its data base. One case (Gottschalk v. Benson) has gone to the Supreme Court with the Court ruling against granting the patent.[31] In effect the Court said that Benson's computer program, although clearly implemented through a machine (the computer) and hence statutory, "is nothing more than a mathematical equation .... independent of whether man or machine calculates the equation". The court also specified, however, that "It is said that the decision precludes a patent for any program servicing a computer. We do not so hold". Thus the issue remains unsettled.

The U. S. Patent Office has no organization or system set up to deal with the flood of patent applications which would develop if there were advantage involved. It determines the patentable qualities of computer programs submitted to it, and in effect refuses to process these. Codes submitted to the office are filed indefinitely. Objections raised by the Patent Office are that the cost and complexity of getting into this matter would be enormous.

It should be noted that, akin to the situation surrounding adjusted data bases, it is a tricky question to define what constitutes a "new" code. If a few key instructions are changed in an existing code, significantly changing the operation of the code, does this consistitute a new code?

4. Use of Proprietary Information in a Government Contract. Information and data generated under government contracts cannot be protected as company proprietary and must be given adequate disclosure. The pertinent regulation is contained in ERDA Manual Chapter 3201, Reporting and Disseminating Technical Information. It is frequently the case, however, that proprietary information, including data bases and computer programs, is used on a government contract. Clauses in some government contracts can grant the government extensive rights to proprietary information used on the contracts. However, special contract provisions can be negotiated with the government which protect against specified contingencies proprietary data bases, computer programs, and manufacturing techniques used on the contract. While a proprietary computer program (and associated data base) can be protected under a government contract, the computational results obtained using the program under the contract must be fully disclosed.

ERDA regulation 41CFT9.5019 - Rights in Inventions and Technical Data in ERDA-Supported Contractor Independent Research and Development (IR&D) Projects - governs the disclosure of information in the case of government IR&D reimbursement. If a company recovers a significant percentage (usually over 20%) of the cost of company-funded research and development leading to proprietary information, the government may have the right of access to the information. In government contracts where both the company and the government share the costs, special terms are usually negotiated which govern the access to the information developed under the contract.

D. Impact of Proprietary Policies

The major impacts of proprietary policies related to nuclear data bases have been felt in the functions related to reactor design, fuel management, reactor safety, and reactor operations. Among reactor vendors themselves and independent fuel manufacturers, the effect has been a lack of uniformity in the nuclear data bases. Although this lack of uniformity may have little effect on the design function itself, it does obscure the realistic comparison of different designs, systems, and processes.

There is some controversy as to the degree of effect of lack of uniformity on design methodology and success. Those who feel that current adjusted nuclear data sets are adequate may see little effect. In contrast, those who feel that nuclear data adjustment is risky at best may feel that important design failures can follow from the fragmented development of proprietary data bases.

By far the largest impact of the proprietary policies surrounding nuclear code library data sets has been felt among the electric utility industries, and, to a somewhat lesser degree, among consulting and commercial firms which provide services to utilities. Proprietary policies related to nuclear data have effectively prevented access by electric utilities to the data base used in the design, safety, and fuel cycle analysis of the reactors owned and operated by the utilities. This, coupled with the limited nuclear engineering capabilities of electric utilities, has contributed to the difficulties utilities are facing in assuming fuel management, reactor testing, and reactor operation responsibilities. Looking ahead to the next decade, and to the number of nuclear power plants expected to be in operation, it is evident that these responsibilities will have to be assumed by the utilities in order to insure the reliable, effective, and economic operation of these plants.

The impact of proprietary policies on the regulatory process has thus far been minor, primarily because the burden for reactor safety analyses has been left to the reactor vendors themselves, and because the content of Safety Analysis Reports (SARs) as required by the NRC does not require documentation of the nuclear data bases. This is discussed further in the next section.

E. Regulatory Aspects

As part of the regulatory process connected with the licensing of commercial nuclear power plants, the electric utility that has purchased the plant must submit to the NRC Safety Analysis Reports (SARs) that form the basis for the granting of construction permits and operating licenses. As the reactor suppliers, the reactor vendor provides the utility with a significant portion of the SAR, including all design aspects. NRC regulations specify that SAR's become public information.

NRC regulatory guide R61.70 specifies the content of SAR's.[32] Section IV.C.3 of the guide specifies the extent to which analytical methods used in nuclear design should be documented. According to the guide, the applicant must

> "Provide a detailed description of the analytical methods used in the nuclear design including those for predicting criticality, power distributions, reactivity coefficients and burnup effects. Computer codes used should be described in detail as to the name and the type of code, how it is used and its validity based on critical experiments and/or confirmed predictions of operating plants. Code descriptions should include methods of obtaining parameters such as cross sections. Estimates of the accuracy of the analytical methods should be included."

There are no requirements to document or release the nuclear data base used in design of the reactor core, except that the methods used in arriving at a given data base must be described and that the validity of the combination of nuclear data bases and computational methods must be established through comparison with integral data.

A regulatory agency has the right to request or subpoena proprietary information, if it is deemed necessary for the regulatory process. It is unlikely that this would happen in relation to proprietary nuclear data bases, in part because detailed confirmation of vendor claims by regulatory personnel would be difficult. When proprietary information is required in a SAR, the procedure is to incorporate the information by reference to proprietary technical or topical reports. The proprietary information is then separately submitted to the agency by the utility, usually with the request from the reactor vendor that the information be accorded further protection under the U. S. Freedom of Information Act. NRC regulations are that each proprietary topical report submitted to the NRC must be accompanied by a nonproprietary version. In the proprietary version, however, all proprietary information must be bracketed and marked to indicate the criteria upon which the determination of proprietary classification was made. If the deletion of the proprietary information in the nonproprietary version makes the report unreadable, summaries of the deleted information, but not the numerical values themselves, must be provided.

V. NUCLEAR DATA BASE STANDARDS

A. Current Standard Developments

1. The Preparation of Nuclear Standards. The current high level of activity in the nuclear standards area [33,34] has been spurred on largely by the adoption of appendixes to ERDA regulation 10CFR50 and by the 1970 Williams-Steger Occupational Safety and Health Act, all of which put an emphasis on the establishment of and adherence to standards. In this context, it is useful to identify three general types of nuclear standards:

-- existing industry standards originally written for nonnuclear applications, which may have been adapted or supplemented for nuclear applications
-- new industry standards written specifically for nuclear applications
-- federal regulations and regulatory guides (primarily AEC-ERDA-NRC)

The role of the AEC-ERDA-NRC in nuclear standards stems from its current responsibility for protecting the health and safety of the public, as assigned by the Atomic Energy Act. In 1972, the AEC created the Directorate of Regulatory Standards, with sole function to develop criteria, guides, standards, and regulations.[35] To date, the AEC has issued over one hundred regulatory guides. Some regulations and guides directly reflect or reference existing industry consensus standards, while others have been developed essentially in-house by the AEC-ERDA-NRC and/or its contractors.[36]

National concensus industry standards are prepared primarily by technical and professional societies, such as the American Nuclear Society and trade organizations.[37] The development and writing of standards is done by committees consisting of small groups of knowledgeable individuals selected from industry, government, and universities. The proposed standards are reviewed and commented on by larger review groups, usually leading to several rewrites and eventual approval by the society or organization. American Nuclear Society standards are labeled by number, such as ANS 19.1.

ANS standards are submitted for approval as national consensus standards to the American National Standards Institutes. ANSI is a nonprofit federation of technical and professional societies, trade organizations, federal agencies, and computer organizations, whose main functions are to coordinate industry standards development, approve national consensus standards, and identify needed industry standards. The responsibility for nuclear standards development within ANSI rests with the Nuclear Technical Advisory Board (NTAB), one of twenty such boards within ANSI. NTAB operates through several committees (N-committees) each charged with standards development with a specified subfield of nuclear energy. ANS standards are reviewed and eventually approved by N-committees before final approval by the ANSI Board of Standards Review. ANSI standards are labelled by letters and numbers, such as ANSI N411- (year of approval). Standards, when approved, usually have a periodic review cycle which may range from 2-5 years.

2. Nuclear Data Base-Related Standards. Up to the present time there are no existing AEC-ERDA-NRC regulation or regulatory guides which specify or identify acceptable nuclear data bases. Several ANS standards, however, directly relate to nuclear data bases, and these standards will be discussed in this section. All of these ANS standards are currently in various stages of preparation, review, and approval, except for ANSI N411 which has reached the stage of final ANSI approval. Current contents of these standards should not therefore be considered as final statements of national concensus. Nevertheless, it is instructive to discuss the content of these standards as currently written, in order to gain an appreciation for the trends in industry standards

related to nuclear data bases.

The following proposed ANSI standards are among those that more directly relate to nuclear data bases.

-- ANS-5.1 Decay Energy Release Rates Following Shutdown of Uranium-Fueled Reactors
-- ANS-6.1 Shielding Cross Sections
-- ANS-6.4 The Analysis and Design of Concrete Radiation Shielding for Nuclear Plants
-- ANS-19.1 Nuclear Data Sets for Reactor Design Calculations (Accepted as ANSI 411)
-- ANS-19.3 Reactor Physics Design Calculations (Final stages of approval as ANSI 412)
-- ANS-19.5 Reference Integral Reactor Physics Measurements

ANS-5.1 deals with the energy generation due to radioisotope decay (primarily fission products) following shutdown of a uranium-fueled thermal reactor. As such it addresses itself to the nuclear data base required for loss of coolant and emergency core cooling systems analyses. The standard does not yet specify relevant basic nuclear data, such as fission product yields, decay constants, and energy releases, nor does it specify approaches or methods to process and use such data in decay heat calculations. The standard does specify the total energy generated from the decay of fission products as a standard curve in terms of the fraction of the operating power. An uncertainty and margin for error and further uncertainty due to varying reactor fuel history is specified. A partial basis for this approach is the inadequate knowledge of the many physical constants involved, at early decay times. A possible liability is that it is not sufficiently precise under varying operating conditions. The standard curve is specified with uncertainty bands, and users are given the option to perform their own calculation of decay energy generation, as long as the results of such calculations fall within the uncertainty bounds of the standard curve.

ANS-6.1 deals with the nuclear data base for radiation shielding design and analysis. The standard is still in very preliminary stages, and to date no written version has been produced. A degree of impasse has developed in that Holifield National Laboratory, a leading shielding center, has developed multigroup data with particular multigroup structures appropriate, say, to concrete or iron, whereas working shielding data sets are on general multigroup structures used for all materials and combinations of materials.

ANS-6.6 relates to the analysis and design of concrete radiation shields, and sections of the standard address the nuclear data base for concrete. The standard specifies gamma-ray attenuation coefficients and energy absorption coefficients over an appropriately selected 25 group energy grid structure between 10 MeV and 10 keV. Gamma-ray buildup factors are specified in equation form, with tabulated parameters, and in graphical form as a function of number of mean free paths for 15 distinct energies between 15 MeV and 300 keV. Gamma-ray spectra from secondary production due to neutron capture in the concrete are specified over a seven group energy grid structure. With regard to neutron and gamma-ray cross sections, data required for computer code analysis of neutron and gamma-ray shielding, the standard recommends a multigroup (22 group neutron, 18 group gamma-ray energy group structures) cross-section library distributed earlier by the Holifield Radiation Shielding Information Center. Neutron constants are specified for use in simple point-kernel removal theory calculations. No uncertainty information is specified in contrast to ANS-5.1. All the data listed in the standard are for ordinary concretes, and no account is taken of reinforcing steel.

ANSI 411 directly deals with the nuclear data base required in reactor physics computer programs, and as such is the standard most directly concerned with general nuclear data bases. The standard identifies and describes the specifications for developing, preparing, validating, and documenting evaluated nuclear data sets, processed continuous data sets obtained from evaluated data sets, and averaged data sets. No evaluated nuclear data set is identified as a standard, primarily because no consensus could be reached on a data set which was soundly based yet produced satisfactory agreement with integral observations. However, the ENDF/B files are identified as meeting the procedural requirements stated in the standard, with the latest ENDF/B version recommended for fast reactor design. The standard does specify a supergroup energy grid structure (~700 groups) for averaged data sets and specifies a limited number of weighting functions to be used in generating averaged data sets for specific applications. The standard does not address the generation or specification of working multigroup data sets used with computer design codes. No standard nuclear data sets of any kind are specified as numerical values. This deficiency is justified on the basis of the current evolutionary nature of the nuclear data field, and of the current lack of a consensus on the general acceptability of any given nuclear data set. The standard does look to the eventual identification of standard evaluated, processed continuous, and averaged nuclear data sets at the working level.

ANSI 412 deals with reactor physics design calculations and provides criteria for the selection of computational methods and of appropriate benchmarks for verification of the methods, for the evaluation of the accuracy and range of applicability of data and methods, and for documentation of such. The standard addresses the preparation of multigroup code library data sets. The standard refers to the procedures outlined in ANSI 411 for the preparation of averaged data sets in specifying procedures for the preparation of multigroup data sets from evaluated or averaged data sets. The standard requires that an estimate of the specific reactor spectrum be used in defining weighting functions. The standard does not specify any standard multigroup data sets, nor does it specify a standard working multigroup energy grid structure. The standard also recognizes the adequacy of multigroup data sets prepared directly from experimental data and theoretical models, if not processed from evaluated data sets, as long as use of such data sets leads to acceptable design parameter predictions; this would appear to be incompatible with ANSI 411.

Because of the current high level of standards activity, there are other standards in preparation, or future standards, that relate to nuclear data bases. Other proposed standards, such as ANS-6.2 and ANS-19.4 deal to some extent with integral and benchmark data for shielding and reactor physics calculation, respectively. ANS-19.5 directly addresses integral benchmark observations for reactor design. The discussion in this section illustrates current trends in nuclear data base-related standards development; in particular good methodology is stressed while specific data sets are not.

B. Requirements for Standards

1. General Requirements for Standards. The primary objective of standards is the public good, particularly the protection of the health and safety of employees and the public. Standards are developed to meet the requirements for uniformity in design, compatibility of interfaces, operational reliability, and safety practices and equipment. Such standards are tools for the engineer and guides to industry in that the goal of a standard is to codify sound engineering practice on a specific subject. In addition, standards provide a basis for legal compliance in licensing, and they provide legal protection in contractual relations. They are also useful in international trade by improving the communication of specific practice.

Nuclear industry standards have been written to meet requirements in the areas of administration, design, testing, construction, fabrication, and operation of nuclear power plants and associated nuclear facilities.[34] Nuclear standards are playing an important role in relation to quality commerce, safety and licensing, and nuclear plant design standarization.

Many standards define quality assurance requirements applicable to the design and construction of nuclear power plant facilities. These standards specify good engineering practices to be used to assure that structures, components, and systems be designed, fabricated, erected, and tested to adequate quality standards. Various other quality assurance standards relate directly to the operational phase of nuclear power plants.[38]

Many standards relate directly to the safeguard reliability of nuclear power plants.[39] Such standards benefit the learning process in that they contribute to the codification of the licensing activity by specifying good engineering practices to be used in all safety aspects of nuclear power plant design, construction, and operation. Standards therefore enhance the effectiveness of the learning process while at the same time speeding up the process.

Nuclear power plant standardization has received major emphasis in recent years, as a means to manage more efficiently financial and manpower resources, as a means to simplify the learning process, as a means to stabilize plant construction time, and as a means to better ensure the safety and reliability of the plants. Finally, standards are necessary requirements for the successful implementation of the concept of design standardization.[40-42]

2. Requirements for Nuclear Data Base Standards. As was discussed in Section II.A, nuclear data bases are required in many engineering functions related to design, safety, and operation of nuclear power plants and associated facilities. Thus the specification of good engineering practices in the selection and processing of nuclear data is directly related to the quality assurance and safety and reliability of nuclear power plants and facilities, and is an important ingredient in the achievement of power plant standardization. Recognition of this requirement for nuclear data base standards has led ANSI and ANS to sponsor and develop such standards, as described in Section V.A.2.

There is a basic question as to the form in which nuclear data bases should be specified in relevant standards, that is, from a mere specification of good methods and approaches to the preparation of nuclear data sets, to the actual specification of useful quantitative data to be applied in design codes. A related question is whether cross sections should be specified as evaluated data sets, or as multigroup code library data sets, or both. As discussed in Section V.A.2, certain proposed standards, such as ANSI 411 and ANSI 412 limit themselves to the specifications for developing, preparing, and documenting nuclear data sets, while other standards, such as ANS-5.1, specify the quantitative data to be used directly with design computer codes.

Since the engineer deals directly with design computer codes and their associated working nuclear data libraries, it is evident that the quantitative specification of multigroup library data sets and associated nuclear data for direct use in design computer codes would best satisfy the requirements for nuclear data base standards. On the other hand, one could argue that standards requirements would best be met by specifying only the basic evaluated nuclear data, along with accepted methods for processing these data for use with design computer codes, in view of the widely different applications for which nuclear data are required. The argument that working code library data sets are too application-dependent, and therefore inappropriate for specification in a standard, appears to be irelevant to the objective of enhancing the nuclear design process.

It appears to be a general consensus that the specification of standard evaluated nuclear data sets is a desirable goal in the development of standards for the nuclear power industry. Whether multigroup working code library data sets should or can be specified in a standard will no doubt depend on a variety of economic, technical, and political factors.

C. Impact of ANSI Standards

Federal regulations are part of the law and as such their effect is mandatory. NRC regulatory guides, although not intended as substitutes for regulations but as guidelines concerning specific engineering issues[35] oftentimes assume the practical near-status of regulations, primarily as a result of efforts to avoid scheduling delays.[43]

Standards, including ANSI standards, do not on their own possess legal status. An industry standard will have legal status only if referred to in federal regulation or if it is part of a contractual arrangement between a seller and a buyer.

The beneficial impact of standards on such areas as quality assurance, safety, and standardization has been discussed in Section V.B. In this section we consider the impact of the adoption of nuclear data base-related standards on various user groups.

If a standard limits itself to the specification of good methods and approaches to nuclear data set generation, the impact on user groups will be relatively small. For example, ANSI 411 and ANSI 412 as currently written limit themselves to the specification of data set generation procedures which are essentially those in current use by the ENDF/B system and by users with established nuclear data base capabilities, such as reactor vendors. The adoption of this type of standard could, however, have some impact on the other users, such as electric utilities, who may not have, or could not justify having, the capability required to generate code library nuclear data sets according to standard procedures. Indeed, it is probably fair to say that the adoption even of such limited standards would help electric utilities and their consultants acquire more adequate nuclear data bases for fuel management, licensing, and reactor operations functions.

The adoption of standards which specify integral nuclear data and multigroup nuclear data sets for direct use at the working level with design computer programs, would have a much greater impact on all user and regulatory groups. For example, the specification of multigroup shielding data in ANS-6.4 has the effect of making such nuclear data bases, directly required in shielding design and analysis, available to all concerned user groups, such as reactor vendors, architect-engineering firms, and government agencies, as well as of providing for uniformity in shielding design. The specification of standard multigroup nuclear data libraries for use with nuclear design codes would benefit electric utilities, consulting firms, universities, regulatory groups, and various segments of the public, in making fully available an acceptable nuclear data base required for many functions of concern to these user groups. Since the different user groups often are concerned with the same product, for example, a given nuclear reactor plant, the uniformity acquired by adoption of a standard nuclear data base for design and analysis has obvious additional benefits for electric utilities, consulting firms, and regulatory agencies.

Objections may be raised, however, to the adoption of such standard working multigroup data sets by reactor vendors who are responsible for the design of reactors, on the basis that such standards may significantly limit the ingenuity, flexibility, and creativity required of nuclear engineers and reactor physicists in solving widely different problems for different purposes, and thus could in fact be a detriment to good engineering practice.[44] In addition the identification of a possibly inadequate nuclear data base as a standard could have a detrimental effect in reducing government and private investment in improving the data base. On balance, we feel that the advantages of effective standard nuclear data bases outweigh their disadvantages.

VI. SUMMARY AND CONCLUSIONS

A. Summary

This study has reviewed and assessed the situation surrounding nuclear data bases for nuclear power technology. It is intended that this assessment and any actions that might result from it should be of benefit to all parties related to the development and use of nuclear energy.

The requirements for nuclear data bases in nuclear power technology have been identified, showing the wide spectrum of engineering functions which require nuclear data bases, as well as the many nuclear energy applications and systems which rely on nuclear data bases. Also identified have been user groups showing the many and varied types of users currently interested in nuclear data bases. Current practices in the generation and utilization of nuclear data bases have been described, including the development of the ENDF/B system of evaluated data files, the use of data processing codes, and the reliance on integral test data and integral operational power reactor data in generating and adjusting nuclear code multigroup library data sets. The competitive aspect of the industrial development of design nuclear data bases has been pointed out, with the associated positive effect on the quality of such library data sets, and the associated negative effect of limiting availability of such data sets as far as non-reactor-vendor user groups, such as electric utilities, are concerned.

The major role played by the United States Government in supporting the development of nuclear data bases for defense-related programs, as well as for the fast fission and fusion reactor technologies, was described. The beneficial impact of such large government involvement in nuclear data base development was noted, and the relative merits of continued government support of nuclear data bases were discussed.

The classification and proprietary aspects of nuclear data bases were discussed in relation to government and reactor vendor policies. The general availability, within and outside of the United States, of evaluated nuclear data sets developed under the ENDF/B system, as well as of many nuclear data sets generated overseas was noted. National policies of a number of foreign countries in relation to their own nuclear data bases were described. The proprietary nature of reactor vendor nuclear data code library sets was discussed. Justification for such proprietary status was shown to be related to general proprietary information policies. In particular, nuclear data sets are considered by reactor vendors as assets, in view of the resources expended in generating such design data sets, in addition to providing some economic competitive advantage. The legality of treating nuclear data bases as proprietary information was discussed at some length, pointing to the question of equity as effecting the legality of such treatment. Legal trends were reviewed showing the increasing unlikelihood that such information could in the future be kept out of the public domain. Current contractual clauses that protect information such as nuclear data bases used in government contracts were discussed. The limited relevance of copyrights and patents as far as data bases are concerned was pointed out. The impact of proprietary policies covering nuclear data bases was shown to reveal itself primarily in a lack of uniformity in the nuclear design function, in the added difficulty for various user groups, such as electric utilities, to assume responsibilities for various functions, such as fuel management, and, probably, in inhibiting the regulatory process. The very limited requirements for the reporting, confirmation, or justification of nuclear data bases in the regulatory and licensing process were noted, together with current practices which tend to protect proprietary information required to be included in safety analysis reports.

Current activity in nuclear data standards development was reviewed. The preparation and approval process of nuclear standards was described, showing the role of the American Nuclear Society and the American National Standards Institute. A number of ANS standards, in various stages of preparation, that directly relate to nuclear data bases were discussed in some detail. The limited nature of such standards was noted, in that current standards tend to specify good methods and approaches to nuclear data set generation, as opposed to standard nuclear data sets with the exception of special applications, such as post-shutdown decay heat and radiation shielding, where quantitative data are specified for use in design calculations. The importance of nuclear standards in general, and of nuclear data base standards in particular, were discussed with emphasis on the areas of quality assurance, safety and reliability, and nuclear plant standardization. The probable impact of nuclear data base standards on user groups was discussed, showing the inherent conflict between the desire for access and uniformity, of particular importance to electric utilities, architect-engineer, consulting firms, universities, and regulatory agencies, and the desire for flexibility, of particular importance to reactor vendors.

B. Issues

During the course of this paper, various issues have been raised and commented upon. It is the purpose of this section to focus on and highlight these issues. In many cases these issues listed here are closely connected to one another.

1. What should be the current and future role of the government in supporting the development and generation of nuclear data bases for nuclear power technology, particularly in view of the existence of professedly adequate vendors' data bases?
2. Should nuclear data bases as used with design codes be proprietary information? Relevant considerations in this respect include the legality of such practices, with such a large fraction of the resources used in developing nuclear data bases being government supported in origins; the impact of such proprietary policies on other user groups within the nuclear power program, such as electric utilities; the needs of the regulatory process; and the public good in general.
3. Where does the concept of equity stand in relation to the cost associated with the generation and adjustment of nuclear data sets based on public information and the economic advantage ensuing from the use of such information?
4. Should the generation of nuclear design code library data sets be considered as part of the competitive aspect of the nuclear power industry?
5. Can selection of and adjustments to publicly available nuclear data sets be considered as part of the utilization of public information or part of the computational model itself, and therefore subject to proprietary status? That is, what is a "new" data set?
6. Must a reactor vendor or other company reveal the choice of nuclear data it would make from among a number of publicly available nuclear data sets? Can nuclear code library data sets be considered as part of the code itself, and therefore subject to the proprietary, copyrighted, or patented status of the code?
7. Is it possible to separate a nuclear data library set from the code it is associated with, and in this sense, if there do exist valid justifications for public disclosure of nuclear data sets, do not the same justifications apply to the public disclosure of the computer programs themselves?

8. How applicable to nuclear data base practices are current trends in the law in the area of technology transfer?
9. Should the documentation of nuclear data bases be required as part of the regulatory process and, in particular, as referenced by safety analysis reports?
10. Should nuclear standards be specific or limited in their quantitative identification of nuclear data bases?
11. Should nuclear data set standards be limited to evaluated and averaged data sets, or should they include working multigroup code library data sets?
12. Should standard multigroup nuclear data sets be specified in relation to applications and/or computer programs, or should there be a single standard multigroup set?

C. Recommendations

The objective of this study has been primarily to be informative. Nevertheless, it seems incumbent upon the authors to express certain conclusions and recommendations in selection of the material and issues presented in the paper. These recommendations are:

1. That the federal government continue its role in both the identification of needed improved nuclear data and the development of useful nuclear data bases. The inability to reach national consensus in current nuclear standard development with regard to standard nuclear data sets for design, safety, and other purposes, demonstrates that the nuclear data base is not yet fully adequate. It is well known to workers in the discipline and to nuclear designers that specific areas of the nuclear data base are defective, for example, those areas relevant to the fertile nuclide ^{238}U and to the interpretation and/or prediction of reactivity worths. The role of the government in this area seems justified by the traditional heavy involvement of the government in nuclear data base development, by the existence of strong and comprehensive capabilities for this R&D in government laboratories, by the fact that the nuclear data base is generic to many facets of nuclear power and weapons technology, and therefore related to national impact and public health and safety, and by virtue of the mandates contained in the Atomic Energy Act and recent energy legislation enacted by Congress.
2. That a centralized and coordinated program be set up for the development, evaluation, documentation, and distribution of standard basic data sets and standard working nuclear design library data sets for use by the electric utility industry and other segments of the nuclear power industry. Government agencies, the Electric Power Research Institute, reactor vendors, and other responsible groups would participate in or sponsor this effort. This work should be based on, but not limited to, the methodology requirements of existing nuclear data standards. It is recommended that such a program involve independent institutions, such as universities and government laboratories, as well as vendors, utilities, and other interested parties so as to establish the required consensus.
3. That government and/or industry support a continuing program for the acquisition, processing, interpretation, coordination, documentation, and analysis of integral operational nuclear power plant data, demonstrating the ultimate adequacy of the standard working nuclear data sets. Such a program, of course, would have many other benefits as well.
4. That nuclear standards be written that specify the use of standard nuclear data sets in specified engineering functions for which standardization is in the interest of the industry and the public.

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