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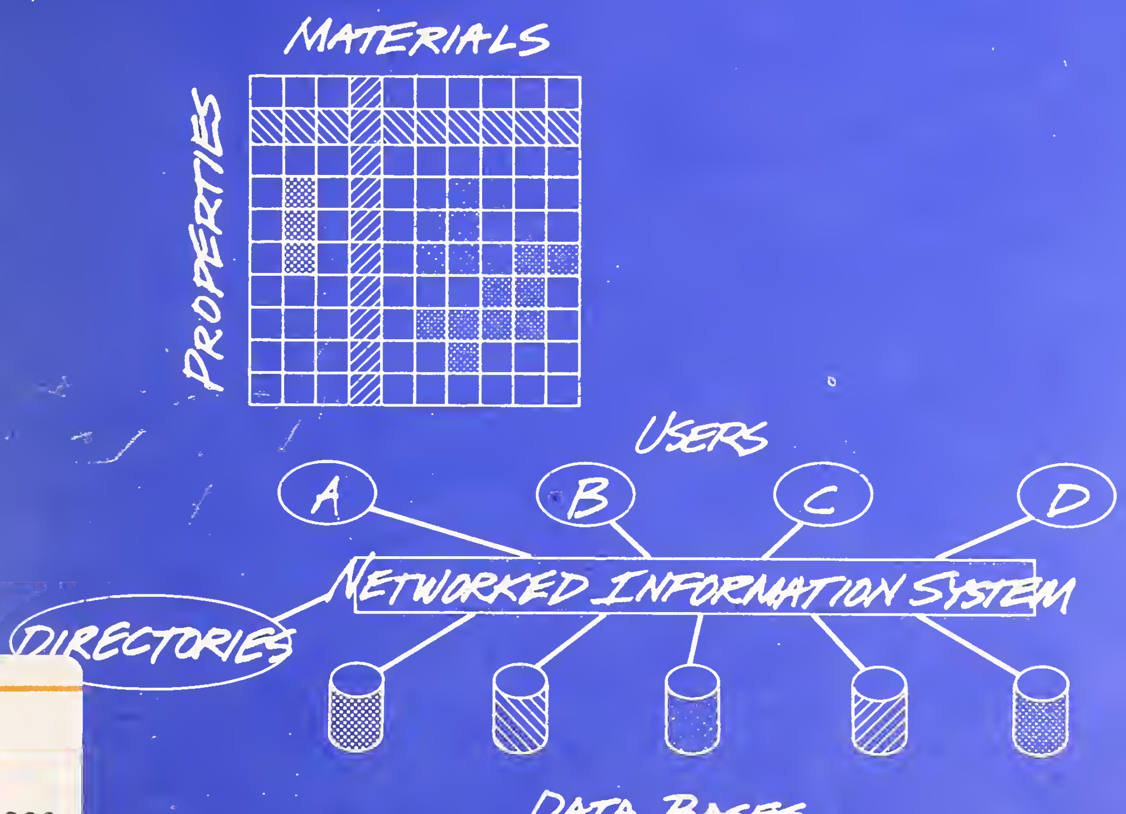
Computerizing Materials Data—A Workshop for the Nuclear Power Industry

John Rumble, Jr. and Jack H. Westbrook



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- Fracture and Deformation[3]
- Polymers
- Metallurgy
- Reactor Radiation

[1]Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.
[2]Some divisions within the center are located at Boulder, CO 80303.
[3]Located at Boulder, CO, with some elements at Gaithersburg, MD.

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Computerizing Materials Data—A Workshop for the Nuclear Power Industry

The Report of a Workshop held at Knoxville, TN May 2-3, 1984

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National Bureau of Standards

and

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General Electric Corporation

Workshop Sponsored by:

The Metal Properties Council
National Bureau of Standards
American Society for Metals
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executive summary

The investment in materials in the Nuclear Power Industry is more than $100 billion. Though construction of new plants has tapered off, the existing facilities are an important part of the United States energy system. The performance of these facilities is critically dependent on the materials used in their construction and operation. Access to accurate and reliable materials property data is a vital part in determining that performance.

The Metal Properties Council and the National Bureau of Standards gathered together in May 1984 a group of engineers and scientists responsible for the use of materials property data in various sectors of the Nuclear Power Industry. At this workshop, all facets of the use of computers in accessing these data were addressed. The discussions concerned the content of a proposed computerized materials data system, its size and data sources, and the user interfaces and system capabilities. The conclusions and recommendations of the workshop participants are summarized below and will supply important input to the National Materials Property Data Network being developed by The Metal Properties Council and others as it progresses in providing this valuable service to American industry.

Endorsement of the Concept

- A materials property data network should be established consisting of independent databases on a distributed system connected by a central or "gateway" computer. Users would access any or all of the databases by a single phone call.
- The gateway will have features such as user friendliness and support programs such as statistical analysis and graphical display of retrieved data. Comprehensive indices to the database contents would be available. Downloading of data would be permitted.
- Individual databases would be developed and maintained by expert groups, especially those now making data available in publications.

Contents and Characteristics of the System

- A wide range of information is needed for users in the Nuclear Power Industry—materials, properties, economic data, and application advice.
- Materials properties needed include—mechanical, corrosion, thermal, physical, radiation effects, and neutronics.
- Ferrous and copper alloys are by far the most important materials. Other alloys, ceramics, and polymers are next in order of interest.
- Users must be able to designate materials in several different ways —by class, by application area, by chemistry, by standard designation, and by trade names.
- A unique designation is important.
- Property relationships should be described and a catalog of test methods included.
- The system must offer a variety of capabilities including number look-up, file inversion (what materials have a given set of properties), as well as other features mentioned above.

General Observations

- Quality indicators should be given for the data included. At first, these may be general and qualitative.
- Increased activities on the validation of engineering data are needed. Technical societies and the National Bureau of Standards should take the lead.

- Validation does not absolve users of the need for good engineering judgment. The final responsibility for data resides with the user.
- Commonly used handbooks must be made machine-readable and be included in the network.
- There is a strong demand for data on service experience of materials.
- In the nuclear industry, data are needed for maintenance, repair, retrofit, and service life extension as well as for design of new plants and equipment.
- The most important gaps in materials property data are—friction, corrosion, wear, and weldments.

Action Plans

- The network must be built through cooperation of industry, technical societies, and government. The National Materials Property Data Network, as established by the Metal Properties Council, should continue to provide the necessary leadership and focus.
- Since their users will be the largest group to benefit, industry must provide the bulk of support.
- A demonstration system must be built as soon as possible to exercise the concept and to show the potential of the network.
- Technical advisory committees are needed to address standardization issues, to evaluate and review data, and to encourage database building.
- Users must be involved in every stage—from planning to design to building.

acknowledgments

The success of this workshop is due to many people. Financial support came from the Office of Standard Reference Data of the National Bureau of Standards. The Metal Properties Council, Inc., of New York was instrumental in laying the groundwork for the topic of this meeting. Special thanks are given to Adolph Schaefer and Martin Prager, Director and Deputy Director, respectively, of the MPC and to James Graham of John Deere, Inc., who is head of the MPC Task Group on Computerized Materials Data.

Several individuals planned and organized this workshop, including

Joe Gilman
Electric Power Research Institute

Martin Prager
The Metal Properties Council, Inc.

John Rumble, Jr.
National Bureau of Standards

Jack Westbrook
General Electric Company

This workshop report was prepared by Jeanne Bride whose careful manuscript preparation, editing, and proofreading made the work go smoothly.

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Chapter 1

introduction and purpose of meeting

Computer access to materials data will become a reality in the coming years. The wide availability of computing facilities, combined with an increasing number of machine-readable databases, have brought this about. For the engineer user to realize the maximum benefits from this trend, three key events must happen. First, computer use must be easy, attractive, and provide more capability than presently available at the engineer's desk. Second, the collective materials/properties scope of the interconnected databases must be reasonably broad and the coverage within that scope acceptably complete. Third, engineers must be involved in defining and designing the system.

In May 1984, a workshop "Computerizing Materials Data—A Workshop for the Nuclear Power Industry" was held in Knoxville, Tennessee. The gathering was designed to provide guidance to a cooperative effort whose goal was to provide such computer access. The meeting was sponsored by the Metal Properties Council, the National Bureau of Standards, and several technical societies. The results of the workshop, given in this report, will help lay the groundwork for activities of the National Materials Property Data Network, Inc. (NMPDN), an independent corporation planned by the MPC.

Planning for the Network has been in progress for several years. The result is a cooperative effort to establish an on-line service to provide access to validated data on the properties of engineering materials. After exploring alternative approaches and technologies, a network of independent databases is now believed to be a feasible objective. In spring of 1984, The Metal Properites Council (MPC) formed NMPDN as a separate incorporated entity which will plan and build the Network.

The overall concept of the Network is quite simple. A central computer would be linked via telecommunications to databases on machines in different locations. The individual databases would be compiled and maintained to expert standards. To access the system, an engineer would make one phone call to the central or "gateway" computer. Software on this computer would let the engineer first identify the type of data wanted and would then present him with a list of databases containing these data. The user would select the databases to be examined and be automatically connected to them.

The gateway computer would have software, including a translator, so the user would need to know only one query language. This type of centralized access means the engineer needs to learn only one set of commands, to set up one contract, and to make only one phone call. The system will have capabilities important for the intelligent use of the data, including graphics, statistical packages, and other post-processing features. Downloading privileges would likely also be available. For such a system to be successful, the potential user community must be involved in the designing and planning from the beginning.

One part of the planning process involves the holding of a series of workshops. The workshop concept developed by NBS brings together engineers involved in the design and manufacture of equipment and components used in a particular industrial segment, here the Nuclear Power Industry, to articulate *their* needs and the way *they* would use this system if it were available. The workshop was structured for maximum involvement of the participant. It featured several discussion sessions during which small groups focused on a number of questions. These related to what data must be included, how they should be specified, and what capabilities are needed.

The topics included the materials of greatest interest, kinds of properties needed for design, modes of data presentation in accord with traditional practices, types of statistics consistent with codes and standards, nomenclature, compositional ranges, and test techniques. Each of these were addressed for a variety of applications.

The results of the workshop are very important both to the NMPDN and to the engineering community at large. First and foremost, they will be used to develop priorities in the kinds of databases to be included and in the types of capabilities offered by the Network. As can be seen from the discussions that follow, detailed recommendations were made which will allow the Network designers to be responsive to the needs of engineers in the Nuclear Power Industry.

In a broader sense, the workshop served to alert this segment of the engineering community to the on-going activity currently associated with computer access to materials data. The meeting was the second of a series of such gatherings held by MPC and NBS for individual industries. The first was a workshop for the Ground Vehicle Industry, held in April 1984 in Columbus, Ohio, under the sponsorship of the Society of Automotive Engineers. Others are being planned.

The present workshop was divided into two parts—(1) presentations on materials data pertinent to the Nuclear Power Industry and progress-to-date in computerizing these data and (2) discussion groups which addressed a series of topics designed to elicit concrete answers from this potential user community. An outline of this report follows.

Chapters 2–5 present summaries of the presentations. Chapter 2 discusses progress made in the past few years towards providing computer access to materials property data. Chapter 3 identifies changes in the use of materials data in the Nuclear Power Industry. Chapter 4 describes the EPRI experience in building computerized materials databases. In Chapter 5, the National Materials Property Data Network is discussed.

The next four chapters present summaries of the workshop discussions and its conclusions. Chapter 6 discusses the content of the proposed system, Chapter 7 its size and the data sources, and Chapter 8 the user interfaces and system capabilities. In Chapter 9, ways of making further progress are outlined.

The report concludes with four appendices. These give a list of attendees, suggestions for further readings, a glossary, and a list of acronyms.

The report itself is not a verbatim account but rather an accurate (hopefully) picture of what took place during those two days. It is difficult to convey on paper the enthusiasm that these materials data users expressed as they got involved. The questions quickly turned from "What?" to "When?". In some sense, we hope the reader will undergo a similar change and will become enthusiastically involved in bringing this tool of the furture—computerized materials data—into being for the benefit of the United States.

Chapter 2

computerized access to materials data a progress report

John Rumble, Jr.
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The need

A number of American industrial sectors are undergoing major changes because of increased competition, new engineering developments, and different public tastes. The Nuclear Power Industry is perhaps one that is experiencing the greatest changes, brought about by a reduced short-term demand for electricity, pressure from regulatory groups, and the recent economic downturn. Yet the nuclear industry is still an important force in the American economy in general and a major part of the U.S. energy system.

As in other industries, computers are playing a leading role in these changes, one of which is the maturing of computerized engineering. The ability of computers to design nuclear power systems and then analyze their performance has been a positive factor in the industry.

The tangible products of any of our industries are either made from or result from the use of materials, and the selection of these materials is a key component in determining how viable the product is. The output of the Nuclear Power Industry is energy, and its viability certainly depends on the materials used in the plants that produce it.

Since one major impact of computers is the increased accessibility to information, the technical community has begun addressing how to exploit this capability in meeting the need for computerized materials data.

The goal is quite simple: To provide engineers and scientists with more effective access to materials property data by using computers.

The economic activity related to the use of materials and their performance within the United States alone is enormous. During the last few years, the National Bureau of Standards and the Battelle Research Institute in Columbus, Ohio, have jointly studied the costs of fracture [1] and corrosion [2] in the United States. Using a well-tested input/output economic model, the annual cost of fracture is estimated at more than $120 billion (1982 dollars) and the annual cost of corrosion is even higher, or $143 billion.

As seen in table 1 and figures 1 and 2, a significant fraction of these costs, about $21 billion for corrosion and $28 billion for fracture, could be recovered simply by using "Best Current Practices." Improved dissemination of existing data would help recover some of these potential savings.

Table 1. NBS/Battelle study of economic effects of metallic corrosion in the United States (1982 Dollars)

- Annual costs=$143B (4.2% of GNP)
- $21B (15%) Avoidable by use of best current practices
  - Improve data dissemination system
- $122B (85%) Unavoidable with best current practices
  - Improve data base through research
  - Upgrade corrosion control practices through evaluation and improved application of available data

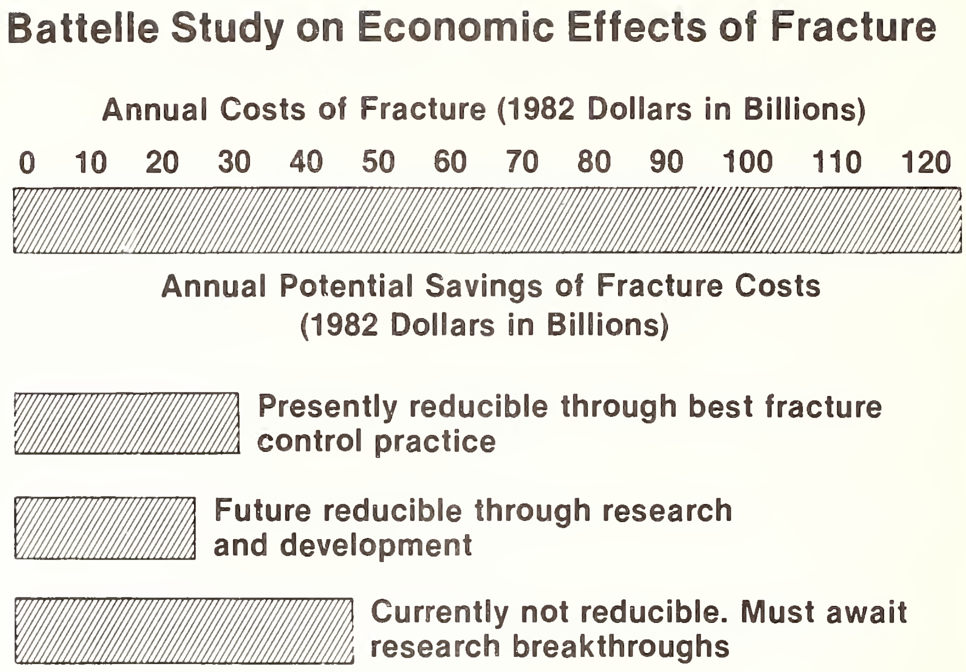


Figure 1. Annual cost of fracture and annual potential savings of fracture costs

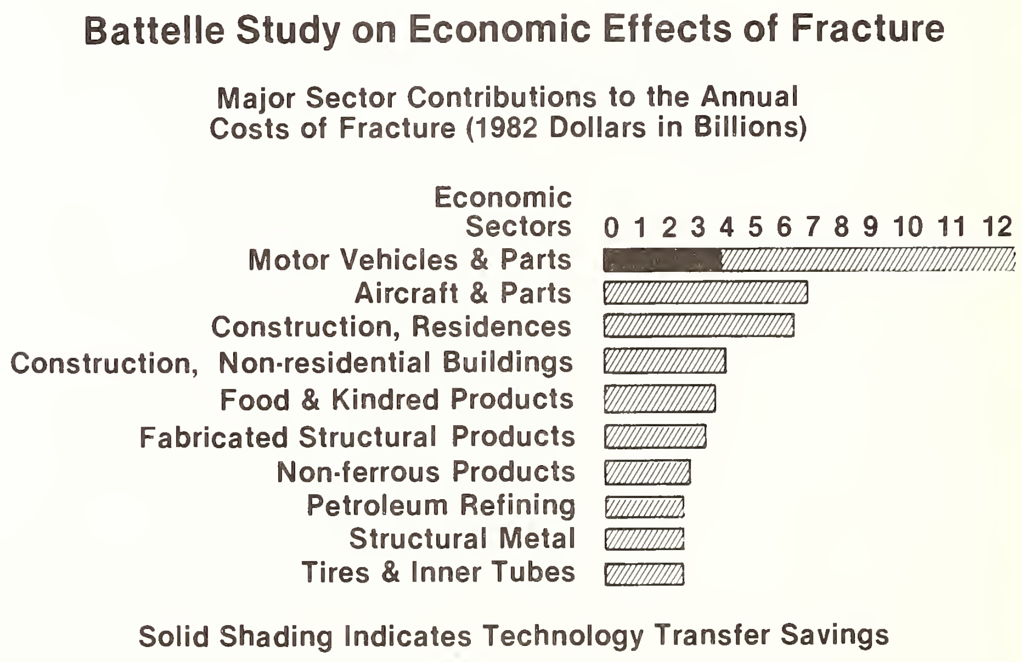
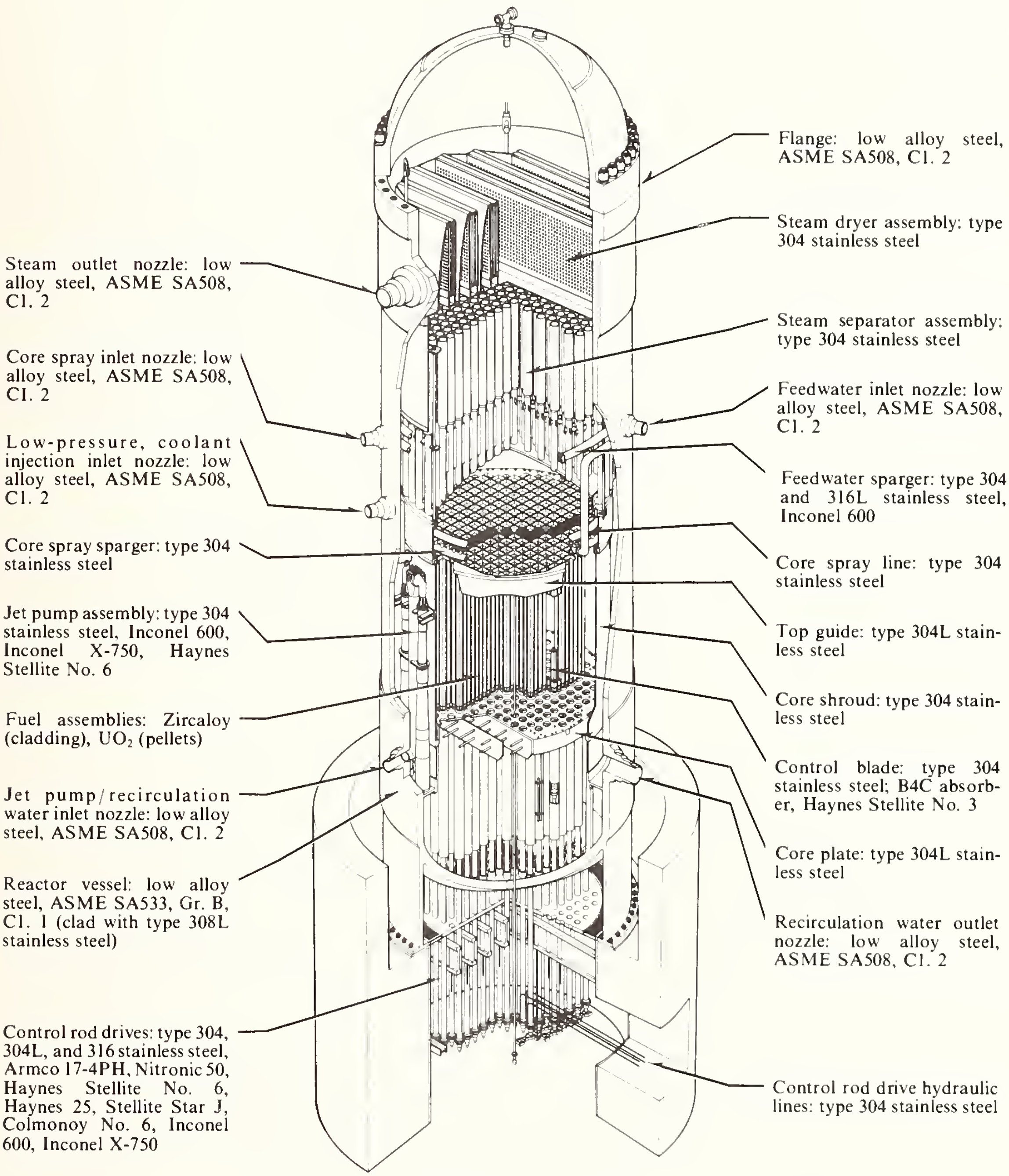


Figure 2. Major sector contributions to the annual costs of fracture

Within the Nuclear Power Industry itself, the performance of materials is extremely important. These are critical in three areas: structures, fuel and heat transfer systems as shown schematically in figure 3. Lapides and Zebroski [3] have calculated that almost half of the average outage of a nuclear power plant is from corrosion-related problems (table 2). These corrosion problems result in reducing the availability of a given plant by about 27 percent.



Source: General Electric Co. The cutaway is of a GE BWR/6 reactor. The listing of trade names does not imply a recommendation.

Figure 3. Materials of construction for a typical boiling water nuclear reactor

Table 2. Representative average outage of nuclear power plants [3]

	Duration (Hrs)	%Total	Corrosion Portion, %
Forced outage (malfunction)	993	35.8	16.9
Scheduled (includes refueling)	1668	60.2	29.3
Regulatory	112	4.0	2.0
	2773	100.0	48.2
Availability factor	$1 - \frac{2773}{8760+1350} = 72.5\%$		

By the end of 1982, over 63,000 megawatts (MW) of electric power were produced by nuclear plants, or about 10 percent of the U.S. total [4]. Since the late 1970's, though construction of new plants has come to a virtual halt, much effort has gone into materials problems related either to life extensions of existing plants or to quality assurance in completed but not-yet-operating facilities.

Often, the problems jeopardizing the investment are quite mundane—for example, bolting. It is not always clear whether these problems are perceived or real and, at $500,000 per day for outage of a 1000 MW plant, the question becomes expensive. When real problems are found, they are often traceable to improper selection or performance of materials.

By these examples, it is evident that materials play an important role in the economic life of the Nuclear Power Industry and that access to better data will in turn lead to better engineering which in turn makes better business.

The Concept

To meet this need for better access to data, the engineering community has begun turning to the computer for help. Over the past few years, a number of meetings and studies [5] have developed a concept that will enable the engineer to use computers to access materials property data. The concept is:

To provide to the technical user, via one phone call, a "gateway" computer with

- Access to many databases regardless of location
- Thesaurus for materials and properties designations
- User-friendly interface
- Capabilities (statistics, graphics, etc.) for massaging of engineering data
- One set of business arrangements with the database builders

In figure 4, a schematic diagram of the database system is given. From the user point of view, the most important feature is that many different databases can be accessed by use of a common set of commands. Upon entering the system, the user would pose a query and be shown a set of databases containing data of possible interest. Upon selection of one or more databases, the host computer would automatically retrieve the desired data for further use such as statistical analysis or graphical display. The data could also be downloaded to a computer at the user's site for other processing as desired.

For such a system to be attractive, the number and coverage of the included databases would have to be sufficiently high to fulfill most of the user's requests, i.e., a nearly complete filling of the matrix in the upper part of figure 4. Though the number of databases now available is limited, this will change in time. The obvious advantage will then be that a large number of data sources—handbooks,

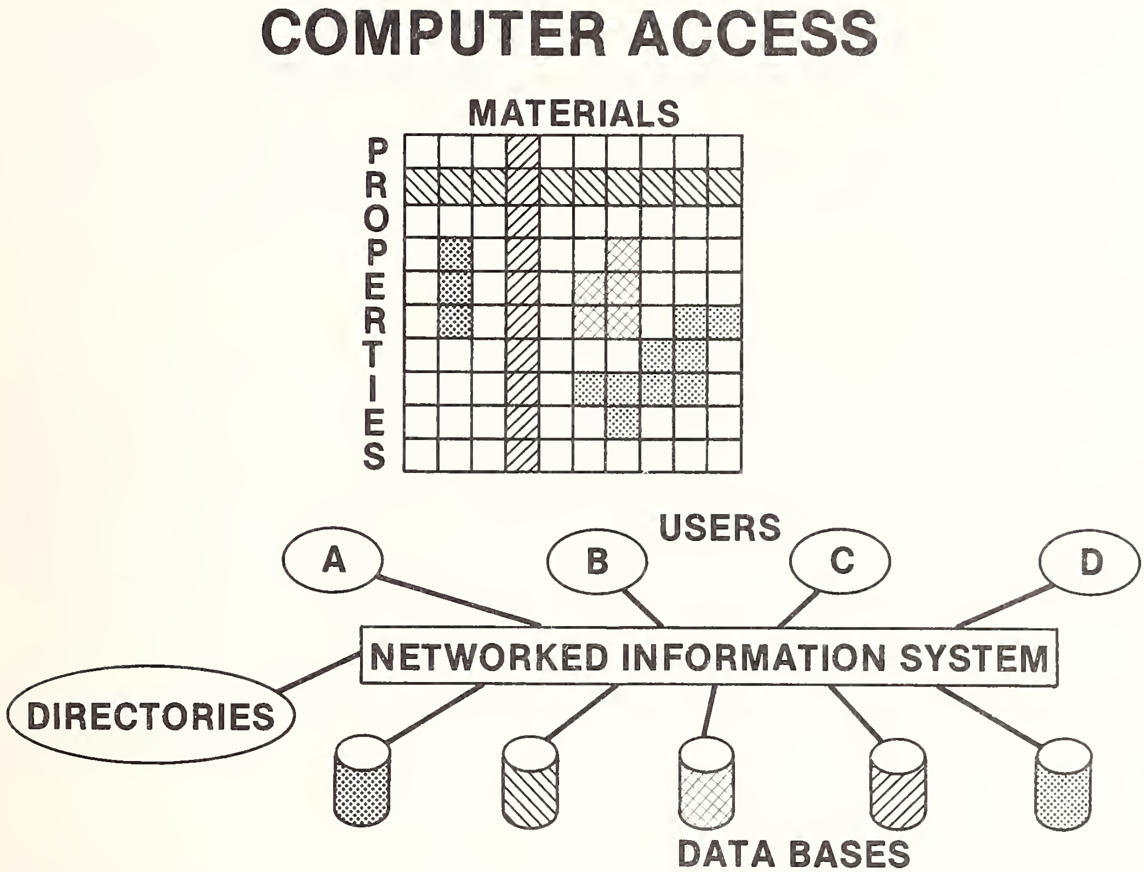


Figure 4. Computerized materials data network (schematic)

data compilations, codes and standards, and vendor information—will be available to the user at his desk. Table 3 lists some other advantages for users:

Table 3. Advantages of computerized materials data system

Compact and comprehensive
Fast access
Increased homogeneity and quality of data
Infinitely flexible formatting
Facile materials comparison
Easy updating
Material/property file inversion
Integration with CAD/CAM,
Other enhanced engineering capabilities
Ensured commonality of database for user population

Database builders and publishers of data also will realize many benefits from the proposed system. Royalties for database use will be collected in a manner similar to that in the existing on-line bibliographic systems. Since the database system will be reaching a larger audience, individual databases should have a larger user community.

An important point to note is that databases will retain identities in a manner exactly analogous to the existing data handbooks, reports, and other publications. As activities by the technical societies and the National Bureau of Standards come to fruition, the number of *evaluated* databases will grow. Since databases will be created by the same groups that now publish data in hard-copy form, an implicit quality indicator will be carried with the identity of the database.

An increase in accessibility of validated materials property data will be of special interest to materials experts. Since they are a group of data users who best understand the nuances and ramifications of materials data, they will still be the group of users who can best use more data.

The new data system will primarily emphasize databases of materials performance properties such as the mechanical and corrosion properties of alloys, ceramics, composites, and polymers. In addition, data on the chemical and physical properties of these materials will be included.

The alternative to a data system such as described above is chaos. Since engineers now use hundreds of data sources, computerized access to each of these individually would mean using hundreds of computers, an impossible situation. Engineers have traditionally met their data needs by collective activities as embodied in the technical and professional societies, working groups, etc. The proposed database system would carry this style into the age of computers.

The Metal Properties Council Effort

Given the need for better access to the properties of materials and a viable concept for meeting that need, the Metal Properties Council (MPC) has undertaken to establish The National Materials Property Data Network, Inc. (NMPDN) to provide on-line access to existing and future numerical data on the engineering properties of materials. Working with many groups in industry and government and with other technical societies, the MPC has become a focal point for the various activities.

Two major studies on this subject of computerized access to materials data are the report [5a] of a workshop held in Fairfield Glade, Tennessee, in the fall of 1982 and a feasibility study [5b] done for MPC itself. Several important conclusions were reached by these studies, which are summarized in table 4.

Table 4. Concordant observations from MPC study and materials data workshop

- Computer access is badly needed but does not exist in any comprehensive way
- Both direct materials information needs and CAD/CAM are driving this development
- An effective and economic system requires cooperative effort
- No significant computer barriers exist
- All stakeholder groups should participate
- A time window now exists to realize an effective system

The last of these is probably the most significant of all. At the present time, the interest in and availability of computers is rising continuously, and our ability to use the computer to deliver data has been well established. Yet the number of computer databases available is still small. The opportunity exists now to build a data system as described previously in a controlled and cooperative manner. In a few years, this chance will have disappeared if a few large databases have been allowed to emerge unilaterally without broad professional participation and endorsement.

The MPC has identified the needed activities as given in figure 5 and, working with the National Bureau of Standards and other groups such as SAE, ASME, ASTM, AIAA, EPRI, and AWS, it has started work in each of these areas.

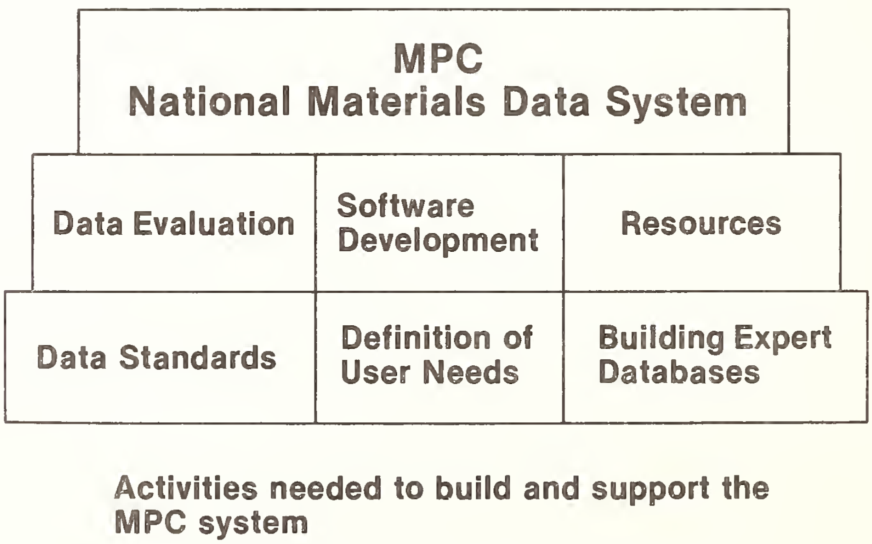


Figure 5. MPC National Materials Property Data Network

Data Evaluation

One ultimate aim of this effort is to improve the quality of mechanical property and corrosion data. Such matters have traditionally been a concern of MPC and it has had many projects on validating data, especially for the Nuclear Power Industry and the ASME Boiler and Pressure Vessel Code. In addition, the Office of Standard Reference Data at NBS has started a number of pilot projects in the areas of mechanical properties and corrosion and is working with selected technical societies to promote other work.

Standards

The use of computers for engineering data will bring about the need for improved standards related to the generation of test data and reporting these results. Since computers allow the intermingling of data to be done easily, more care must be taken to ensure better control of test results. Also, since the computer display terminal allows abstraction of only part of a data record in any one screen, in contrast to the printed page where footnotes and caveats must be visibly confronted, the engineering community must reassess the best mechanism for making the user aware of ancillary information associated with individual data points. Standards societies and code groups must face up to this problem and come up with answers.

Another standardization issue that must be addressed concerns the protocols for communication between databases and the database management system (DBMS) for the whole network. In the gateway concept, the host DBMS will be accessing DBMS's on outside computers. Present ISO communication protocols need to be extended so that extensive software modifications are not needed with each new database added to the network.

Building Needed Databases

The number of comprehensive databases of materials properties is now quite small in comparison to the number of printed data sources. In order for a data system to be most useful, the user must have a high percentage of his/her questions answered. A concerted effort must be made to encourage groups who now publish hard-copy data to build machine-readable databases of the same sort of information. For materials property data, these include the technical societies, trade associations, private publishers, and government research agencies. Because the number of existing databases is so small, an opportunity exists to develop standard formats which should greatly ease the database building process.

Definition of User Needs

An important aspect of the MPC project is to involve the potential user community as much as possible in all parts of the effort, especially with respect to defining what they want from such a system. This workshop is one of a series being held for each of several industries. More will be said about these workshops later.

The MPC has established a task group which coordinates these activities and maintains liaisons with other groups. This task group has set up five committees to oversee and plan individual efforts. These are:

- Materials Designation and Nomenclature
- Testing and Reporting
- Data Evaluation and Analysis
- User Needs
- Computers and Data Suppliers

Resources and Software Development

In early 1984, the Metal Properties Council incorporated a nonprofit organization, the NMPDN, Inc., to lead the business activities associated with the building of the proposed data system. With a board of governors drawn from companies interested in participating in this effort, the new corporation will shortly be selecting an executive director who will be charged with developing the technical and business plans necessary to do the work. Once these are in place, fund raising will begin, and the initial work effort will concentrate on identifying the software and hardware resources necessary. This is discussed further in chapter 5.

This Workshop

As part of these overall activities, a number of user workshops have been scheduled for engineers in individual industries with this, the second, aimed at the Nuclear Power Industry. The goals of the workshop are straightforward:

- To develop a collective *wish list* for a computerized materials data system for users involved in materials selection and component design in the Nuclear Power Industry
- To involve this user community in these overall activities
- To make this user community aware of the benefits of a computerized materials data system

All of the workshops have been designed to maximize participation of the attendees by breaking up into discussion groups to consider in detail a series of questions related to the data systems:

- Specification of the Database
  What materials/property data should be in it?
- Scope Definition
  How many data are needed?
  What data sources must be included?
- User Interfaces and System Capabilities
  How should the system perform?
- Making the System Happen
  How can we speed things up?

The answers to these questions will form valuable input for the MPC effort. Creating a large data system must begin with a clear understanding of the needs and desires of the user community.

Conclusion

As the effort to build a comprehensive computerized materials data system grows, it becomes more obvious that the benefits will be far-reaching. During this workshop, the enthusiasm of the participants grew steadily until the questions became not "What," but "When?".

The engineering community within the United States has banded together many times to advance progress in engineering capability. The computerized materials data system requires such an effort, and the rewards will be substantial.

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Chapter 3

materials data in the nuclear industry present and future

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The most important issue for us to understand as we construct a framework for the workshops tomorrow is that computer-integrated business is a reality today. The critical question for any given enterprise is, in my opinion, whether it can adapt its operations to this new structure rapidly enough to survive. Those who fail to try cannot survive.

Critical to the success of computer-integrated operations is the development of a database on which the various operations can draw for their direction. In companies including engineering functions, this database must include materials properties. So... the question facing us is not **whether** to computerize the materials data in our industry, but rather **how** can it be done most effectively to meet our collective needs.

The database for materials must address the various needs of different participants in our industry. The materials producer must use this base to assure that his product meets required specifications and that his operations are under control. The designer will need the "standard design values" resulting from the analysis of the data, as well as the ability to examine the raw data, to assess the sensitivity of his design to postulated system conditions. Finally, the assessment of materials following extensive service must rely on this database to indicate the effect of environment on the serviceability of a given material. Encompassing all of these needs is the need to know how the data were taken; e.g., temperature control, specimen fabrication, material orientation, test machine calibration, etc. In short, the materials part of the "common database" is complex.

Twenty years ago needs for materials property data were much different from today. Relatively simple properties such as tensile and yield strength, impact strength, hardness, and simple fatigue properties were the basis for design. Today new and more complex properties are necessary to the designer. These include fracture toughness, instrumented charpy testing, and strain hardening exponents which, when combined with an increased awareness of the environmental effects and supplemented by the capability to perform complex computer-controlled tests, have changed the materials selection procedure immensely.

What the future holds for us is both exciting and scary. Clearly, software or computer modeling will become increasingly important and will require test methods we don't know and design approaches we haven't invented. What this workshop will address are these issues as related to the coming computer access to materials proerty data.

We must understand what the existing databases are and how they are accessed. Data change over time. How will databases keep up with these changes? The use of data must be discussed—do we want only the statistically-averaged data, or design minima, or everything? Guidance is needed.

Other issues require equal consideration. Data validation and updating of old files is important. Can data from existing sources be used "as is" or must we start from scratch again? Must we reassess the adequacy of our existing databases?

I don't want to end with a list of questions. We must move ahead with faith in our ability to answer these questions and to solve the problems as we meet them. Automation is no longer optional. We can no longer wait. What we recommend from these discussions will help us in the Nuclear Power Industry to move forward again.

Chapter 4

computerized materials data at EPRI

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In this paper an overview of the development of materials database systems is given as well as brief descriptions of several databases built by the Electric Power Researrch Institute (EPRI) for the Nuclear Power Industry. A number of important lessons about databases have been learned by EPRI and will be discussed.

A schematic outline of the major steps in developing a database is given in figure 6. For materials properties in general, the process begins with raw data from laboratory tests which are recorded by a variety of media which may or may not be machine-readable. After compilation, which often requires manual transcription, checking, and reformatting, the assembled data are loaded into a database. Associated with the dabase is computer software that allows for sorting, searching, etc., and is called the database management system. In addition, other software can provide statistical analysis and graphical displays.

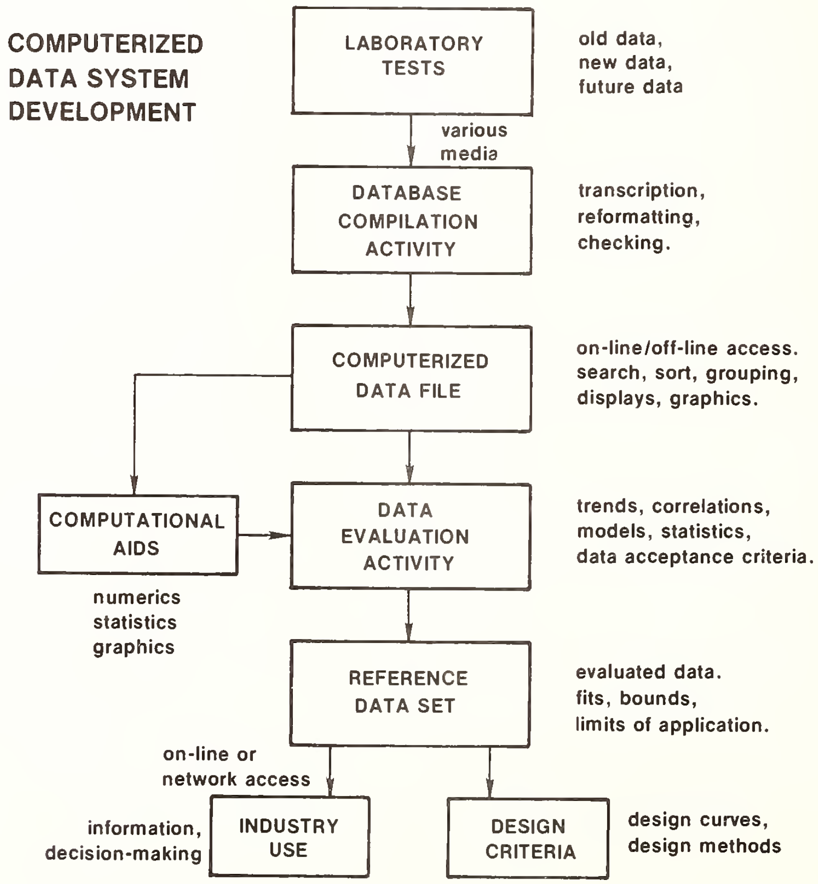

Figure 6. Stages in database development

At this point, depending on resources and priorities, the data can be evaluated by technical professionals. In fact, until the last five years or so, most of the work prior to evaluation was done manually, but computers can obviously greatly reduce this effort as well as provide evaluators with more powerful validation tools.

The result of the validation process is a reference data set or a compilation of recommended values which can be used by engineers in making technical decisions or which can be used to establish design criteria and standards.

Depending on the application of the data, the user community, and available resources, one or more steps of the overall process may be changed or emphasized. For example, data evaluation often results in a useful product itself, and work may not proceed beyond that point.

Over the past few years, EPRI has built a number of databases related to materials used in the Nuclear Power Industry (see table 5). These are available in a variety of ways and contain significant amounts of evaluated data that have been used in determining solutions to problems related to the service performance and life of various components.

Table 5. EPRI databases of materials properties of interest to nuclear power industry

EDEAC—Environmentally-Assisted Cracking
MATSURV—Materials Surveillance
Nuclear RPV Steel
Irradiated NPV Steel
MPC/PVRC Fracture Toughness
AIF/MPC Structural Steel
AIF/MPC Bolting

The EPRI database for environmentally-assisted cracking (EDEAC) [1] was set up to support data evaluation by the Metal Properties Council (MPC)/Pressure Vessel Reactor Committee (PVRC) task group on crack propagation. It contains data from 2400 tests of crack growth rate for nuclear plant materials in light water reactor (LWR). It covers corrosion fatigue and stress-corrosion cracking. The database was created at Battelle.

The MATSURV Database contains information on materials surveillance for nuclear reactor pressure vessels (RPV). The data are supplied by owners of RPVs and are concerned with the fracture toughness of irradiated materials. At present, there is limited access to this database.

A number of the EPRI databases contain several different properties for various steels and other materials used in nuclear power plants. These are summarized in table 6. The data in these databases have been incorporated into a larger database called the Pressure Vessel Steel Database [2].

Table 6. Summary of properties in some EPRI databases

Database	Properties (partial)	Materials (partial)	Reference
Nuclear Pressure Vessel Steel	Tensile Charpy V-notch Nil ductility transition temp. Pre-cracked Charpy Large specimen fracture toughness	7 base metals 25 weldments	3
Irradiated NPV Steel	Charpy V-notch	From 50 reactors and 73 capsules	4
MPC/PVRC Fracture Toughness	Tensile Charpy Fracture toughness (Static & dynamic)	14 metals	5
AIF/MPC Structural Steel	Tensile Charpy Fracture toughness	61 metals	

The AIF/MPC Bolting Database [6] was established for data on materials in bolts used in nuclear utilities. It contains not only composition and manufacturing information including heat treatment, but also various mechanical properties. An additional database has been set up to catalog bolt failure experience.

In addition to the databases themselves, the Nuclear Safety Analysis Center of EPRI has established a system of powerful retrieval and accessing capability to be used with the MATSURV Database. The system includes a versatile, easy-to-use report generator that greatly enhances the value of the database. An interesting feature is CHEMGEN which allows specification of materials by their chemical composition. CHEMGEN allows identification, for example, of plants with materials containing the same amount of copper, nickel, phosphorus, silicon, and associated related data, crucial for nondestructive testing calculations.

The EPRI experience with the above and other databases has made clear some important lessons. First, it is possible to set up materials properties databases which can serve different needs, as has been done for different segments of the nuclear industry. The applications have included:

- Materials screening and selection
- Materials development and improvement
- Model for materials behavior
- Failure analysis and remedy development
- Establishment of design criteria
- Prediction of component life

Cooperation of diverse interests is needed to avoid duplication of effort, proliferation of databases, and loss of continuity in efforts to establish and maintain them. The initial compilation of a database can be difficult and expensive. It is therefore important to plan ahead for efficient data transmittal and checking. It is equally important that the database system has good storage, access, search, retrieval, sort, and analysis capability. Finally, data evaluation is a prerequisite to general use to ensure accuracy and to guard against misinterpretation.

For The Metal Properties Council to be successful in their effort to build a materials data system which links individual databases together, the databases themselves must be put together in an intelligent fashion. The work described above should help as database building increases.

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Chapter 5

The National Materials Property Data Network, Inc.

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During the past few years, The Metal Properties Council (MPC) has become interested in seeing that engineers in American industry have access to valid materials property data via computer. This workshop in fact has been put together as a result of that interest. Until recently, oversight of the MPC activities in this area has resided with our Task Group on Computerized Materials Data which has been led by James Graham of John Deere, Inc.

During the last year, the need for a more formal organization to lead the effort to build the proposed data system has become obvious, and in late 1983, The National Materials Property Data Network filed incorporation papers in Albany, New York. In spring of 1984, these papers were approved.

The purpose of this organization is to develop an overall strategy to plan, design, and build a comprehensive materials data system as described elsewhere in this book. This Network will embrace a number of autonomous databases. A Board of Directors, headed by Ernest Daman of Foster Wheeler, Inc. (table 7), has been named. The Board of Directors has met and authorized the start of work on the national system.

Table 7. The National Materials Property Data Network, Inc.—Members of Board of Directors

John C. Bard The Aluminum Association, Inc.	Wallace Markert, Jr. Babcock & Wilcox Company
Arden L. Bement, Jr. TRW, Inc.	Darrell H. Reneker National Bureau of Standards
Harry E. Cook Ford Motor Company	Charles W. Robinson Energy Transition Corporation
Ernest L. Daman Foster Wheeler Corporation	Kenneth A. Roe Burns & Roe, Inc.
J. Lee Everett Philadelphia Electric Company	Adolph O. Schaefer The Metal Properties Council, Inc.
J. J. Harwood Metropolitan Center for High Technology	George H. Siegel Allied Corporation
John Landis Stone & Webster Engineering Corporation	Charles K. Leeper Combustion Engineering, Inc.
William D. Manly Cabot Corporation	

Following the recommendation of an MPC-sponsored feasibility study, the Board has two immediate objectives—one short-term and one long-term. In the short term, the first step is to hire a President or an Executive Director whose responsibility will be to formulate an appropriate business plan to achieve the stated goals of the corporation and to develop pilot or demonstration projects. The Director will be able to draw on the work of the existing MPC Task Group as well as that of other interested parties. The planning stage is expected to be accomplished within two years.

The longer term goal of the present Board is to shape the structure of the permanent corporation to plan, build, and run the system in the future. Such plans of course will be developed as the work of the new executive, but the Board will be the body to set in motion the plans that are made.

The MPC effort to date has made use of the time and energy of many enthusiastic people to reach the present stage. Not only has the need for computer access been firmly established and endorsed, but also a viable concept to answer those needs has been developed. These latest steps by MPC ensure that in the coming revolution of computerized engineering, computer access to materials data will be available in the United States.

Workshop conclusions

The four major groups of questions

1. Specification of the Database
2. Scope Definition
3. User Interface
4. Making the System Happen

were each discussed by two or three independent task groups who later reported their findings at a plenary session. The findings of each set of task groups are blended in the summary report of the conclusions of the workshop which are presented in the next section of this report. The discussion questions are listed in italics at the beginning of each chapter.

Chapter 6

specification of the data system

How should the database be specified in terms of the following? Give as many examples as possible.

- *Materials*
- *Properties*
- *Precision of data*
- *Validation of data*
- *Source of data*
- *Derived data*
- *Test methods*
- *Other*

Perhaps the most important consideration in building a comprehensive materials information system is the specification of the data to which the user community wants access. The general conclusion of the workshop was that such specification must also reflect applications and economics as well as the more traditional material/property associations. Further, it is critical that the data be well documented as to their reliability, source, and test method. Materials identification must be as precise as possible and equivalencies defined accurately. More specific points follow.

Materials. It is important that materials be designated in several ways: on an individual basis, by classes, and by application areas. Examples of the last two are shown.

Class	*Application areas*
Steels	Weldments
Structural	Bolting
Tool	Hard-facing
etc.	High-temperature
Aluminum alloys	Corrosion resistance
Polymers	etc.
etc.	

The identification of an individual material must be as complete as possible. Not only does the chemical composition—both actual and nominal—as well as its heat treatment need to be given, but also the vendor, time of production, specimen orientation, and location and microstructure if available. Materials identification should include both a unique designation such as is given for alloys by the Unified Numbering System (UNS) but also common and trade names wherever possible. For alloys, much of this information is routinely available, but for ceramics, polymers, and composites, it often is not.

A file of materials specification literals and equivalencies must also be associated with any materials information system. Such a database should be international and cover all engineering materials, not just alloys.

Properties. Because of the nature of the energy source—nuclear fission, the materials data users in the nuclear power industry need properties in addition to those commonly needed in other industries. These include radiation effects and neutronics. A summary of needed properties is given below.

Materials properties	*Economic*	*Applications*
Mechanical	Cost	Weldability
Physical	Availability	Machinability
Thermophysical		Fabricability
Wear and erosion		
Corrosion		
Radiation effects		
Neutronics		

It was recognized that cost information can be highly variable and that often, only relative, or the range of cost is really what is needed. Availability also is a very subjective set of data but a very desirable one.

In addition to the properties themselves, the relationship between the properties, especially for a given application, is important. Consequently, if a user were interested in heat transfer, he would be presented with a list of all properties that need to be considered and not just thermal conductivity. Such information or "metadata," as it is often called, has not as yet been developed in any substantial way for engineering data. The utility of engineering metadata is, however, very high.

Precision, Validation, and Source of Data. Most materials data are used either in designing and making a product or in analyzing why it worked or failed to work. The quality of data plays an important role in the decision-making process. Often, the cost-effectiveness of a design depends on material selection, and the better the quality of data, the better is the selection.

The validation of these data is the key to improving their quality. At present, only a small amount of validation of mechanical property data is being done. As a consequence, the quality of data is implicit and relies heavily on the reputation of the compiler or group issuing the data.

Since the proposed materials data network will access individual databases, the identity of the database source will be evident. In this way, the network will be no different from a library which provides access to numerous individual books. It would be very useful, however, if the data network would add a quality indicator to individual databases and if individual databases would provide traceability for individual data values. The long-term solution is to increase validation activity under the leadership of groups such as MPC, NBS, and the technical societies.

The precision of the data is intertwined with the validation process. Researchers may assign their estimated precision, but this is usually only a rough estimate. Mechanical and corrosion property data are test-method dependent, and independent assessment of the precision through consideration of a large amount of similar data is necessary.

The fact that data have been validated does not mean that the user is absolved of exercising good engineering judgment. But questions of liability for validated databases should parallel those for printed data compilations as long as accepted indications of source are included.

Derived Data. In many cases, evaluated "raw" data are most useful to the user since these data will more accurately portray the full range of possible values. However, derived values often can be equally usable. By "derived" is meant either ranges of values—minimums, maximums, nominal values; combined or synthetic data; curve fitting; and interpolations/extrapolations. While there is a place for each of these, their use must be clearly indicated. It is particularly important that when used, the derivation technique is specified.

It may be most desirable for individual databases to store only raw or experimental numbers but to include the capability to execute calculations on demand. In that case, the functional forms could either be standardized or provided by the user.

Test Methods. A catalog of test methods and associated standards on an international basis will be a necessary part of a comprehensive materials data system. Since so many mechanical and corrosion properties are test-dependent, the capability to compare different test methods will be important.

It was pointed out that a need exists for standard reference materials to calibrate mechanical property test methods and that the National Bureau of Standards should issue such materials.

Other. One type of data often mentioned as being important in improving the quality of product design is *service experience*. Data pertaining to how a given material performed under such-and-such conditions are extremely valuable. Such data often are hard to find and even more difficult to quantify but, when available, they are extremely useful.

In summary, the needs of the nuclear power industry for industrial data are often similar to needs of other user groups with the exception of the radiation effects on various materials. The expense of replacing failed or suspect components is costly, and convenient accesss to validated materials data will bring significant savings.

Chapter 7

scope definition

- *What is the minimum size system that would be useful?*
- *What traditional data sources in your industry/organization must be included?*
- *What are the significant gaps in reliable materials data that have to be filled for your applications?*
- *Can data from recognized, reputable sources be accepted as input or must the data be reviewed again?*

The primary criteria for determining the size of a materials data system are that it should contain answers for the majority of the questions asked. In the Nuclear Power Industry, there are two generic applications of materials, namely:

- Structural
- Fuel assembly

From this point of view, the number of materials is probably less than in many other industries. But in another sense, the range of materials is large when other related applications are included:

- Piping and Pressure Vessels
- High-temperature Systems
- Heat Exchangers

Many of the demands for materials data in the industry are not related to the design of new plants and equipment, but instead to maintenance, repair, and retrofit of those already in place, including many small components. So for highest utility, the materials data system should contain data for a wide range of ferrous and copper alloys.

A better way to indicate the range of materials and properties is to list some of the traditional handbooks used by engineers in this field (table 8). While not inclusive, the list as a whole would provide answers to many questions. Unfortunately, few, if any, of these are machine-readable, and no assessment has been made of discrepancies, gaps, and contradictions.

Table 8. Materials data handbooks commonly used in the nuclear power industry

	Ref.
ASME Code—Section II	1
NRC Regulatory Guides	2
Stainless Steel Handbook	3
Corrosion Handbook	4
American Welding Society Handbook	5
Super Alloy Handbook	6
International Metallic Materials Cross Reference	7
American Society for Metals Handbook	8
Military Handbook 5	9
Welding Research Council	10
Metcut Machining Data Handbook	11
Structural Alloys Handbook	12
Aerospace Structural Metals Handbook	13
Mechanical Properties Design Data Reports	14
Properties of Heavy Section Nuclear Reactor Steel	15
Worldwide Guide to Equivalent Irons and Steels	16

One very positive feature of using the existing handbooks in a database is that each has an identity of its own, which means that some validation of the data has already been accomplished. Therefore, additional review will be needed only by exception. The situation is different with respect to data that have only been published in a journal or a report. Usually the authors have not assessed the quality, and therefore an independent evaluation is needed. The computer itself has become a tool to help do this. Documentation of the validation process is most important. The conclusion is that validation is necessary for data to be useful, and the validation process to create a handbook in published form is good enough for the computerized form. In general, there needs to be an improvement in the quality of mechanical and corrosion property data, but it is not a barrier to building a materials data system.

A particular problem in "computerizing" such printed handbooks is how to digitize graphs and autographic records and how to handle the necessary textual notes and explanations within the limited character-space format of the terminal screen.

A major important traditional source of materials data is the vendor/supplier data sheets. A number of trade associations have put together some of this information. Such sets might also be candidates for computerization.

Yet, even taken all together, all the existing handbooks and compilations do not provide all the materials data that are needed. For example, actual stress-strain curves are often needed rather than just the yield strengths. There are other examples of where original experimental data have been reduced to fewer numbers. These include the use of nominal values, minimum design values, etc. Now that the full power of the computer can be made available, some of these data gaps caused by compression could be avoided by more complete reporting of results.

Other gaps are caused by the fact that some data are difficult to characterize. Examples are friction, wear, corrosion, and weldments. In each case, it is hard to specify the exact internal structure and stress state, external loading conditions, environment and surface parameters, and processing history necessary fully to qualify the test data. In any case, the ability to use these data in design is subject to problems. These data, however, really reflect the possible service performance of the materials, and efforts to improve their quality and application would lead to potentially better performance.

Yet again, one can classify gaps in existing materials data in an entirely different way. First some data are obscure, or hard to find or know about. It is often impossible to track down old data that are published in foreign journals or government reports. However, once they are found, their use is straightforward and relevant. A comprehensive materials data system with a diversity of individual databases does offer the possibility that these data can be found, but an effort will be needed to take advantage of that possibility.

Another class of data missing from the usual collections are those considered proprietary. In a contracting and competitive industry such as nuclear power, this can be a very complex situation. Here the problem is that someone can know where the data are but cannot get to them. A materials data network can also help in the case of new data, allowing for easier updating. It can also aid in identifying nonexistent data and alert both data generators and users that important values are missing.

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Chapter 8

user interface and system capabilities

What kinds of system capabilities should be built in?

- *Number look-up*
- *File inversion*
- *Statistical analysis*
- *Graphical display*
- *Computational packages*
- *Print output*

What auxiliary files should be built in?

- *Tutorial programs*
- *Materials designation cross-references*
- *Units conversion*
- *Internal validation*

What kind of CAD/CAM capabilities should be available?

A consensus was reached by all groups discussing this topic that the system capabilities defined in the question were *all* needed. They were in fact the minimum required for the interface to be user-friendly. Several other needs were also identified.

Downloading privileges are considered necessary. For many users, the results of a particular search are used as input to further computer manipulation, either on a personal computer or on another local facility. The user will want to load this information onto local files for further access, and there should be some flexibility in how this downloading can be formatted.

It was suggested that the system allow for user-defined files, either large ones containing a proprietary database or small ones for further reference. There should also be a provision for electronic user feedback so that minor problems, suggestions for improvements, etc., could be brought to the attention of the system operators.

Graphics capability was viewed as not merely "nice to have" but **essential** for many types of engineering analysis: qualitative comparison of materials, comparison with theory, testing empirical property correlations, display of raw data for sensing of "outliers," abnormal distributions of data, etc.

The question of how to make sure the engineer properly uses the data presented was discussed. It was strongly felt that only tutorials relating to the use of the system, e.g., control commands, should be available. Tutorials on materials engineering should *not* be present. Yet there was also the feeling that the user should be as aware as possible of relevant information outside the system. It was suggested that an option be included to provide, for each material in the system, primary constraining properties such as "cost $100/pound" or "should not be used in seawater." However, since much of this information is not contained in present-day handbooks, the ASM Metals Handbook being one notable exception, the question of how to develop such information was raised, with no conclusion being reached.

An extension of this view was the suggestion of including experience whenever possible. As can be imagined, such enhanced databases would be extremely difficult to build and, more realistically, would begin to approach "expert systems." It was pointed out that the proposed system is aimed at providing better access to data for input into the materials selection, not computerizing the materials selection process itself.

There was general agreement that comprehensive materials designation cross-references and units conversion capability will be necessary. Internal validation and consistency checks were also seen as important. A number of standard algorithms often used in nuclear engineering were desired, including:

- Neutron fluence translators
- $CVN \rightarrow K_{I_C}$
- da/dn parameter calculations (ΔK_{th}, C, and M)
- Larsen-Miller parameters
- Dorn parameters

While CAD/CAM is regarded a primary driving force for computerized materials data, it is regarded as unfeasible that the gateway system itself have CAD capability. In fact, because CAD software will become so application-dependent, it will be more available to users on their own computers. This conclusion matches that of other workshops.

Another consideration is that such systems will have to be made suitable for student use—not just as a convenient means of access to data but in order to teach modern design procedures.

Underlying all of the above discussion was one very important theme: that the user interface be truly *user-friendly.* Though the term user-friendly is overused, here it has a specific meaning: that an engineer can use the proposed materials data system *without* having to turn constantly to manuals or telephone hotlines, *without* having to adopt new nomenclature, and *with* being able to do simple searches easily, to make more difficult searches straightforwardly, and to manipulate data without hassle. With a system like this, acceptance would be no problem.

Chapter 9

making the system happen

- *How can industry, technical societies, and government make sure computerized access to materials data becomes a reality?*
- *What kind of technical committees need to be established and under what auspices?*
- *How can we ensure that the user community gets what it wants from such a system?*
- *How can we persuade our individual companies to support this system?*

The conclusion of the workshop was that industry, technical societies, and government must work together cooperatively to bring computerized access to materials data into being. Since engineers in industry will be the largest users, it is appropriate to turn to industry for the bulk of the support needed to build the system. The MPC effort to establish its oversight corporation was highly commended, and the participants indicated that they would work to alert their managers of their interest in the system.

There was a consensus that government groups, such as the National Bureau of Standards, should continue to act as facilitators for working to bring different groups together to cooperate. In addition, the need for a demonstration system was put forward, and the group felt it was appropriate for the government to provide the necessary resources. The demonstration system should be large enough to exercise the gateway concept fully, yet be designed and implemented for use as a building block by the MPC and other private sector groups for their own systems.

The workshop felt it was important that an active technical advisory committee be formed to provide guidance during the demonstration project. It was suggested that MPC, ASTM, NBS, and other technical societies establish committees to resolve standardization issues, to evaluate and review data, and to encourage database building. In addition, advisory committees from various industries, such as the Nuclear Power Industry, should be set up to help plan the system and maintain user interest during the building stages.

Once set up, the demonstration system will be a valuable tool for involving the general membership of various technical societies through its use at meetings and exhibitions. It should be coupled with a more active publicity program which should feature news articles in society news magazines and talks at technical meetings and before local chapters.

The report from this workshop, similar to those from the meeting for the Ground Vehicle Industry and the Fall 1982 Workshop at Fairfield Glade, Tennessee, should be widely circulated. Future workshops for other industrial users will be very useful, especially with advance publicity.

It was suggested that an in-depth review of individual databases would be extremely useful since the information is not generally available. A proposed study of the economic benefits of such a system was also endorsed.

In conclusion, the most important recommendation was that definite action be undertaken towards building the system. A demonstration system will be extremely valuable and would help generate industrial support for a more comprehensive system.

Appendix A
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Appendix B
further readings

Prior to a workshop on a similar subject, held in Fairfield Glade, Tennessee in 1982, a bibliography was prepared of 29 articles of importance in the field of computerized materials data. Since that time, several additional articles and books on this subject have appeared. The entire list is given here with hope that the reader will find value from the additional ideas contained therein.

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Appendix C
glossary

algorithm A term used to describe a procedure or set of procedures for solving a problem.

application software Special programs (see software) that actually use the computer and its auxiliaries to solve a problem identified by a user.

CAD/CAM Computer-Aided Design/Computer-Aided Manufacturing: these terms have become descriptive of the use of computers—first to design products, then to produce them.

central facility A computing center at some institution that provides services to several users.

computation package Software that calculates data by solving mathematical equations.

computerized (computer-readable, computer-searchable, computer-processible, machine-readable) Converted to a form (digitized) which can be stored, read, and retrieved by a computer.

computerized access The use of computers to find information or data.

computerized engineering A term that has arisen to describe the use of computers in the full range of engineering activities, from design and analysis to manufacturing and testing.

computer modeling The process of solving a mathematical model of a physical phenomenon by use of a computer.

data That subset of scientific or technical information or facts that can be represented by numbers, tables, graphs, models, or symbols (sometimes called *information bits*) or *data bits*.

data bank A collection of information or data in numerical form, or equivalent, for a particular subject area.

database A collection of computerized files, whether in numerical, alphabetical, alpha-numeric, tabular, graphical, or mathematical form.

database generator (producer) An organization that develops and maintains the database. In the bibliographic field, these often are the abstracting and indexing services which also produce the paper copy service.

database management system (DBMS) A computer system with management and administrative capabilities for control of record storage, selection, updating, formatting, and reporting from a database.

database vendors Information-supply companies that purchase or lease a number of databases, develop searching and billing procedures, arrange for telecommunication networks to make the search services available, promote the use, train potential users, and charge user fees.

data evaluation (sometimes called validation or appraisal) A multistep process involving examination and appraisal of the data in question, assessment of experimental technique and associated errors, comparison with other experimental or theoretical values, reanalysis and recalculation of derived quantities as required, selection of "best" values, and assignment of probable error or reliability.

data item (also data element) The smallest unit of data that has meaning in describing information; the smallest unit of named data.

data system See *information system*.

demonstration system Here, this refers to a small data network which will show that computer access to materials data via a gateway system works and is feasible.

derived data Property data that result from a combination of stored property data by use of empirical or theoretical models.

descriptors The word definitions of the characteristics of the material, property, test, environment, etc., necessary to define the data.

digitized Converted into computer-readable form wherein all information units (letters, numbers, symbols, graphs, picture elements) are represented by on-off sequences of electronic impulses.
display The graphic representation of data on an output device.
distributed system A decentralized system of computer utilization through an electronically connected network of computers that are able to interface with each other.
documentation Records or documents kept to show how a computer system, language, or program works; changes made to the original design and reasons for them.
download Transfer of a large body of data from one computer memory to another storage location.

evaluated data Data that have been examined by experts who assign indicators of the data's quality and reliability.
expert system A computer system design based on logic.

field A subdivision of a record in a data file.
file inversion Implementation of a computer program that searches all files for a particular property or combination of properties and then "inverts" the record to display all materials having the desired property or properties.
format A "template" used for the input and output of data values.

gateway A computer that primarily acts as a switchboard or node for a number of components of a total information system. It should contain a master index to the available resources (databases), connect authorized users automatically to any of these databases, translate protocols and formats, permit the aggregation of reasonable amounts of extracted information and data, and offer a resident library of software tools by which these data can be postprocessed, analyzed, and displayed.
graphics As commonly used, this is software that generates graphs and other computer-drawn figures.

hardware Any piece of physical equipment associated with computer processing and communication networks.
help file A file of tutorial instructions or explanations that can be invoked when the user is baffled by terms appearing on the screen or is unable to ascertain his or her status within an operating program.

information Knowledge acquired or derived; knowledge that can be collected, stored or filed, retrieved, and used to create other knowledge. To be useful, information must be pertinent, comprehensible, dependable, and convenient.
information/data center A specific organization committed to handling a set of material under a formalized information/data storage and retrieval system. If the stored material is reviewed by experts in the field, the activity is called an information (or data) analysis center.
information system (sometimes information storage, retrieval system) A mechanism for acquiring, filing, storing, and retrieving an organized body of knowledge, together with the access mechanisms and other user assists.
input/output economic model An analysis model developed by W. W. Leontief to estimate the direct and indirect costs and benefits for a given economic situation.
interactive The term applied to the interplay between the computer and the user at a terminal.
internal validation and consistency checks The procedures included in software to make sure that data are reasonable and expressed in proper units. For example, a birth date cannot be greater than the present date and must show month, day, and year. Often data are combined to make sure that every item is consistent within specified limits.

keyword A term used for indexing or retrieval purposes, either *derivative*—keyword-in-context (KWIC) and keyword-out-of-context (KWOC), or *assigned*—usually from a controlled vocabulary or thesaurus.

language The means by which users describe to the computer the kinds of operations to be performed. Machine language is the set of instructions wired into the computer. Query language is especially designed to aid the user in searching a database.

literals Long strings of characters processed by the computer without any transformation or reformatting, as opposed to numbers, etc.

machine-readable Information that is digitized and can be stored, read, retrieved, and manipulated by a computer (see *computerized*).

material identification The data necessary to specify a material. For alloys, ceramics, and polymers, this includes chemistry, molecular weight, microstructure, heat treatment, and many other data.

material performance For the purposes of this report, these are mechanical, corrosion, and physical properties of a material that help determine the service life of a product.

materials designation cross-reference A table of synonyms for specification of a material. It can contain trade names, common names, and chemistry.

materials profile A listing of desired properties for a particular material with quantitative values specified whenever possible in terms of allowed range, minimum, maximum, etc.

metadata A detailed description of data in a database that provides systematic information for users, application programs, and database management software. Metadata itself can be manipulated and searched.

network A communications system, wired or radio-linked, which connects computers and users.

number look-up The process of searching a database for the values in one or more data descriptors when some data items are specified. An example would be finding the tensile strength of a designated material at a given temperature.

numerical database A database containing information in numerical form, such as physical and chemical properties or quantities manufactured.

on-line Access to an information system by a user in what appears to be direct, constant connection to the operating computer via a computer terminal.

personal computer Usually refers to a desktop computer with CRT display, keyboard, and sometimes disks, that sells for a few thousand dollars or less.

post-processing facilities The software that is used to manipulate and display data retrieved from a database.

primary constraining property This is the property that most likely determines that a material will not be used. Examples are *cost—$100/lb* or more qualitative such as *corrodes rapidly in sea water*.

program (software) A set of instructions that tells the computer exactly what to do, how to do it, and when.

proprietary database A database which contains data that are considered the property of a particular organization.

protocol A formalized set of conventions for establishing and maintaining contact between the communicating devices. Possible functions can include sign-on/sign-off procedures, error checking, and recovery.

quality indicator A quantitative or qualitative value which expresses an evaluation of the reliability and validity of data.

query language The commands which allow a user to ask questions of a database, such as "search," "combine," etc. This is a major part of the user interface.

raw data Property data from a given test not yet evaluated, analyzed, or combined with other test data.

record A logical subdivision of a data file or database. A record contains all the data bits associated with one entity in the file.

reference data set A set of data that has been evaluated by experts and found to be accurate, reliable, and of high quality.

report generator A computer program that can take files of numbers and textual material and produce a printed version of text and table suitable for a report. Often associated with a database management system.

scope definition The identification of the size and contents of a database.

software The step-by-step set of computer programs and documentation which function to control the hardware elements in such a way as to perform a given task (see *program*).

standards In the context of this report, these are the procedures and rules to generate and report data. These are usually developed collectively by engineering groups.

statistical packages Software that can perform standard and nonstandard statistical analyses on a set of data.

synthetic data These are the individual data points that are derived from use of curve fits and interpolation schemes.

system See *information system*.

telecommunications The electronic communication that ties the user and terminal, printer, and other peripherals to the computer and to the databases to be searched.

translator In the context of database management, this is software that transforms one set of commands into another.

tutorial programs Software that is designed to instruct a user about some subject. In the context of a database management system, it often is used to explain the definition of data items or the possible use of the data.

units conversion The procedure whereby software will display a property value in whatever units are specified by the user. Often, the range of possibilities is quite limited.

update An editing process by which data are corrected or added so that the database reflects current knowledge.

user friendly Computer system characterization—easy for a novice user: simple English instructions, prompts, menus, etc., "fail-safe" programs, and special keys.

validated data See *evaluated data*.

Appendix D
acronyms

AGARD	Advisory Group for Aeronautical Research and Development (operated by NATO)
AIAA	American Institute of Aeronautics and Astronautics
AIF	Atomic Industrial Forum
AIME	American Institute of Mining, Metallurgical and Petroleum Engineers
AISI	American Iron and Steel Institute
ANS	American Nuclear Society
ASIS	American Society for Information Science
ASM	American Society for Metals
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CINDAS	Center for Information and Numerical Data Analysis and Synthesis
CODATA	Committee on Data of the International Council of Scientific Unions
DBMS	Data Base Management System
DOE	Department of Energy
EDEAC	EPRI Database on Environmentally-Assisted Cracking
EPRI	Electric Power Research Institute
GNP	Gross National Product
LWR	Light Water Reactor
MPC	The Metal Properties Council, Inc.
NASA	National Aeronautics and Space Administration
NBS	National Bureau Of Standards
NBSIR	National Bureau of Standards Internal Report
NDAB	Numerical Data Advisory Board
NMPDN	National Materials Property Data Network, Inc.
NPV	Nuclear Pressure Vessel
NRC	National Research Council
NTIS	National Technical Information Service
OSRD	Office of Standard Reference Data (NBS)
PVRC	Pressure Vessel Research Committee (MPC)
PVS	Pressure Vessel Steels
RPV	Reactor Pressure Vessel
SAE	Society of Automotive Engineers
UNS	Unified Numbering System (U.S.)

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11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report summarizes the recommendations of a Workshop in Computerized Materials Data as related to engineers in the Nuclear Power Industry. Four areas of discussion are featured: the content of a proposed data system; its size and data sources; the user interfaces and system capabilities; and ways of making further progress. In addition, changes in the use of materials data in the Nuclear Power Industry and progress-to-date in computerizing these data are presented.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

computerized data; computerized materials data; corrosion data; gateway systems; materials data; materials selection; mechanical properties; national materials property data system; nuclear industry; nuclear power; on-line systems

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