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Journal of Nuclear Materials 233-237 (1996) 1593-1596

journal of nuclear materials

Section 22. Data bases and data nets

ITER material properties handbook [1]

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Abstract

In December 1993, the ITER Joint Central Team authorized the creation of a Material Properties Handbook. This handbook is a cooperative activity between the four parties of ITER (Japan, the European Union, the Russian Federation, and the US). The US Home Team has been selected to coordinate the documentation and publication, while all four parties provide data. Since its creation approximately 18 months ago, the effort focused on organizing the handbook, developing a common format for use by all of the parties, demonstrating the ability to electronically transfer files between the four parties, generation of data pages, and release of the Handbook for review by members of the ITER Joint Central Team.

1. Introduction

The design of many ITER components depends strongly on the accuracy and reliability of the material property data. Uncertainties in the material properties can be caused by inaccurate data, errors in interpreting the database and uncertain sources of the data. Material properties can come from a variety of sources, some developed from actual data, while others are extrapolations from similar materials. To minimize such uncertainties and to provide a single reference source of material data for designers, the ITER JCT commissioned the Home Teams to develop a Material Properties Handbook.

Currently there are a number of data books and databases available which contain information on materials of interest to fusion. Some of these are: the US Materials Handbook for Fusion Energy Systems, IAEA Fusion Reactor Plasma Facing Materials Data Bank, IEA Fusion Materials Handbook, JAERI Material Performance Database (JMPD), the EU's High Temperature Materials Data Bank (HTM-DB), and the Russian Federation's PFC materials database, which is a PC Windows based system.

Many of these databases have restricted distribution and cannot be used by all of the ITER participants or do not contain all of the materials of interest to ITER. The collection of information from these sources and from the open literature, plus the expert evaluation of the information, is a principal objective of the Material Properties Handbook task.

The ITER Material Properties Handbook (IMPH) was formally created on 13 December 1993 with the release of ITER Task Agreement S72TD 04 93-11-23 FU. The Handbook is the responsibility of the San Diego Joint Work Site of ITER. The US Home Team is responsible for coordinating this activity along with equal participation among the four ITER partners (Japan, the EU, the RF, and the US). Actual work began early in 1994. One of the first challenges was to develop a common format for use by all of the parties.

2. Development of a common format

In looking at the various handbooks available, each has a different format because each is designed to serve a different customer who has a different need for the data. As a result, the first step in developing a common format is to know who is going to use the handbook and what form of the data (format) they need to do their analysis. In the case of the ITER project, there will be a variety of users each wanting a different form of the data. For example a designer who is trying to size the structure would be interested in a trend curve which shows the

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[1] Work performed under Subcontract #32X-SN767C with Martin Marietta Energy Systems, Inc., acting under prime contract #DE-AC05-84OR21400 with DOE.

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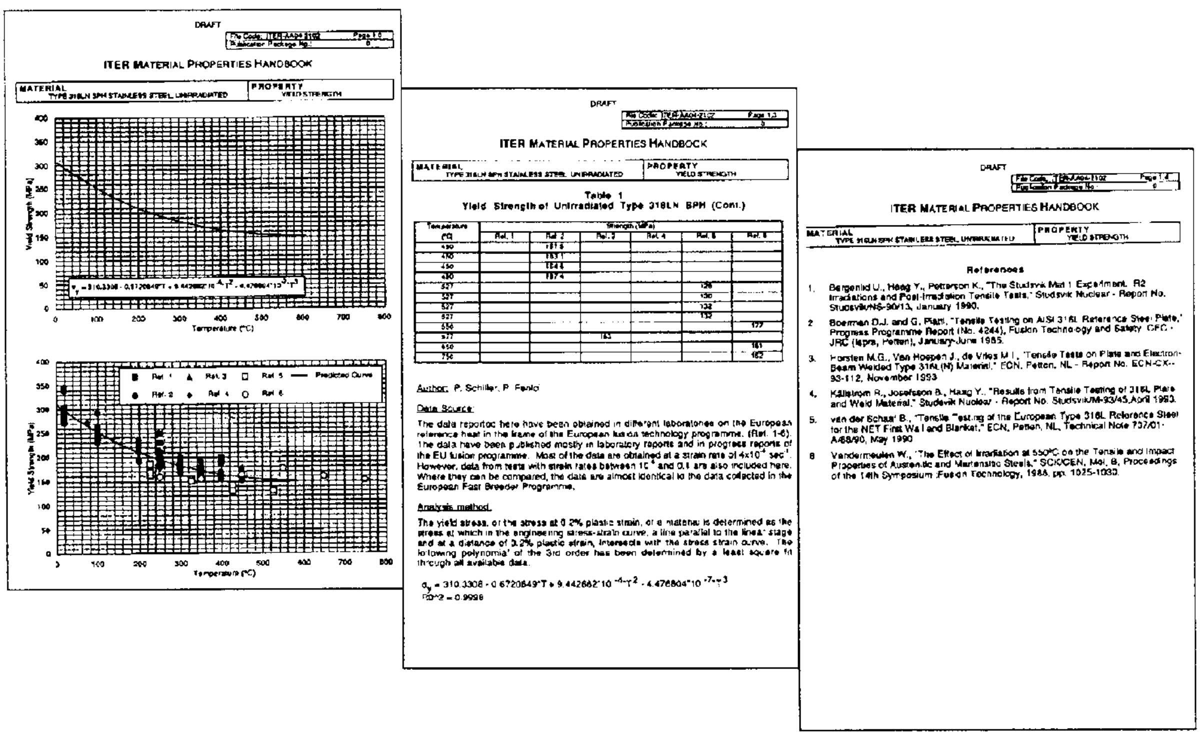
PII S0022-3115(96)00202-4

change in properties with temperature. A structural analyst or thermal analyst is interested in an equation which can be incorporated into a finite element analysis code. A safety engineer or an analyst trying to develop a design criteria is interested in the distribution of data around the predictive curve, while a materials engineer or experimentalist is interested in the source of data along with the actual data points which can be compared to current experimental results. Considering these factors, the format shown in Fig. 1 was selected. Two graphs are shown on one page. One of these is a trend curve, which shows the change in properties as a function of temperature or other appropriate variables (see Fig. 1). Included on this curve is the mathematical expression describing the curve. Below the trend curve is a second curve which plots both the predictive curve and the actual data points that were used to develop the curve, along with the references from which the data was extracted.

Following this information is a tabular listing of the data points along with descriptive information relating to how the data was analyzed and the references where the data was obtained. The tabular data is in a format that can be used in subsequent analysis with new experimental data. The tabular data can also be used directly in some analysis codes and hand calculations. The establishment of a common format is only the first step. The second step, which is much more difficult, is the form of the publication. In ITER there is a desire that the data pages be available in both paper (hard copy) and electronic format, which can be read by all four parties regardless of computer configuration. The electronic format is the most difficult, primarily because of differences in computer software and types of computers. The situation is further complicated by a desire to have the handbook on a server so that all users would be assured of an up-to-date version. Since the format selected by ITER contains a mixture of both text and graphics, that means that the users need to have the same software to interpret the text and graphics and the software must be compatible with various computer platforms. In talking to the other ITER partners, it was found that each had a different graphics program and a curve fitting program along with different computers. For example, the ITER project uses Macintoshes. Europe, Japan, and the US use both IBM-compatible and Macintosh machines, while Russia uses mostly IBM-compatible machines. The only common thread is that all of the participants can read text-based documents. Microsoft Word was selected as a common text-based format because Word is available on both IBM-compatible and Macintosh machines, it allows the use of embedded graphics, and it is already being used by most of the participants. Because of incompatibilities between Word 6 and Word 5.1a (used by the JCT), all of the Material Properties Handbook documents are in MS Word 5.1a. The tables



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ITER MATERIAL PROPERTIES HANDBOOK

MATERIAL TYPE 316LN SPH STAINLESS STEEL UNIRRADIATED | PROPERTY YIELD STRENGTH

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MATERIAL TYPE 316LN SPH STAINLESS STEEL UNIRRADIATED | PROPERTY YIELD STRENGTH

Table 1
Yield Strength of Unirradiated Type 316LN SPH (Cont.)

Temperature (°C)	Strength (MPa)					
	Ref. 1	Ref. 2	Ref. 3	Ref. 4	Ref. 5	Ref. 6
430		181.6				
410		183.1				
450		184.4				
480		187.4				
527					128	
527					130	
527					132	
527					132	
550						177
577			163			
650						161
750						162

Author: P. Schiller, P. Fenici

Data Source:

The data reported here have been obtained in different laboratories on the European reference heat in the frame of the European fusion technology programme. (Ref. 1-6). The data have been published mostly in laboratory reports and in progress reports of the EU fusion programme. Most of the data are obtained at a strain rate of 4x10⁻⁴ sec⁻¹. However, data from tests with strain rates between 10⁻⁴ and 0.1 are also included here. Where they can be compared, the data are almost identical to the data collected in the European Fast Breeder Programme.

Analysis method.

The yield stress, or the stress at 0.2% plastic strain, of a material is determined as the stress at which in the engineering stress-strain curve, a line parallel to the linear stage and at a distance of 0.2% plastic strain, intersects with the stress strain curve. The following polynomial of the 3rd order has been determined by a least square fit through all available data.

$\sigma_y = 310.3308 - 0.6720849 T + 9.442662 \cdot 10^{-4} T^2 - 4.476804 \cdot 10^{-7} T^3$
$R^2 = 0.9998$

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Fig. 1. Format of data pages used in ITER Material Properties Handbook.

contained in the data pages are compatible with Microsoft Excel which can be imported into other data analysis programs such as DeltaGraph Pro or KaleidaGraph for subsequent analysis with results of newer experiments. For easy access, the handbook is stored on Unix-based servers located at Joint Central Team sites in San Diego and Garching, Germany. Rather than having a long list of files that the user would have to go through to find a specific material and property, the handbook is organized like a set of file cabinets, containing specific properties of materials. The structure is actually a nested sequence of Macintosh folders. To those not familiar with the Macintosh, the highest level structure is essentially a file cabinet named for a class of materials: metals, ceramic material, composite materials, lubricants, etc. Within each cabinet is a drawer containing a generic class of materials. For example in the metals drawer are a series of folders entitled austenitic steels, ferritic/martensitic steels, nickel base alloys, copper alloys, beryllium, and so forth. Contained in the drawers are folders on specific materials. In the case of austenitic steels, the folders would be 316, 316 LN, 316 LN SPH, JN1, and RF-20Cr–16Ni–6Mn. Within each folder are separate files, each file consisting of all the data pages associated with a particular property such as tensile, elongation, and thermophysical properties. While this appears cumbersome, in practice it is easy to use and allows quick extraction of a complete file or data page. An additional benefit is that it can be tied into a data retrieval system or networked data bank. Once the format was established and an access path for obtaining data pages developed, the next step was to actually develop the data pages.

3. Operation of the handbook

As mentioned earlier, the handbook is managed by the ITER JCT in San Diego. At the kick-off meeting held in San Diego in early 1994, there were representatives of the participating Home Teams as well as the other JCT sites. At this meeting it was agreed that the highest priority for the development of data pages would be for the in-vessel components (divertor, first wall, blanket, and shield) and the next priority would be the ex-vessel tokamak components (magnets). The in-vessel components are being designed in Garching, Germany while the ex-vessel components are being designed in Naka, Japan. The organizational relationship between the design sites and the other participants is shown in Fig. 2. In operation the design sites (Garching and Naka) define the data needs and the priorities. The San Diego site (the integration site) consolidates this information. Task group meetings are then held to organize the work and report the results. Discussions are held among the parties to see which party has the greatest amount of information or is willing to accept responsibility for the preparation of the data pages. One Home Team is

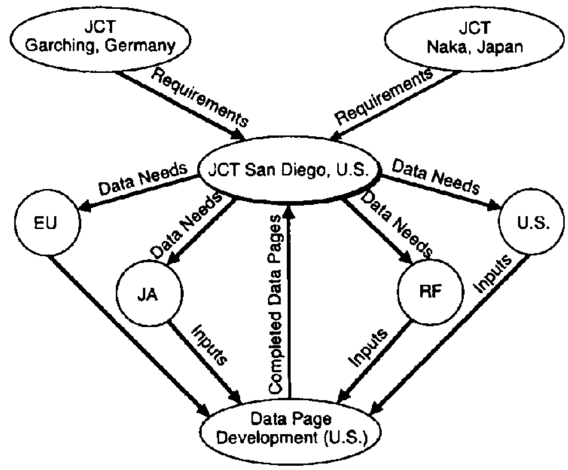

Fig. 2. Process flow.

selected as the lead for each particular material. Other Home Teams can support the collection of data. A key element is that the data should be collected from all available international sources, not only that party's research program. To accomplish this requires the cooperation and support of all four parties. The current responsibilities for data collection are shown in Table 1. As can be seen in this table, each of the partners is treated equally with none of the partners taking a disproportionate share of responsibility. Once the parties accept the assignments, they are responsible not only for the collection of data but also for the development of the trend curves. This is required because the trend curves must be more than a curve fit of the data; they must also match theory on the behavior of the data. This is critical because a good curve

Table 1
Data page development is a cooperative activity

Material	EU	Japan	RF	US
316				Lead
316LN		Lead		Support
316PH	Lead			
Beryllium			Lead	
CFC	Support	Lead		Support
Cu–Cr–Zr	Lead		Support	
MAGT-0.2			Lead	
GlidCop			Lead	
Cu–Be–Ni				Lead
F-82H	Lead	Support		Support
Inconel 625				Lead
Ti–6Al–4V		Lead		Support
JN-1		Lead		
Tungsten	Support		Lead	Support
V–Cr–Ti				Lead
20Cr–16Ni–6Mn			Lead	
Lithium				Lead

fit of the data within a temperature range may yield a completely different behavior outside of the temperature range.

While there can be a number of caveats on the treatment of data, engineers will be tempted to extrapolate the data outside of the data range. Therefore, it is important that the resultant values they see or calculate match the anticipated behavior of the material. For this reason the suppliers of the data are responsible for ensuring that the fitted curve is compatible with theory outside of the data set. The analyzed data, predictive equation, data points, references, and descriptions of the analysis are submitted to the coordinator, identified in Fig. 2 under data page development, who then puts the information into the appropriate format. This information can be provided to the coordinator in a variety of electronic ways. The graphics can be in either a PICT, TIFF, or encapsulated postscript format. The tables can be in Excel or any other format that can be imported into Excel. The text can be in any format that is compatible with the Rich Text Format (RTF) that contains margins and tabs. Any of these forms are acceptable and are subsequently incorporated into the MS Word documents.

4. Electronic communications

Electronic communications are vital to successful coordination with the international partners. A key element in this communication is the ability not only to send notes but also to transfer files either through FTP or as attachments to e-mail messages. In communicating with the various partners, it was quickly found that it was relatively easy to send text-based e-mail messages but it was not easy to attach documents and then to extract them from the message. The cause of this problem is that e-mail software uses an encoding scheme to assemble the file into the message for sending and a decoding scheme to extract the file from the message upon receipt. This extraction is done automatically if the e-mail software receives a code it can understand. However, different e-mail software packages can use different coding schemes; and when these schemes are incompatible, the attached file is not extracted but appears as garbage characters in the message. Sometimes these characters can be translated manually, but this is a bother even if it is possible. Following some trial and discussion, it was decided to avoid these difficulties to the extent possible by requesting participants use a common e-mail program called EUDORA. EUDORA was already in use by the JCT, the US Home Team, and some participants in Japan. EUDORA can be used on both the IBM-compatible and Macintosh systems as well as on UNIX machines. It is available as both a free (no cost) version and a commercial version. The free version, used most widely, uses BinHex as the standard encoding scheme, which enables communication among those who use it. The US Home Team task coordinator and a few other participants use the commercial version of EUDORA, which also includes the UUENCODE scheme. This enables an even wider compatibility. For sites that do not have or cannot use EUDORA, a connection to a MicroVax has been established where the files can be transferred via file transfer protocol (FTP). Using these methods, successful transfer of files between most of the sights has been demonstrated.

5. Current status

The IMPH is now a little over 18 months old but the work has made significant progress in that short time due in large part to the cooperation and support of the ITER participants. The first six months were spent developing a format and a method to easily transfer files. Also during that time the ITER partners were generating data pages. The first draft of the handbook was released six months after its inception and contained information on 316 stainless steel, 316 FR, 316 LN, Inconel 625, dispersion strengthened copper, Ti–6Al–4V, and lithium. By the end of the first year, the handbook contents were expanded to include Cu–Cr–Zr, 316 SPH LN, Incoloy 908, V–4Cr–4Ti, and beryllium in addition to expanding the information on materials previously contained in the handbook. Work is in progress to expand the amount of data for the above materials and to include information on carbon fiber composites, tungsten, Cu–Be–Ni, MAGT-0.2, RF 20Cr–16Ni–6Mn, and F-82H. These data sheets should be available at the end of 1995 or early 1996.