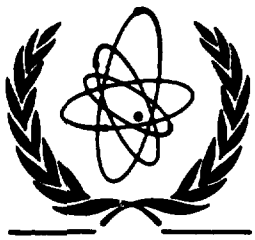

International Atomic Energy Agency

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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

2nd IAEA Research Coordination Meeting on

"Collection and Evaluation of Reference Data for Thermo-mechanical Properties of Fusion Reactor Plasma Facing Materials"

March 25-27, 1996, Vienna, Austria

SUMMARY REPORT

Prepared by R.A. Langley

August 1996

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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ABSTRACT

The proceedings and results of the 2nd IAEA Research Coordination Meeting on "Collection and Evaluation of Reference Data for Thermo-mechanical Properties of Fusion Reactor Plasma Facing Materials" held on March 25, 26, and 27, 1996 at the IAEA Headquarters in Vienna are briefly described. This report includes a summary of presentations made by the meeting participants, the results of discussions amongst the participants regarding the status of data, publication of a multi-author review paper and recommendations regarding future work.

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1. INTRODUCTION

The 2nd Research Co-ordination Meeting (RCM) on "Collection and Evaluation of Reference Data for Thermo-mechanical Properties of Fusion Reactor Plasma Facing Materials" (March 25, 26, and 27, 1996 at the IAEA Headquarters in Vienna) was organized as part of the activity within the IAEA Co-ordinated Research Programme (CRP) on the same subject. The objectives of the Meeting were:

a) to review meeting participants work in the field since the 1st RCM;
b) to review the available data which the meeting participants had measured/collected;
c) to plan the future activity of the CRP.

These objectives were reached either in total or in part during the meeting.

The meeting was attended by only three of the chief scientific investigators of the CRP or their representative, one observer, and the staff of the IAEA Atomic and Molecular (A+M) Data Unit. Two members of the CRP could not attend due to their participation in a parallel subject meeting and two members could not attend due to the pressing needs of dealing with their budget. One meeting participant came as an observer and contributed greatly to the output of the meeting. The List of Meeting Participants is given in Appendix 1.

After opening remarks and adoption of the proposed Agenda the Meeting proceeded with presentations by each of the participants on current work pertinent to the CRP subject.

2. BRIEF MEETING PROCEEDINGS

The first day was spent reviewing work preformed by the CRP participants since the 1st RCM. After opening remarks, **Dr. Burchell** of Oak Ridge National Laboratory chaired the first scientific session. **Dr. Mazul** of the Efremov Institute, St. Petersburg, Russia, presented information on the characterization of various grades of beryllium, beryllium coatings, beryllium-copper joints, and various grades of tungsten, and the neutron radiation resistance of CFC and graphites, and corrosion of different metals in gallium. This included contributions from Dr. A. Khomutov et.al. from the Bochvar Institute, R. Watson et.al. from Sandia National Laboratories, Dr. A. Karpov et.al. from the Efremov Institute, Dr. A. Makhankov from the Efremov Institute, Dr. K. Povarova et.al. from the Baikov Institute, Dr. O. Chugunov et al

from the Kurchatov Institute, Dr. I. Kirillov et al from the Efrenov Institute and Dr. S. Yatsenko et al from the Institute of Chemistry, Sverdlovsk.

Dr. Mazul described three regions on the tensile stress versus Elongation curve where the first region has the properties of good relaxation, coarse grains, and low oxide content and is represented by DShG-200, where the second region has the properties of materials of common use and are represented by TShG-56, TGP-56 and S-65, and the third region has the properties of bad relaxation, fine grains, and high oxide content and is represented by TR-30. Results of Dr. Khomutov were given for the ultimate tensile strength, yield strength and elongation for TR-30 beryllium in the temperature range RT-600 C. Dr. Mazul described collaborative experiments with SNLA dealing with crack initiation and propagation in numerous types of beryllium. An in-pile testing facility was described and results presented for the change of thermo-mechanical properties for various neutron irradiated beryllium types. Results were presented on Be/Cu bonded materials by brazing, bonding and joint rolling. Both shear and tensile testing were performed. The impurity content and microporosity of the various beryllium grades were investigated and results reported as well as results for beryllium coatings.

Dr. Mazul described work on tungsten performed by Drs. Makhankov and Povarova. Five tungsten grades were described giving advantages and disadvantages. Elongation, reduction in area, ultimate strength, and yield strength results were reported as a function of temperature from 200-500 C. The work of Dr. Chugunov was described for the thermal expansion and conductivity of various types of graphites and CFC for various neutron irradiation conditions. His final topic of discussion was properties of liquid gallium wettability, corrosion, and solubility for many metals of interest to fusion designers.

Dr. Stamm of the Institute for Advanced Materials, Joint Research Centre, ISPRA, presented the next review talk. His colleagues were Drs. Fattori, Fenici, Shiller and Vinche. He described the JRC Data Bank, data input and evaluation, and application. The network structure of the data bank was described where a relation table joins the various aspects of the data input, i.e. data source, specimen, material, test condition and test result. The file data source was described as well as file material, file test condition, and file test results including both mechanical and physical properties. At present the data bank contains information on 316 stainless steels, Cu-Cr-Zr materials, and martensitic/ferritic steels, e.g. F82H. In addition information on various weldments are included. Data evaluation was done in accordance with ITER requirements. Dr. Stamm presented examples of the format for the data bank and

discussed application of the data to tables/plots, combination of plots, data fitting and data export. He concluded with remarks concerning comparability of data, reference materials, data presentation and data transfer.

The second session was chaired by Dr. Mazul and the first speaker was **Dr. Tim Burchell** of Oak Ridge National Laboratory. Dr. Burchell of the Carbon and Insulation Materials Group discussed results dealing with the mechanism of neutron damage and its relation to dimensional change. A model was formulated to account for radiation damage effects on mechanical properties, also a model was formulated to account for changes in thermal conductivity due to radiation damage in carbon materials. He presented the physical interpretation for the changes in properties as a function of radiation damage for both graphite and CFCs. Experimental data were shown along with the model output for dimensional change, brittle ring strength, and thermal conductivity as a function of displacement per atom, DPA, and temperature. The materials studied were 1D, 2D, 3D CFCs, H-451, FMI1D, K139 fiber, MFC1 composite, P-120 fiber, and many other graphites. Data for many of the graphites and CFCs were compiled and compared with the models to provide reasonable extrapolations in temperature and DPA for the mechanical properties studied.

Dr. V. Barabash of the Materials Group, ITER Garching Joint Work Site presented a review of the ITER material requirements for the various plasma facing components. For the armor components the following general classes of materials are being considered: beryllium, carbon fiber composites and tungsten. One of the main goals of the engineering design activity, EDA, is to select a reference material for each class and to reduce the number of materials grades. The components which are being considered are first wall, baffle, limiter, and diverter. The first material addressed was beryllium of which there are four candidate materials: S-65C, DShG-200, TShG-56, and TR-30. The first is a Brush Wellman/USA product while the later three are Russian products. Dr. Barabash stated that the five main selection criteria were thermal shock/thermal fatigue resistance, n-irradiation resistance, plasma materials interaction features, joining technologies, and experience/availability. He reviewed the physical and mechanical properties of the different materials and delineated areas where data was lacking. He reviewed recent data from on thermal fatigue (performed by SNLA) and neutron irradiation effects, both mechanical properties and swelling. The areas to be investigated are: initial mechanical properties, thermal fatigue after irradiation, swelling and mechanical properties after irradiation. He pointed out that the critical areas are: low irradiation temperature data, creep

and fatigue properties both before and after irradiation and the influence of overheating during transients on swelling and mechanical properties.

The second material addressed was tungsten. The areas of concern for the selection criteria were the same as for beryllium. Each of the four parties have proposed different types of tungsten; there are 18 different types being considered. They ranged from monocrystal to plasma sprayed material. He noted that many of the thermophysical properties of the different grades of tungsten are well documented and that the mechanical properties depend strongly on production history, alloying, impurity level, form of the material, etc. Some of the needed properties are not available in the literature. Dr. Barabash presented different schemes for the possible use of tungsten in the armor and briefly compared the different grades of tungsten. He presented data on the effects of neutron irradiation and noted four areas to be investigated: mechanical properties before and after irradiation, thermal shock/thermal fatigue and swelling.

The third material addressed was carbon fiber composites. Dr. Barabash gave a brief description of the CFCs studied of which there are seven, three from the EU and four from Japan. These consisted of 1D, 2D, and 3D materials. In addition to the above mentioned criteria thermal conductivity was added for these materials. He discussed the development of doped CFC with the goals of reducing chemical erosion, reducing tritium inventory and increasing the resistance of water and oxygen interaction at high temperature. He noted recent achievements in increasing thermal conductivity, reducing chemical erosion and increasing oxidation resistance and pointed out critical data needs, i.e. irradiation influence and joining technology. In reviewing the data base for materials properties he noted that CFCs were relatively new and therefore there was limited data available. He also stated that the material properties have strong dependencies on the technology of manufacture. He presented new data on the effects of neutron irradiation and concluded that it leads to degradation of thermal conductivity and induces an increase in tritium retention, anisotropic shrinkage/swelling, and a change of Young's modulus. The areas to be investigated are thermal diffusivity and shock resistance, coefficient of thermal expansion, bending properties, and tritium retention for both unirradiated and irradiated materials. Dr. Barabash concluded by emphasizing the development of CFCs, especially doped with silicon, and the measurement of the material properties for all three categories of materials.

The final presentation was made by Dr. R. Langley. He summarized the recent ITER materials properties handbook meeting held at the ITER site in Garching on March 4-7, 1996.

This consisted of discussions of data in the handbook and future requirements and schedule. It was noted that much of the data needed by machine designers was needed now but that documentation was needed for material properties for future siting of ITER and the required documentation was dependent on the local safety codes pertaining to the construction site.

3. DATA STATUS AND NEEDS

It was recognized by the meeting participants that in order to do definitive experiments and to obtain meaningful results for the material studied it was very important to specify in as detailed a manner as possible the characteristics of the material since many of the material properties needed are very dependent on the specifics of the material such as method of formation, initial starting material, impurity content, grain size, density (porosity), anneal temperature and other possible factors. In order to provide as useful results as possible it is especially pertinent to identify the ITER reference materials. Specific data needs were put forth by Dr. Barabash in his presentation on ITER.

4. CONCLUSIONS AND RECOMMENDATIONS

This Research Coordination Meeting provided the opportunity for the participants to collectively assess the status of materials properties data for fusion reactor plasma facing materials. The participants concluded that considerable data was available for specific materials under specific conditions but that for many of the conditions which will probably be encountered in ITER and other devices, e.g. the diverter chamber, data is not available.

It was proposed by the meeting participants that a review article dealing with material properties of plasma facing materials be prepared which would present to the fusion community a reviewed summary article on the subject. Preliminary discussions were had with the editor of Nuclear Fusion on the inclusion of this summary in the supplement to Nuclear Fusion in the series Atomic and Plasma-Material Interaction Data for Fusion. A tentative outline for the publication was made as well as potential authors, chapter lead authors, and editors. These are noted in Table 1. A letter of confirmation to each of the potential chapter lead authors was written so that it can be sent after confirmation of interest; this letter is shown in Appendix 3. Also a tentative schedule was agreed upon and is shown in Appendix 4. The participants agreed that this publication would represent a very useful output and conclusion for the CRP.

Table 1: Outline of Proposed Nuclear Fusion Supplement

Volume Title: Thermomechanical Properties of Plasma Facing Materials
Editors: Langley, Barabash, Burchell, Mazul, Stamm

Preliminary Content

Chapter	Title	Contributors	Guest Editor
	Forward: R. Langley		
1	Introduction - Requirements for Plasma Facing Materials	V. Barabash R. Langley R. Matera	-
2	Thermomechanical aspects of the application of tungsten as armour material	I. Mazul - Lead M. Rödig M. Akiba J. Davis - Lead L. Snead I. Smid V. Barabash	Mazul
3	Influence of neutron irradiation on the properties of Be for PFC application	L. Snead - Lead F. Moons S. Fabritsiev V. Barabash - Lead	Burchell
4	Radiation induced degradation of the thermal conductivity- Impact on the design of PFC	T. Burchell - Lead C. Wu J.P. Bonal	Burchell
5	Renewable coatings for fusion plasma facing components	R. Castro R. Matera N. Noda	Barabash
6	Joining of plasma facing materials to heat sink structure for PFC application	R. Watson - Lead B. Odegard A. Gervash - Lead M. Akiba N. Noda V. Barabash (?) C. Ibbott	Mazul
7	Thermomechanical testing of high heat flux components	M. Akiba - Lead N. Noda J. Linke - Lead D. Yochisson C. Ibbott (?) F. Chapius (CEA)	Barabash

(contd. Table 1)

Chapter	Title	Contributors	Guest Editor
8	Thermal fatigue aspects of first wall . . .	R. Stamm (Ispra) R. Matera	Stamm
9	Fusion Related properties of liquid metal for PFC ication	I. Kirillov - Lead P. Romanov R. Mattas I. Lublinsky	Mazul
10	Low activation SiC/SiC materials	R. Stamm (Ispra)	Stamm
11	Materials Property Database - Current Status and Illustration	R. Stamm (Ispra) R. Matera (?) M. Akiba (?) J. Davis (?)	Stamm
11A	To be decided		
12	Carbon base materials in current fusion facilities - experience of applications	M. Pick - Lead Z. Deschka TFTR C. Wong (?)	Burchell

Appendix 1

IAEA 2nd Research Coordination Meeting on
"Collection and Evaluation of Reference Data for Thermo-mechanical Properties of Fusion Reactor Plasma Facing Materials"

March 25 - 27, 1996, IAEA Headquarters, Vienna, Austria

LIST OF PARTICIPANTS

Dr. V. Barabash (Observer)	ITER Garching Work Site, Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, D-85748 Garching bei München, GERMANY
Dr. H. Stamm	European Commission, Institute for Advanced Materials, Materials Performance & Reliabil, I-21020, Ispra (Varese), ITALY
Dr. I. Mazul	D.V. Efremov Scientific, INST Electrophysical Apparatus, Fusion Materials Laboratory, P.O. Box 42, St. Petersburg 189631, Metallostroi, RUSSIAN FEDERATION
Dr. T. Burchell	Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37931-6088, U.S.A.

IAEA

Dr. R.K. Janev	IAEA Atomic and Molecular Data Unit, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, AUSTRIA
Dr. R. A. Langley	IAEA Atomic and Molecular Data Unit, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, AUSTRIA
Dr. Wang Dahai	IAEA Atomic and Molecular Data Unit, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, AUSTRIA

Tuesday, March 26, 1996

Session III: Discussion I

Chairman: Langley

09:30 - 12:00: Discussion of Current Status of TMP Data including ITER

12:00 - 14:00: Lunch

Session IV: Discussion II

Chairman: Langley

14:00 - 17:00: Discussion of Data Needs

17:00 **Session close**

Wednesday, March 27,1996

Session V: Discussion III

Chairman: Langley

09:30 - 12:00: Discussion of CRP Continuation and Future Objectives

12:00 - 14:00: Lunch

Session VI: Discussion IV

Chairman: Langley

14:00 - 17:00: Discussion Continued

17:00 **Adjournment of the Meeting**