ORNL/FTR--3519

DE90 006142

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ORNL

FOREIGN TRIP REPORT

ORNL/FTR-3519

DATE: January 24, 1990

SUBJECT: Team Trip Report of Foreign Travel of E. E. Bloom, M. L. Grossbeck, R. L. Klueh, L. K. Mansur, F. W. Wiffen, S. J. Zinkle, Metals and Ceramics Division, and J. W. Davis, McDonnell-Douglas Astronautics Co.

TO: Alvin W. Trivelpiece

FROM: E. E. Bloom (Coordinator)

PURPOSE: To attend the Fourth International Conference on Fusion Reactor Materials (ICFRM-4), December 4-9, 1989, in Kyoto, Japan, and to participate in several international workshops and planning meetings on fusion materials research.

SITES VISITED: All travelers attended ICFRM-4 held December 4-9, 1989, in Kyoto, Japan. Other sites visited by individuals are listed in the itineraries of individual travelers.

ABSTRACT: This report summarizes the International Conference on Fusion Reactor Materials (ICFRM-4) which was held December 4-9, 1989, in Kyoto, Japan, as well as the results of several workshops, planning meetings, and laboratory visits made by the travelers.

The ICFRM-4 is the major forum to present and exchange information on materials research and development in support of the world's fusion development efforts. About 360 papers were presented by the 347 conference attendees. Highlights of the conference are presented. A proposal by the United States to host ICFRM-5 was accepted by the International Advisory Committee. ORNL will be the host laboratory.

A meeting of the DOE/JAERI Annex I Steering Committee to review the US/Japan Collaborative Testing of First Wall and Blanket Structural Materials with Mixed Spectrum Fission Reactors was held at JAERI Headquarters on December 1. The Japanese emphasized the critical importance of a resumption of HFIR operation. Even though the HFIR outage has lasted three plus years this program has continued to provide new and important data on materials behavior which has particular relevance to ITER.

All other workshops and visits are described.

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COMPREHENSIVE TRIP REPORT

Purpose

The purpose of this travel was to attend the Fourth International Conference on Fusion Reactor Materials (ICFRM-4) held December 4-9, 1989, in Kyoto, Japan. Each of the travelers presented papers and/or chaired sessions. Several of the attendees were members of the various conference organizing committees. In addition to the conference, several travelers were involved in workshops and meetings to review and plan the numerous international collaborations in which the United States fusion materials program is involved.

Appendix A lists the itinerary of each of the travelers.

International Conference on Fusion Reactor Materials (ICFRM-4),
December 4-9, 1989, Kyoto, Japan

ORNL Attendees:	E. E. Bloom	L. K. Mansur
	J. W. Davis	F. W. Wiffen
	M. L. Grossbeck	S. J. Zinkle
	R. L. Klueh	

This conference, the fourth in the series and held in Kyoto, Japan, December 4-9, 1989, is the main forum for researchers throughout the world to exchange information on the materials aspects of fusion reactor technology. It was by far the largest of these conferences, having some 347 attendees. About 360 papers were presented. Approximately half of these were oral plenary papers, with the remainder presented in poster sessions. ORNL was responsible for three of the invited papers and presented a total of 19.

General impressions are that the meeting was well-organized and that great attention was paid to the mechanics of running the meeting. It was estimated that about 40 people were involved in some aspect of the meeting operation, covering functions ranging from the overall organization and technical program to coordinating reviews of manuscripts and gauging paper length for compliance with guidelines. Many were students. This is a substantially higher number of functionaries than is usually associated with meetings of similar size in the USA or Europe.

The meeting overall placed considerable emphasis on fundamental issues, perhaps reflecting the interests of many of the principal researchers in the host country. An area that received repeated attention was the nature and effects of differences in primary recoil spectra on microstructure and macroscopic property changes. Much of this discussion was sharpened and put into more tangible requirements in the final discussion session, which was devoted to irradiation correlation and the need for an intense high energy neutron source.

A high level of emphasis was also placed on mechanical properties of irradiated materials from both experimental and theoretical points of view. Helium effects received continued attention. It was repeated in several papers of the conference that hydrogen embrittlement should also be considered for the International Thermonuclear Experimental Reactor (ITER). Criteria and performance of low activation materials was another area of emphasis with respect to mechanical properties. A trend to more applied problems was evident, as well as a trend to miniaturized mechanical testing. Several papers addressed disk punching methods for mechanical properties determinations.

With respect to microstructures, Kiritani described a strong effect of temperature on microstructure. During reactor irradiations, one set of specimens saw a "controlled" temperature, meaning that regardless of whether or not the reactor was operating, the temperature was maintained at 400°C. In the companion set, the temperature was "uncontrolled," meaning that the temperature was 400°C when the reactor was operating, but that the temperature ramped up and down with reactor startup and shutdown. The microstructures were drastically different for the two sets of specimens. This brought home the importance of temperature history on microstructural evolution. These were low dose experiments, and it is not known at this time whether the differences in microstructure diminish with increased dose. There was much emphasis on primary recoil spectra and the fraction of defects avoiding in-cascade recombination, particularly, and the subset of these migrating freely. Papers by Wiedersich and Averback emphasized these ideas. It was pointed out in a discussion session that single defects arising from the thermal shrinkage of cascade-produced loops and stacking fault tetrahedra must also be considered. Kinoshita described experiments in progress on ceramic materials. These employed varying fluxes of electrons and ions to investigate recoil spectra and ionizing-to-displacive ratio irradiation effects in ionic- and covalent-bonded ceramics.

Most work on ferritic steels concerned reduced-activation steels. Results presented generally justified the early optimism that ferritic steels offered the best opportunity to develop reduced-activation materials with properties equivalent to those of the alloys being replaced. The introduction of tungsten as a replacement for molybdenum has resulted in Cr-W steels with properties comparable to those of the 9Cr-1MoVNb and 12Cr-1MoVW steels they are replacing. Recent work has concentrated on optimizing compositions for strength and toughness and optimizing properties by heat treatment and thermomechanical processing. Welding and thermal aging studies have also begun. A consensus appears to be forming that steels with 9% Cr offer the best possibility for properties comparable to those of 9Cr-1MoVNb and 12Cr-1MoVW steels. Although most of the work involves studies of unirradiated properties, limited studies on irradiated specimens indicate that the Cr-W steels will behave like the Cr-Mo steels when irradiated. Presentations at the conference also indicated potential problems for ferritic steels. Numerical calculations indicate that up to 4% Mn will be produced by transmutation in the first wall of a fusion reactor. Experimental papers showed that such manganese levels lower the toughness of Cr-W steels.

Further, irradiation of a manganese-containing ferritic steel produced chi-phase, which is expected to degrade toughness. Another presentation indicated that the problem of decreased toughness after irradiation may be more severe than previously thought. Irradiation of 9Cr-1MoVNb to ~40 dpa in the High Flux Isotope Reactor (HFIR) resulted in an increase in ductile-to-brittle transition temperature (DBTT) by 207°C. This contrasted with previous work that indicated an increase in DBTT of only 52 and 54°C after irradiation in EBR-II to 13 and 26 dpa, respectively. The high helium concentration developed by irradiation in HFIR was cited as the most likely cause for the large difference.

Helium effects on austenitic stainless steels were discussed in several papers. The effect of helium on the tensile properties of type 316 stainless steel could be seen from the paper by Grossbeck. Here high-temperature helium embrittlement was easily seen by its effects on ductility. Strength did not seem to be affected by helium up to 4000 appm, the highest level examined. However, the high strain rate of a tensile test favors high ductility with respect to helium embrittlement. This was also pointed out in the paper by Schroeder and Ullmaier. High-temperature helium embrittlement was also illustrated in the paper by Shamardin et al. In this paper, the tensile properties of several alloys with diverse amounts of helium were compared. It was evident that temperature had a much greater effect than helium when helium was present in levels of 100 appm or greater.

There were also a few papers, such as the one by Garner, which attempted to show that helium has no effect on properties. This was further brought out in the papers by Hamilton et al. Here it was shown that the helium had no effect on strength in the temperature range investigated. This finding was generalized to other mechanical properties and swelling without experimental evidence. It was pointed out that the method of isotopic tailoring to vary the helium concentration is a superior method of investigating helium effects. This technique has not proved the absence of helium effects. The issue was brought into better perspective in the paper by Rowcliffe et al. Here the effects of helium on swelling and irradiation creep were pointed out and discussed in terms of the importance of controlling the He:dpa ratio. The special importance of helium, and gas in general, on swelling was discussed from a theoretical point of view in the paper by Mansur and Lee.

Hydrogen embrittlement emerged as an issue at this conference more strongly than in the past, mostly because of the projected low-temperature operation of the ITER. Boutard discussed this in his presentation at a discussion session. He also pointed out the excellent resistance of most austenitic alloys to hydrogen embrittlement. The primary concern appears to be for ferritic alloys. This concern was also mentioned in the review paper by Schroeder and Ullmaier, but few details were presented. The details were left to a paper by Schroeder, where tensile properties were presented; no large effect was demonstrated. The importance attributed to hydrogen is illustrated by the fact that hydrogen appeared in the titles of 12 papers.

It is also significant that papers on mechanical properties are addressing more practical aspects of materials application. There were more papers, mostly Japanese, on welds than at previous conferences. Also, the area of corrosion was represented in a number of papers. In addressing the specific needs of the ITER, irradiation creep experiments have been conducted at lower temperatures than before. A paper by Grossbeck and Mansur presented experimental evidence for creep at temperatures as low as 60°C and proposed a mechanism for the phenomenon.

The ICFRM International Advisory Committee accepted the proposal of the United States to host ICFRM-5 with ORNL being the host laboratory. This conference will be held in approximately 2 years in the southeastern United States.

DOE/JAERI Annex I Steering Committee Meeting, December 1, 1989, Tokyo, Japan

Attendees:	T. C. Reuther, DOE	T. Kondo, JAERI
	R. E. Price, DOE	M. Saïdo, JAERI
	E. E. Bloom, ORNL	A. Hishinuma, JAERI
	F. W. Wiffen, ORNL	S. Hamada, JAERI

A meeting of the DOE/JAERI Annex I Steering Committee was held at Japan Atomic Energy Research Institute (JAERI) Headquarters, Tokyo, on December 1, 1989. The primary purpose of the meeting was to review with the Japanese the status of HFIR and plans for restart and to review recent progress in the US/Japan Collaborative Testing of First Wall and Blanket Structural Materials with Mixed Spectrum Fission Reactors.

In introductory remarks both sides emphasized the importance of an early resumption of HFIR operation. While important postirradiation examination (PIE) work continues on irradiated specimens now available, the need for the planned new irradiations is becoming increasingly critical. The United States mentioned the optimism at ORNL and at DOE that approval for HFIR restart will be granted very soon. The importance of the results generated by this program to the future prediction of materials performance in reactors, especially in the conditions that will be found in ITER, is becoming clear. Bloom presented a review of the status of work at ORNL on the DOE/JAERI program, emphasizing progress since the previous review in March 1989. Hishinuma reviewed current JAERI activities on the fusion reactor materials program. Kondo also gave a brief overview of other JAERI programs that directly or indirectly support fusion reactor materials development. These include the development of irradiation research facilities, research on radiation-resistant functional ceramics, and an extensive data base development activity. A major study has defined a proposed new irradiation facility, the Energy Selective Neutron Irradiation Testing Facility (ESNIT). ESNIT incorporates accelerator advances since the fusion materials irradiation test (FMIT) design, and a decision on construction is anticipated in 1993. A triple-beam ion irradiation facility is also planned, to be available in 1992.

Meeting minutes are being reviewed for final approval and will be distributed to participants soon.

United States - People's Republic of China Discussion Meeting on Fusion Reactor Materials, December 7, 1989, Kyoto, Japan

Attendees:	R. E. Price, DOE	J. P. Qian, Sichuan, P.R. China
	T. C. Reuther, DOE	M. L. Hu, Hefei, P.R. China
	E. E. Bloom, ORNL	C. Shan, Beijing, P.R. China
	D. L. Smith, ANL	J. Sun, Beijing, P.R. China
	F. W. Wiffen, ORNL	

The first meeting on the subject of Fusion Reactor Materials between teams from the United States and the People's Republic of China (PRC) was held December 7, 1989. This luncheon meeting in the Miyako Hotel, Kyoto, Japan, took advantage of the presence of U.S. and PRC attendees at ICFRM-4.

The PRC delegates agreed that since the U.S. fusion reactor materials programs were adequately reviewed at the conference, in Reuther's plenary session paper and other presentations, it was not necessary to again review these programs.

Qian reviewed programs in the PRC supporting fusion reactor materials. Their program consists of four parts:

1. Development of structural materials for fusion reactors,
2. Neutron irradiation studies,
3. Plasma surface interactions, and
4. Compatibility.

Qian said their primary interests at this stage of the program are on neutron irradiation effects and on plasma materials interactions. The PRC has approximately 20 scientists involved in the fusion reactor materials program, supported by additional engineers, technicians, and students. The PRC stated that the first Chinese fusion reactor will be fabricated of austenitic stainless steel, due to the DBTT and high-temperature strength limitations of the ferritic steels. However, they are continuing the broad-based program outlined below.

The Structural Materials activity includes five materials groups.

1. Austenitic stainless steels - 316; modified versions of 316 with Ti, with Nb, and a hydrogen-embrittlement-resistant version, Chinese PCA, and modified for low activation with Ni, Mn, and Nb replaced by Mn, W/V, and Ta/Ti.

2. Ferritic steels - CHT-9, CHT-7, and mod CHT-9. The first two are analogues of the 12Cr-1Mo and 9Cr-1Mo steels; the modified alloy has W and V replacing Mo, Ni, and Mn. An oxide dispersion strengthened (ODS) ferritic steel is also included.
3. Vanadium-based alloys include V-20Ti and V-8Ti-5Mn-5Cr-2Fe, apparently both under development for fast reactors, and V-15Cr-5Ti. There is little or no funded work on this last alloy.
4. Composites - C/C, SiC/CF, Al/C, and Al/SiC, where the matrix element is designated first. These are under study as candidate plasma-facing materials. Preparation processes include chemical vapor deposition (CVD) and chemical vapor infiltration (CVI).
5. Tritium breeding materials include solid ceramics, liquid PbLi eutectic, and liquid lithium. Ceramics under study are Li_2O and $\gamma\text{-LiAlO}_2$. China has the capability for separation of lithium isotopes and can produce these ceramics or other desired ceramics with any required enrichment of ^6Li .

The Neutron Irradiation study uses 14 MeV D-T neutron sources, a D-Be source, two fission reactors, and charged particle simulations. The D-T source is an RTNS-I type, with maximum source strength of 2×10^{12} neutrons/s. The D-Be source produces the same average neutron yield, with 10 to 200 Hz pulses and average neutron energy 5.78 MeV. The fission reactors include a pool-type thermal reactor with fast neutron flux of 4.5×10^{13} neutron/cm²s (>1.0 MeV) and a high flux reactor (HFTR) with 1.1×10^{15} neutrons/cm²s (>1.0 MeV). The latter reactor is also used for fission reactor material studies. Gas flow control experiments are used for measured and controlled elevated temperature irradiation experiments. Use of this reactor is apparently limited by operating funds, and exposures above ~ 10 dpa are difficult to achieve. A range of ion accelerators with energies from 100s keV to 100s MeV and a 1 MeV high voltage electron microscope are also in use in the PRC program.

Plasma Surface Interaction studies focus on surface damage produced in materials by plasma irradiation. Studies include sputtering, blistering, and stripping, using ion sources and the HL-1 Tokamak.

Compatibility studies are evaluating liquid breeder-structural material interactions. A major facility is a liquid lithium pumped loop, to be used for magnetohydrodynamic (MHD) pressure drop (1.9 T magnet) and compatibility studies. The loop design is complete but construction is not yet completed. Many of the components have been fabricated. Supporting compatibility studies use static capsule experiments, and work with thermal convection loops is also planned.

Tritium release and tritium permeation experiments are also included in the PRC program, but were not discussed further.

The time available did not allow the PRC members to describe the work in detail. Reprints were provided that describe some of the work.

The PRC members informally proposed that future U.S./PRC collaboration on fusion reactor materials research include the following elements.

1. A visit by Qian to the United States about June 1990, following the plasma materials interaction (PMI) conference in the United Kingdom. Qian hopes to spend about 3 weeks at Argonne National Laboratory (ANL) using the MHD loop to do experimental work supporting the PRC loop development. He hopes also to visit ORNL, UCLA, and General Atomics.
2. A bilateral workshop in China in September or October 1990, to be followed by site visits to the PRC laboratories engaged in fusion reactor materials work.
3. Future exchange of scientists, for periods of a few weeks.

Speaking for the United States, Price and Reuther suggested that the proposed pace of developing this exchange was too rapid. The United States committed to assembling and sending to the PRC a package of information on United States specimen design, experiment design, and test methodology, in the hope that the extensive work on developing techniques for the use of small specimens would be useful in the PRC experiments. Price and Reuther further suggested that possible elements for future collaboration include exchange of materials and joint experiments. The United States is not yet ready to plan a team visit to the PRC.

Third FFTF/MOTA Experimenters' Workshop, December 11-12, 1989, University of Tokyo, Tokyo, Japan

Working Group on Copper Alloys Attendees:

F. W. Wiffen, ORNL	T. Muroga, Japan
S. J. Zinkle, ORNL	T. Shikama, Japan
F. A. Garner, PNL	H. Yoshida, Japan
K. R. Anderson, Univ. of Ill.	H. Sekimura, Japan
J. F. Stubbins, Univ. of Ill.	

The subject workshop reviewed a large number of experiments within this collaboration and discussed potential future directions of the work. The workshop consisted of several working group sessions on copper alloys, austenitic alloys, ferritic alloys, vanadium alloys, low fluence fundamental studies, and small specimen development and use. The purpose of the workshop was to explore opportunities for collaborative US/Japan experiments. The format for the working group meeting consisted of a brief, informal summary of the U.S. and Japanese research programs followed by proposals for collaborative research projects. This proved to be an effective way to focus the discussion to relevant topics. In the working group on copper alloys attended by Zinkle, most of the discussion was centered on experimental techniques to investigate transmutation effects (gaseous and solid) in irradiated copper. Several specific collaborations were proposed: above core (low-dose) irradiation in FFTF;

comparative irradiations in different reactors (RISO, DR3, JMTR, LAMPF, OWR); irradiation of organometallic copper alloys (developed by Japan); and irradiation of braze joints in copper alloys. The summaries of these sessions included the following important points.

1. Continued, detailed coordination is needed to assure that the experiments produce the required material and irradiation condition comparisons.
2. Better inventories of available material and previously irradiated specimens are needed to most effectively utilize the available Japanese manpower and the limited equipment resources.
3. Space in future MOTA experiments will continue to be scarce, and careful planning is required to maximize the value of the experiments.

Detailed reports on this workshop should be available from Garner or Hamilton of Battelle-Pacific Northwest Laboratories.

Annex II Working Group Meeting and IEA Materials Data Base, December 11, 1989, held at Japan Atomic Energy Research Institute, Tokyo, Japan

Attendees: J. L. Boutard, The NET Team, Garching, FRG
 F. Clinard, LANL
 J. W. Davis,* MDMSC
 K. Ehlich,* KFK Karlsruhe, FRG
 H. Frost, LANL
 M. L. Grossbeck, ORNL
 A. Hishinuma,* JAERI, Japan
 S. Iwata, University of Tokyo, Japan
 G. Phillips,* CRNL, Canada
 H. Nakajima, JAERI, Japan
 K. Noda, JAERI, Japan
 R. E. Price,* DOE
 T. C. Reuther,* DOE
 P. Schiller,* JRC, Ispra, Italy
 D. L. Smith,* ANL
 M. Victoria,* Paul Scherrer Institute, Switzerland

The objective of the International Energy Agency (IEA) Materials Data Base Meeting was to review the progress on the handbook task groups (structural materials, ceramic breeding materials, and PFC materials) in developing data pages for the International Fusion Materials Handbook. Following this meeting, a meeting of the IEA Working Group was held, in which the results of the previous meeting was presented.

In general, the organizational structure, consisting of a steering committee, handbook coordinator, and task groups, is in place and

*Members of Working Group.

functioning. An operating system for the electronic version of the handbook has been developed and is currently being tested. Formats for data presentation have been distributed to the task group chairman. Group status presentations were made by Grossbeck on the development of irradiated 316 stainless steel data pages and by Noda on the development of ceramic breeder data pages. No presentation was made in the PFC materials task group. The ceramic breeding materials task group has grouped the data pages into topical sections, e.g., physical properties, thermochemical properties, mechanical properties, compatibility, and diffusion, and assigned the lead responsibility for each of these sections to various countries so that the preparation of these pages is a team effort. It was recommended that the other task groups follow this example. While the ceramic task group is better organized, they are currently 6 months behind the schedule agreed upon at the Petten meeting in releasing data pages and it appears that another 5 to 6 months will be needed before these data pages can be submitted for final review. This is in contrast to the structural materials task group, which is currently reviewing data pages on the elongation of annealed 316 stainless steel prior to submittal for final review in 2 to 3 months. At this meeting a revised schedule for page preparation for the structural material and ceramic breeder task groups was developed by the respective task group chairman and submitted to the coordinator.

While the task groups on structural materials and ceramic breeders are making good progress in the development of data pages, there does not appear to be any activity in the PFC materials task group and past requests for status reports by the handbook coordinator (John Davis) have gone unanswered. Since the chairman of the PFC materials task group is from the UK, Schiller agreed to review the status of this task group with the task group chairman and recommend in January whether a change in the chairmanship of the PFC materials task group is appropriate. An overview of the status on the ceramic insulator data base was presented by Clinard. While this task group has been identified in the organization structure of the International Handbook, it has not been activated, primarily because of the decline in the ceramics research budget and the inability to get a task group chairman to accept the responsibility.

An overview summarizing the findings of the IEA Materials Data Base Meeting was presented to the Working Group by Smith. Following the presentation a recommendation was made by Reuther and seconded by Smith that participation in the IEA data base development be expanded to include the Soviets. After discussion on various approaches to accomplish this, it was agreed that a decision should be deferred to the Executive Committee, which was meeting on the next day. At the Executive Committee meeting (Tuesday, December 12), Reuther proposed that the USSR participate in the development of an international materials data base. In discussions by the members of the Executive Committee, it was the opinion that they would prefer to have the ITER organization request participation in the IEA activity. This approach was recommended by the EC and Japan. The net result was a decision to table the motion.

In other actions the Executive Committee approved the convening of a Second Workshop on the International Fusion Materials Data Base to be held in September 1990 in Europe and a Workshop on Low Activation Materials to be held before April 1991; a location was not identified.

Nagoya University, December 11, 1989

Attendee: S. J. Zinkle, ORNL

Zinkle visited with staff members of the Nuclear Engineering Department at Nagoya University on December 11. Discussions were held with Prof. M. Kiritani and research associates S. Kojima and Y. Satoh, and a tour of their experimental facilities was given. The high voltage electron microscope (HVEM) at the University is scheduled to be equipped with a field emission gun source starting in January 1990. Professor Kiritani is performing pulsed irradiation experiments on the HVEM [operating in the scanning transmission electron microscopy (STEM) mode] in order to investigate point defect migration behavior in metallic alloys. The pulse frequency is currently limited to 60 Hz, but they plan to reduce the pulse length to 10 μ s with the aid of a microcomputer. This will allow them to study interstitial migration in selected alloys at elevated temperatures.

The possibility of several collaborative research projects was discussed with Kojima. These projects stem from work that was performed at Oak Ridge while Kojima was a visiting scientist, and are concerned with effects of grain size on radiation hardening in metals.

Japan/US Cooperative Planning Meeting P-149, "Evaluation of Radiation Damage in Ceramics and Graphite," December 12-13, 1989

Attendees:	T. D. Burchell, ORNL	C. Kinoshita, Japan
	S. J. Zinkle, ORNL	N. Yoshida, Japan
	F. W. Wiffen, ORNL	H. Ohno, Japan
	F. A. Clinard, LANL	N. Itoh, Japan
	H. M. Frost, LANL	T. Tanabe, Japan
	W. F. Sommer, LANL	

The purpose of this meeting was to draft recommendations for research and development priorities for the next 2 years for radiation effects studies on ceramics and graphite. A summary of the recommendations will be distributed to the meeting attendees by February 1990. Approximately one-third of the meeting was devoted to formal presentations with the remaining time reserved for discussion. Zinkle made two presentations, provided viewgraphs for two additional presentations, and cochaired one of the discussion sessions.

Several informative presentations were made by Japanese attendees. Yoshida described the TRIAM-IM tokamak machine operating at Kyushu University that is available for in-situ testing of high heat flux

materials. The device produces a moderate density plasma and high heat fluxes (1 to 10 MW/m² at the test location). The plasma has been sustained for time periods exceeding 1 h. Itoh (Nagoya Univ.) presented experimental and calculational results on the effect of ionizing radiation on defect formation. He indicated some possible synergistic effects that could occur in the presence of ionizing and displacive radiation fields, in particular, the possibility of enhanced defect production due to ionizing radiation effects. Ohno (JAERI) presented data on the ac electrical properties of Al₂O₃ and Si₃N₄ as a function of neutron dose (postirradiation) and also in-situ measurements in the presence of an ionizing radiation field. Large increases in the electrical conductivity were observed. In the neutron-irradiated specimens, the conductivity increased rapidly with dose up to $\sim 10^{22}$ n/m², and showed little change thereafter.

The general consensus of the attendees was that research over next 2 years should be fundamental in nature (as opposed to device-specific) in order to bolster the data base for radiation effects in ceramics and graphite. In agreement with previous ceramic workshop recommendations, it was recognized that there is a strong need for in-situ measurements (e.g., dielectric and electrical conductivity measurements vs frequency), using accelerator or research reactor radiation sources. Several attendees emphasized the need to perform experiments in irradiation environments that produce different ratios of displacive to ionizing radiation so that possible synergistic effects between these radiation fields can be unfolded in a systematic manner. It was suggested that pulsed irradiation sources (possibly combined with in-situ electrical measurements) may be useful to gain insight on the physical mechanisms associated with defect formation and migration.

Japan Atomic Energy Research Institute, Tokai-mura, December 13-14, 1989

Attendees: F. W. Wiffen, ORNL
R. E. Price, DOE

Wiffen visited the JAERI site at Tokai with Price for tours of facilities used in the fusion technologies programs and discussions with the staff. The visit was hosted by T. Kondo, Director, Department of Fuels and Materials Research, and A. Hishinuma, Head, Radiation Effects and Analysis Group. The main areas covered in this visit are listed below with the host identified.

1. Fusion Reactor Physics Laboratory (T. Nakamura). Group uses a fusion neutron source that is similar to a small RTNS-I for neutron cross section and activation measurements. Integral experiments are used to measure activation, shielding, heating, and tritium breeding. This is a well-established program that has contributed significant data. Collaborations have included Argonne National Laboratory and University of California, Los Angeles.

2. Tritium Engineering Laboratory (K. Okuno). This is a new laboratory set up to develop processes for the handling and processing of tritium. All equipment is new, and the laboratory is set up for triple containment (the apparatus, glove box, and building). The current tritium inventory is 16 g, and the facility is approved for a maximum inventory of 60 g.
3. Tandem Accelerator (Y. Ishii). This existing accelerator facility is used for some experiments on fusion reactor materials. It has been used to irradiate Li_2O with 60 MeV Li ions and measure the resulting volume change.
4. Materials Performance and Testing Laboratory (N. Nakajima). This laboratory is involved mainly in the testing of materials for high-temperature gas-cooled reactor (HTGR) systems. They have an elaborate gas system to supply helium with controlled impurities, and use this atmosphere for creep tests and other property test systems. Emphasis is on Hastelloy X, Alloy 800H, and a developmental Ni-Cr-W superalloy.
5. Material Strength Laboratory (M. Suzuki). The key facility of this group is the Helium Engineering Demonstration Loop (HENDEL) operated in support of the HTGR development program. This loop supplies helium at 400 to 1000°C to a 16-m-high simulated reactor section for material exposure tests.
6. Materials Processing Qualification Laboratory (H. Watanabe). This group is conducting tritium production and release experiments in the JRR-2 research reactor. Two experiments are in place, one containing Li_2O , the other LiAlO_2 . Tritium release rates are measured as a function of temperature.
7. JAERI Materials Performance Data Base (JMPD). This is a new system under development to store all materials data. The current content of the system is limited, but the potential value of the system is very large. Proposed integration with the IEA fusion material data base activity was mentioned.

JAERI - Tokai and Naka Sites, December 14-15, 1989

Attendee: E. J. Zinklo, ORNL

Zinklo visited with staff members of the Material Innovation Laboratory and the Department of Fuels and Materials Research on December 14-15, 1989. Of particular interest to the traveler was the JAERI research program on radiation effects in ceramics, headed by Ohno and Katano. Their research program is similar to that at ORNL, and includes transmission electron microscopy (TEM) examination of ion-irradiated Al_2O_3 and SiC. They also have an active program on in-situ measurements of ac conductivity (50 Hz to 100 kHz) using a 10^5 R/h ^{60}Co source. Measurements have been made over a wide temperature range. From

their data analysis on Si_3N_4 , the grain boundaries have a large effect on the conductivity at high temperatures.

A tour was given of several of the radiation effects facilities at JAERI, including the hot cells (in-situ conductivity measurements), the 2 MV Van de Graaff accelerator (equipped with five target lines and operated 16 h/day), and the 20 MV tandem Van de Graaff accelerator. Hojou demonstrated the JEM 100C electron microscope that is linked to a 10 KV light ion accelerator for in-situ ion radiation damage studies. The microscope is equipped with a TV camera and energy dispersive X-ray and parallel electron energy loss spectroscopy devices. They are currently installing similar equipment on a JEOL 4000 FX microscope, which will be linked to two 40 KV ion beam accelerators.

A tour was also given of the JT-60 tokamak reactor site. The machine is currently being upgraded and is scheduled to become operational in March 1991. The modification involves a replacement of the poloidal field coils and vacuum vessel. The new vessel will have D-shaped cross section and will be nearly twice the volume of the original. The plasma heating systems will also be upgraded to twice the original power. Neutral beams (20 MW) and both ion cyclotron and lower hybrid radio frequency heating systems (120 MHz and 26 Hz, respectively, each at 10 MW) will be used in 10 s pulses to heat the plasma. Deuterium fuel will be used in the upgrade.

National Research Institute for Metals, December 16, 1989, Tokyo, Japan

Attendee: S. J. Zinkle, ORNL

On Saturday, December 16, Zinkle visited with Masao Takeyama of the National Research Institute for Metals. The effect of grain size on the yield stress of polycrystalline metals was discussed. A recent analysis suggests that grain size effects have a strong influence on the radiation hardening of metals, particularly at low doses. Takeyama also mentioned a new fellowship program for visiting young scientists (under the age of 35). The program pays the salary and provides a housing allowance for foreign scientists who wish to work in Japan for one or more years. Zinkle talked briefly with a U.S. scientist from the University of California-Berkeley who was participating in the fellowship program and recommended it to any interested U.S. citizens.

DISCLAIMER

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APPENDIX A

Itineraries1989E. E. Bloom

11/29-30 Travel from Kingston, TN, to Tokyo, Japan
12/1-2 U.S./Japan Collaborative Program on Use of HFIR, Tokyo, Japan
12/2-3 Weekend and travel to Kyoto, Japan
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel from Kyoto, Japan, to Kingston, TN

J. W. Davis

12/1-2 Travel from St. Louis, MO, to Kyoto, Japan,
12/3 Rest and time adjustment
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel to Tokyo, Japan
12/10 Weekend
12/11 IEA Materials Data Base Meeting at JAERI Headquarters
12/12 IEA 10th Executive Committee Meeting
12/12 Travel from Tokyo, Japan, to St. Louis, MO

M. L. Grossbeck

12/1-2 Travel from Oak Ridge, TN, to Kyoto, Japan
12/3 Weekend
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel to Tokyo, Japan
12/10 Weekend
12/11 Meeting on ITER Data Base, Tokyo, Japan
12/11 Travel from Tokyo, Japan, to Oak Ridge, TN

R. L. Klueh

12/2-3 Travel from Knoxville, TN, to Kyoto, Japan
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel to Tokyo, Japan
12/10 Weekend
12/11-24 Vacation, Thailand
12/25 Travel from Thailand to Knoxville, TN

L. K. Mansur

12/1-2 Travel from Clinton, TN, to Tokyo, Japan
12/3 Travel to Kyoto, Japan
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel to Tokyo, Japan
12/10 Travel from Tokyo, Japan, to Clinton, TN

F. W. Wiffen

11/29-30 Travel from Oak Ridge, TN, to Tokyo, Japan
12/1 11th DOE/JAERI Annex I Steering Committee Meeting, Tokyo, Japan
12/2 Travel to Kyoto, Japan
12/3 Weekend
12/4-8 ICFRM-4, Kyoto, Japan
12/9 Travel to Tokyo, Japan
12/10 Weekend
12/11-12 3rd FFTF/MOTA Experimenters' Workshop, Tokyo, Japan
12/13 JAERI, Fusion Reactor Materials Programs, Tokai-mura, Japan
12/14 Travel from Tokyo, Japan, to Oak Ridge, TN

S. J. Zinkle

12/2-3 Travel from Knoxville, TN, to Kyoto, Japan
12/4-8 ICFRM-4, Kyoto, Japan
12/9-10 Weekend and travel to Nagoya, Japan
12/11 Nagoya University, Nagoya, Japan
12/12-13 3rd FFTF/MOTA Experimenters' Workshop and Japan/US Meeting on Evaluation of Radiation Damage in Ceramics and Graphite, Tokyo, Japan
12/14-15 JAERI, Tokai-mura, Japan
12/16 National Research Institute for Metals, Tokyo, Japan
12/17 Travel from Tokyo, Japan, to Knoxville, TN

APPENDIX B

Distribution

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10. D. J. Cook, Deputy Director, Safeguards and Security Division, DOE/ORO
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