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Destination(s) and Dates for Which Trip Report Being Submitted: England - August 27-September 7, 1990

Name of Traveler: Peter F. Tortorelli

Joint Trip Report ☐ Yes ☒ No

If so, Name of Other Traveler(s): _____

OAK RIDGE NATIONAL LABORATORY

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ORNL

FOREIGN TRIP REPORT

ORNL/FTR-3745

DATE: September 21, 1990

SUBJECT: Report of Foreign Travel of Peter F. Tortorelli, Corrosion Science and Technology Group, Metals and Ceramics Division, Oak Ridge National Laboratory

TO: Alvin W. Trivelpiece

FROM: Peter F. Tortorelli

PURPOSE: To attend the 1990 European Workshop on Lead-Lithium Corrosion and Chemistry, the Symposium on Fusion Technology (SOFT), a meeting of the Program Committee for the Second International Symposium on Fusion Nuclear Technology (ISFNT-2), and to visit Harwell Laboratory.

SITES VISITED:

8/29/90	Harwell Laboratory	Didcot, U.K.	M. J. Bennett
8/30-9/1/90	Workshop	Nottingham, U.K.	P. Hubberstey
9/3-5/90	SOFT	London, U.K.	
9/6/90	ISFNT-2	London, U.K.	J. E. Vetter

ABSTRACT: The traveler participated in the 1990 European Workshop on Lead-Lithium Corrosion and Chemistry. Main areas of emphasis in the European liquid metal (exclusively Pb-17 at. % Li) program are now on deposition effects and corrosion-resistant surface product layers that can also serve as barriers to tritium permeation and insulators. Dr. Tortorelli also visited Harwell Laboratory to discuss innovative methods of corrosion analysis. He attended the 16th Symposium on Fusion Technology in London and the initial meeting of the Program Committee for the Second International Symposium on Fusion Nuclear Technology, which will be held in June 1991. He toured the JET facilities as part of the SOFT program.

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COMPREHENSIVE TRIP REPORT

Harwell Laboratory, August 29, 1990

On August 29, I visited Harwell Laboratory at the invitation of Dr. Michael Bennett to discuss specialized surface preparation and analysis procedures in corrosion science. For many years Bennett's group has been at the forefront of developing new and imaginative ways to characterize corrosion processes. One result of this has been the establishment of specialized equipment and techniques to carefully prepare specimens for high resolution analysis. Now that Harwell is part of a business unit known as AEA Technology, Dr. Bennett is actively promoting these unique abilities in "surface microsurgery" (his terminology). I reviewed several of these techniques with Bennett, Joe Desport, Anne Thunder, and Rex Hussey of the National Research Council (NRC), Canada, who was just completing a four-month assignment at Harwell. Hussey devoted much of his time there to the study of these specialized methods and became absolutely convinced of their utility in corrosion research. NRC will be funding Harwell to replicate some of the equipment for delivery to his laboratory in Canada.

Knowing of my work on the mechanical properties of oxide scales, Bennett and Thunder gave me some preoxidized specimens of chromium (with and without implanted cerium). With these specimens, I can determine whether the cerium addition (which definitely improves the oxidation resistance of chromium) has an influence on the mechanical properties of the chromia scales formed upon oxidation. Several had been tapered in the surface microsurgery facility. Such tapering appears to offer several advantages for submicron indentation testing of scales. If this proves to be the case with the chromium specimens, we should seriously consider a taper approach in future characterization work (both mechanical and chemical) involving oxide films and other surface layers.

While at Harwell, I also discussed the results of some secondary ion mass spectrometry work done for us by Hugh Bishop and Bennett as part of an oxidation study of Ni_3Al matrix composites. Their contribution was crucial in definitively showing that the presence of fibers in Ni_3Al led to internal oxidation along the fiber-matrix interfaces. We also decided on the format for publishing the results in the open literature.

1990 European Workshop on Lithium and Lead-Lithium Corrosion and Chemistry, August 30-September 1, 1990

I attended the 1990 European Workshop on Lead-Lithium Corrosion and Chemistry at the University of Nottingham, England, from August 30 to September 1. My European colleagues convene this meeting annually as a means to informally discuss their recent findings and keep abreast of each laboratory's efforts, much of which is coordinated through the European Community (EC) fusion program. I have been fortunate in being invited to participate in these meetings several times. With the possible exception of the Soviet program, most fusion-relevant liquid metal work is now conducted in EC countries and these workshops provide me with the best way of staying current in this field and getting some external feedback on my liquid metal corrosion research. The European fusion corrosion efforts are centered around experiments in support of a

liquid metal self-cooled Pb-17 at. % Li (Pb-17Li) blanket concept or a design in which semistagnant lead-lithium is used for tritium-breeding. Given the close ties between the European design efforts and the liquid metal corrosion programs at the various laboratories, it is not surprising that there now is no interest in lithium work among the Workshop participants.

A list of the Workshop presentations is shown in Appendix A. My contribution, "Deposition in Pb-17 at. % Li," was based on recent mass transfer analysis of our thermal convection loop data and was very timely. It was obvious that the emphasis of the European efforts has shifted toward deposition concerns (as well as surface layers, as described below) and my work was very well received. We had very good, productive discussions regarding the influences of particle transport, deposit detachment, and magnetic fields on mass transfer. Hans Borgstedt of Kernforschungszentrum Karlsruhe (KfK), Germany, has observed nickel-enriched deposits similar to what I reported.

Other important information/conclusions presented by the Europeans included:

- A definite influence of a magnetic field on dissolution and deposition of austenitic stainless steel in semistagnant Pb-17 at. % Li [Terlain, Commissariat a l'Energie, Atomique (CEA) - Fontenay-aux-Roses, France]. Corrosion can be enhanced for certain orientations of the magnetic field lines with respect to the liquid metal flow.

- Very good agreement among all European and U.S. data for ferritic/martensitic steels in Pb-17Li when dissolution rates are properly corrected for flow velocity (Terlain).

- A possible two-step corrosion process for Fe-Ni-Cr alloys in Pb-17Li (Simon, CEA, France).

- Use of aluminized layers for corrosion protection in Pb-17Li. Researchers at CEA, KfK, the Joint Research Centre (JRC) Ispra, and the Austrian Research Centre, Seibersdorf, Austria, are pursuing this line of investigation. I suggested that they expose some bulk nickel and iron aluminides (which ORNL can supply) to Pb-17Li so they can address basic compatibility with the liquid metal apart from any complications arising from coating imperfections. (We have previously exposed some bulk iron aluminide to Pb-17Li at ORNL and saw no significant improvement in corrosion resistance.)

- Good data on the solubility of iron in Pb-17Li and some limited information for molybdenum (Barker, University of Nottingham).

- Assembly of an oxidation facility at JRC Ispra to form chromia on stainless steel so as to investigate $LiCrO_2$ as a tritium permeation barrier (Coen).

- Use of equilibrium resistance measurements to more accurately determine phase boundaries in the Pb - (<20 at. %)Li system (Hubberstey, University of Nottingham).

A very important aspect of current and future lead-lithium corrosion and chemistry research in Europe is the use of corrosion-resistant surface product layers that also function as tritium permeation barriers and insulators (to avoid interactions arising from movement of a liquid metal through a magnetic field). It is hoped that the above-mentioned aluminized layers may satisfy all these requirements and I anticipate significant European progress toward experimental assessment of this possibility within the next two years.

The European work on surface product layers somewhat parallels my current plans for the continuation of lead-lithium work at ORNL, although I will be concentrating on the corrosion inhibition aspects. There is a good opportunity to conduct my program in a way that complements the European agenda by combining our experience in liquid metal corrosion and high-temperature oxidation with the excellent surface characterization capabilities at ORNL.

16th Symposium on Fusion Technology, September 3-6, 1990

I attended the 16th Symposium on Fusion Technology (SOFT) in London, England, on September 3-6, 1990. The vast majority of papers were presented as posters (over 300) and were supplemented by oral presentations on selected topics. It had been many years since I attended a fusion meeting not devoted exclusively to materials and I found the conference to be helpful in keeping apprised of developments in the other areas of fusion technology. For example, I was interested in the recent work being done on the design of blanket modules for the Next European Torus (NET) type of devices, several of which incorporate liquid metals. Safety and environmental concerns were important themes at the conference. R. S. Pease described the results from the recent European assessment of fusion safety and environmental issues and compared the findings with those from the equivalent U.S. study. Roger Hancox of Culham Laboratory gave an interesting account of the management of fusion waste in terms of the requirements for the Joint European Torus (JET), NET or the International Thermonuclear Reactor (ITER), and commercial reactors. Tom Wilkie, science editor for The Independent, a major English newspaper, spoke on public faith in fusion. His basic message was that "safety is not enough" and that fusion viability will ultimately be determined by economic and social issues. He urged the fusion community not to ignore the nontechnical aspects of the technology and to take the initiative in funding some sociological studies.

While I welcomed the opportunity to learn more about other areas of fusion technology, I paid particular attention to the papers dealing directly with materials behavior. A listing of such papers is included as Appendix B. There were two invited papers on materials: "Recent Developments in Superconducting Materials" (B. Turck, CEA, Cadarache) and "Fusion Materials Research Problems, Recent Developments, Present Trends" (H. Ullmaier, Jülich). I found that Dr. Ullmaier's views on the current problems associated with materials research closely mirrored my own and those of many of my colleagues. He listed five basic problems as being:

1. mismatch between the fast turnover in fusion design and the slow pace of materials research and development;

2. the large variety of fusion materials and partially conflicting requirements;
3. lack of a prototypic test environment, particularly for fusion neutron damage;
4. limited funding and manpower (materials research and development comprises 7.5% of the European fusion program and about 4% of the U.S. effort); and
5. difficulty of balancing requirements for materials data for near-term fusion components with necessity of materials research for long-term applications.

As examples of recent developments, Ullmaier described work on carbon-based materials and beryllium for plasma-facing components and the effects of neutron irradiation and surface conditioning on the fatigue of type 316L stainless steel. His listing of present trends in materials research included mechanical and irradiation behavior of welds and joints, high heat flux testing of potential plasma-facing materials (graphite, beryllium, etc.), greater development of materials data bases for selection and design, low activation materials, and ideas for an intense high energy neutron source. He remarked that materials databases were not further advanced because there was a basic lack of interest in such things by materials scientists. As with his remarks on research problems, I think he was again on target with this observation.

On September 5, I toured JET as part of the Conference program. We were shown the torus hall, the control room, the active gas (tritium) handling system (currently being installed), the diagnostic center, the power supplies, and the assembly (robotics) facility. I found the experience of seeing how the various components operate and are integrated into a fusion tokamak system to be extremely informative.

Meeting of the Program Committee for the Second International Symposium on Fusion Nuclear Technology, September 6, 1990

On September 6, I attended the initial meeting of the Program Committee of the Second International Symposium on Fusion Nuclear Technology (ISFNT-2) in London. Other U.S. members of the Committee are Abdou (UCLA), Baker (ORNL), Holland (EG&G Idaho), Kazimi (MIT), and Mattas (ANL), but, of this group, only Steve Piet of EG&G Idaho (representing Holland) and I were in attendance. (I will mail copies of my meeting notes and the handouts to the other U.S. Committee members.) A complete list of the membership of the Program Committee is shown in Appendix C. J. Vetter of KfK is chairman of the Program Committee and presided at the meeting. He reported on the deliberations of the International Steering Committee (ISC), which met earlier that day. They decided that ITER work should have a strong presence at the conference, that the published papers will appear in a refereed journal (as at ISFNT-1), and that the Program Committee should be highly selective in their acceptance of papers. I questioned Vetter on his opinion of how materials-related papers fit into ISFNT-2, particularly in view of the fusion materials conference in November 1991. (ISFNT-2 is in June 1991.) He replied that it was his view (and that of the ISC) that only papers emphasizing fusion engineering and design aspects of materials would be accepted and that those dealing with materials science/behavior would be rejected. I was quite satisfied with his response since it coincided with my idea of how materials should fit into ISFNT-2.

Of the 139 preregistration forms that were returned, 19 were from the United States. This prompted D. Vollath, the scientific secretary for the Conference, to remark that the U.S. contribution was "relatively small" at this point. (At ISFNT-1 in Tokyo, there were 48 U.S. papers out of 210.) There was some concern about the poor preliminary response to certain topics. For example, there were no titles submitted for repair and maintenance. It also appeared that there were just a few contributions in the discipline of neutronics/activation.

The principal functions of the Program Committee are to select the invited papers and corresponding speakers, accept or reject contributed papers based on the abstracts, and organize review and publication of the submitted manuscripts. To the first end, each member was asked to suggest possible topics for invited papers and then for possible speaker candidates. After discussions, a tentative list of topics and possible presenters was compiled. Per the wishes of the ISC, it showed a strong ITER representation. In anticipation of the review and editing process that will take place next spring, each Committee member was asked to take responsibility for coordinating the review of a certain number of papers in one or two topical areas. Paper selection will be done at the second meeting of the Program Committee in Karlsruhe on January 15, 1991. A book of abstracts will be mailed to the Committee members for review several weeks prior to that date.

APPENDIX A

Presentations at 1990 European Workshop on Lead-Lithium Corrosion and Chemistry

LITHIUM WORKSHOP

Ancaster Hall, Nottingham University

Programme

Corrosion in Pb-17Li Systems

a Hans Borgstedt
Results of corrosion tests in the "PICCOLO" loop
b Anne Terlain
The influence of magnetic fields on corrosion in semi-stagnant Pb-17Li
c Anne Terlain
Corrosion of martensitic steels in flowing Pb-17Li
d Nathalie Simon
Corrosion and mass transfer of ternary Fe-Cr-Ni in anisothermal semi-stagnant Pb-17Li
e Inge Schreinlechner
Results of capsule tests of stainless steels in Pb-17Li
f Peter Sattler
Initial experience with a PC-controlled Pb-17Li loop
g Gianluca Benamati
Initial corrosion results for AISI 321 and Inconel 718 in Pb-17Li

Deposition in Pb-17Li Systems

a Peter Tortorelli
Deposition in Pb-17Li
b Horst Feuerstein
Deposited particles in an austenitic thermal convection loop containing Pb-17Li
c Marten Barker
Solubilities in Pb-17Li

Mechanical Properties of Steels in Pb-17Li

a Hans Borgstedt
The influence of Pb-17Li on the mechanical properties of MANET steel
b Pietro Agostini
Experimental programme for corrosion fatigue in Pb-17Li
c Vittorio Coen
A review of recent research work at JRC Ispra

Monitoring Pb-17Li Systems

a Peter Hubberstey
Composition determination in Pb-Li sytems by equilibrium resistance measurement of phase boundaries
b Hugo Tas
Sensors for Pb-17Li systems
c Pietro Agostini
Experimental calibration procedure for electromagnetic flowmeters in Pb-17Li

Miscellaneous Topics

a Horst Feuerstein
The use of getter materials for tritium extraction from Pb-17Li
b Tony Sample
Preliminary work on the Bi-Pb-Li system
c Gianluca Benamati
Experimental programme for the water Pb-17Li reaction

APPENDIX B

SOFT Papers Related to Materials Behavior

B. Turck, "Recent Developments in Superconducting Materials"

H. Ullmaier, "Fusion Materials Research Problems: Recent Developments - Present Trends"

M. Zucchetti, "Comparison of Thermal Behaviour and Activation of Some Proposed Materials for Fusion-Reactor First Wall"

G. L. Jackson, "Wall Conditioning and Plasma-Surface Interactions in DIII-D"

G. P. Tartaglia, "Irradiation Effects on Mechanical Properties of 316 Welded Joints"

A. Sagara, "Chemical Erosion of Selected Carbon-Carbon Composites in the PISCES-B Facility"

H. Takatsu, "Material Behavior of Graphite and C/C Composite Divertor Plates in JT-60"

A. T. Dijksman, "The Release of Implanted Deuterium From Clean and Impurity Covered Tungsten"

I. Smid, "Hydrogen and Deuterium Plasma Interactions with Brazed First Wall Elements"

K. Koizlik, "Carbon Fiber Reinforced Carbons for First Wall Application - Material Characterisation, Thermal Shock and Erosion Behaviour"

C. M. Mingam, "Application of SiC and B_4C Coat-Mix-Material: A New Candidate for plasma Facing Components"

M. Victoria, "A Comparison Between Irradiation Results with Intermediate Energy Protons and those of Other Irradiation Paricles"

A. Hishinuma, "Advanced Structural Materials Developed for the First Wall"

M. Miyake, "Outgassing Behaviour of Various SiC Ceramics"

A. Chanfreau, "Role of Welding on Tritium Distribution and Helium Precipitation in an Austenitic Stainless Steel"

I. E. Schreinlechner, "Compatibility of Ferritic Chromium Steels in Static PB17Li"

E. Kny, "High Heat Flux Testing and Cycling of Actively Cooled TZM-Mo41Re Divertor Targets with Brazed Graphite and CC Armor"

APPENDIX B (Cont'd)

SOFT Papers Related to Materials Behavior

P. Hofmann, "Chemical Interactions of Li-Based Oxides with Be and Stainless Steel"

R. A. Forrest, "Activation of Structural Materials in the Outer Regions of a Fusion Reactor"

J. M. Perlado, "Evaluation of Low Activation Martensitic Alloys as FSW using Operation, Recycling and Disposal Criteria"

N. Simon, "Corrosion and Mass Transfer fo Ternary Alloys (Fe-Ni-Cr) in Anisothermal Semi-Stagnant Pb17Li"

T. Flament, "Influence of Magnetic Field on Thermohydraulic and Corrosion in the Case of the Water-Cooled Blanket Concept"

A. Terlain, "A Study of Permeation Barriers for Pb17Li Breeding Blankets"

B. Rasneur "Mechanical Properties of Lia102 and Li2Zro3 Tritium Breeding Ceramics"

D. Vollath, "Irradiation Effects on Ionic Conductivity of Al-Doped Li4Sio4"

B. Van der Schaaf, "Mechanical Properties of Electron Beam Welded in 1.4914 Steel for Fusion Devices"

APPENDIX C

Annex 2

International Program Committee

Name	Institution	Country
Prof. Abdou, M.A.	University of California	U.S.A.
Dr. Baker, C.C.	Oak Ridge National Laboratory	U.S.A.
Dr. Casini, G.P. *	Joint Research Centre	European Community
Prof. Chuyanow, V.	I.V. Kurchatov Institute of Atomic Energy	USSR
Dr. Dautovich, D.P.	Canadian Fusion Fuels Technology Project	Canada
Dr. Dietz, K.J. *	JET Joint Undertaking	U.K.
Dr. Hircq, B. *	Centre d'Etudes Nucléaires	France
Dr. Holland, D.F. 1)	Idaho National Engineering Laboratory (INEL)	U.S.A.
Prof. Kazimi, M.	Massachusetts Institute of Technology (MIT)	U.S.A.
Prof. Madarame, H.	University of Tokyo	Japan
Dr. Mattas, R. F.	Argonne National Laboratory	U.S.A.
Prof. Miya, K. 3)	University of Tokyo	Japan
Dr. Moons, F. *	SCK / CEN	Belgium
Prof. Morita, K.	Nagoya University	Japan
Prof. Nishikawa, M.	Osaka University	Japan
Dr. Okamoto, M.	Tokyo Institute of Technology	Japan
Prof. Orolov, V.	Research and Development Institute of Power Engineering	USSR
Dr. Saksagansky, G. 2)	D.V. Efremow Scientific Institute of Electrophysical Apparatus	USSR
Dr. Salpietro, E. *	The NET-Team	Germany
Dr. Seki, M. *	Japan Atomic Energy Research Institute	Japan
Dr. Shatalov, G.E. 2)	I.V. Kurchatov Institute of Atomic Energy	USSR
Dr. Strebkov, Y. 2)	Research and Development Inst. of Power Engineering	USSR

APPENDIX C (Cont'd)

Dr. Takagi, T.	Tohcku University	Japan
Prof. Tanaka, S. *	University of Tokyo	Japan
Dr. Toda, S.	Tohoku University	Japan
Dr. Tortorelli, P. *	Oak Ridge National Laboratory (ORNL)	U.S.A.
Dr. Vetter, J.E. *	Kernforschungszentrum Karlsruhe GmbH	Germany
Dr. Vollath, D. *	Kernforschungszentrum Karlsruhe GmbH	Germany
Dr. Yoshikawa, K.	Kyoto University	Japan

* present at the 1st meeting on Sept. 6

1) represented by Dr. Piet, INEL

2) represented by Dr. G. Kalinin, R&D Inst. of Power Eng.

3) represented by Prof. S. Tanaka, University of Tokyo

APPENDIX D

Itinerary

Date	
1990	
8/27-28	Travel to London, England, from Knoxville, Tennessee
8/29	Discuss corrosion-related surface analysis at Harwell Laboratory, Didcot, England
8/30-9/1	Attend 1990 European Workshop on Lithium and Lead-Lithium Corrosion and Chemistry
9/2	Weekend
9/3-5	Attend SOFT Conference in London, England
9/6	Attend program committee meeting for ISFNT-2
9/7	Travel to Knoxville, Tennessee, from London, England

APPENDIX E

List of Literature Acquired

Harwell Laboratory

CH News, Issue 10, August 15, 1990

Materials Characterization Service News, AEA Technology, No. 7, Spring 1990

H. E. Bishop and S. J. Greenwood, "SIMS of Microelectronic Structures using a Liquid Metal Ion Gun," Surface and Interface Analysis *16* (1990) 70-76.

H. E. Bishop, "The Influence of Diffraction Effects on Quantitative Auger Electron Spectroscopy," Surface and Interface Analysis *16* (1990) 118-128.

1990 European Workshop on Lead-Lithium Corrosion and Chemistry

J. Alessandrine et al., "Experimental Calibration of E.M. Flowmeters for Pb-17Li," unpublished report, ENEA-Brasimone, 1990.

SOFT Preprints

M. Merola and M. Zucchetti, "Comparison of Thermal Behaviour and Activation of Some Proposed Materials for Fusion Reactor First Wall"

H. Feuerstein, H. Grabner, and S. Horn, "Extraction of Tritium from Molten Pb-17Li by Use of Solid Getters"

I. Schreinlechner et al., "Compatibility of Ferritic Chromium Steels in Static Pb17Li," Austrian Research Centre

V. Coen and T. Sample, "Pb-17Li: A Fully Characterized Liquid Breeder"

JET Visit

Descriptive brochure about JET

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10 / 18 / 90