SUMMARY OF PRESENT DISCUSSIONS ON INTERNATIONAL COLLABORATION ON FUSION NUCLEAR TECHNOLOGY

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Introductory Remarks

- Fusion Nuclear Technology has received increasing attention during the 1980's. Various studies (e.g., FINESSE, BCSS, EC Blanket Study) were carried out

- Present Status

  - We understand the technical issues

  - We know how to go about solving these issues

  - Required facilities and experiments have been defined in detail

- Implementation is the next major step

  - How about resources/budget?

  - Role of international collaboration?

Efforts to Develop Collaborative International Programs for New FNT Initiatives

- 1985 International Workshop at UCLA
- 1987 TWP Meeting
  - Recommendation to form Ad Hoc group for blanket
- Ad hoc group was formed (under IEA)

  Darvas (EC), Chairman
  Dowling (USA)
  Iijima (JAERI)
  Philips (Canada)

- The Ad Hoc group requested a specialist meeting in Cadarache, France, April 11-13, 1989

Cadarache Specialist Meeting
11-13 April 1989

Topics Considered for Collaboration

- Thermomechanicla Testing
- Liquid Metal Facilities
- Solid Breeder Irradiation
- Tritium Recovery from the Blanket
- Neutronics

Participants

From EC, Canada, Japan, USA

Output

Summarized on a set of viewgraphs by F. Carré

THERMOMECHANICAL TESTING OF SOLID BLANKETS

BACKGROUND

1. Thermomechanical testing is necessary to check the reliability and the integrity of the blanket modules in relevant normal and off-normal operating conditions. However, they call for a close simulation of the actual bulk heating to be fully representative.

2. Even though specific of the tested concept, thermomechanical tests may address generic issues and generate valuable data for other designs

   - Brasing of pressure tube to Beryllium plates
   - Attachment of Beryllium blocks to steel module shells
   - Thermal cycling effects on ceramic material

STEPS TOWARDS A POSSIBLE COLLABORATION

3. Most national programs have plans for thermomechanical tests of solid blanket generic elements

   - Submodule in the short term (90-93)
   - Full scale blanket module in the longer term (after 93)

   No plans have been made so far for a collaboration in this area

4. The incentive to share both the existing facilities and some results on blanket concepts of common interest, could initiate international exchanges or collaboration in thermomechanical testing.

RECOMMENDATION TO THE IEA AD HOC GROUP

5. It could be profitable to provide the blanket design teams, with the basis to judge the opportunities of collaboration such as:

   - the summary of scheduled programs and plans of thermo-mechanical tests.
   - the list of existing helium and water test loops in the US, Japan, Canada and Europe.
   - the list of blanket concepts under consideration and their generic thermomechanical issues

WATER INTERACTION EXPERIMENTS WITH LIQUID AND SOLID BREEDER

BACKGROUND

Water Cooled Pb-17Li Blankets

- DEMO Test Blanket in EC
- ITER Driver Blanket

} Existing bilateral EC & US Safety Program

Water Cooled Solid Blanket

- FER Blanket (Japan)
- US
- NET/ITER Driver Blanket

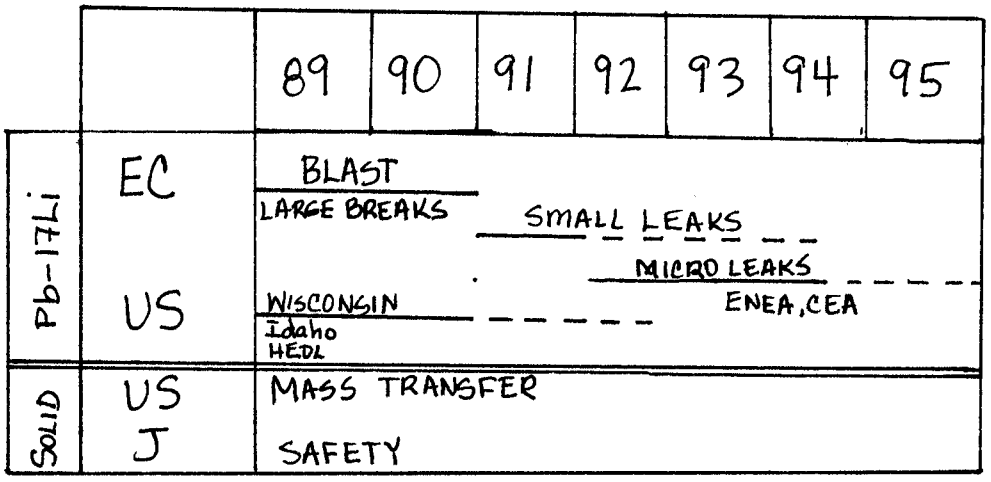
} Existing national programs
- on safety (J)
- on mass transfer (US)

EXISTING COLLABORATION

Safety of Water Cooled Pb-17Li Blankets

EC (JRC-Ispra) BLAST Experiments
Large breaks (1987-90)
Small leaks (91-)
(+ CEA & ENEA) Micro leak detection + crack propagation (92-93/94)

US University of Wisconsin — Modelling of Pb-17Li/water reactor
Idaho Laboratory — Interpretation of the BLAST experiment
Westinghouse Handford



WATER INTERACTION EXPERIMENTS WITH LIQUID AND SOLID BREEDER

PROSPECTS FOR EXTENDED COLLABORATION

Japan
- Concentrate the effort on solid blankets
- Limited work on liquid blankets

US
- Have presently no interest in water cooled Pb-17Li blankets
- Have been exclusively interested in self cooled blankets so far
- Both Li and LiPb are being considered as coolant/breeders but most experimental work is now focused on lithium

CANADA
- No national liquid metal blanket development program
- existing program on ceramic breeder materials

EC
- Current interest in both self cooled and water cooled LiPb blankets
- current interest in helium cooled solid blankets
- might reconsider the use of water as coolant for solid breeder in view of Li_2ZrO_3 performance

RECOMMENDATIONS TO THE IEA AD HOC GROUP

1) There are safety studies related to water cooled Pb-17Li or solid blankets conducted in the frame of:

   - either bilateral collaboration (EC & US) for Pb-17Li blankets
   - or national programs: J (safety), and US (mass transfer) for ceramic blankets

2) The existing bilateral collaboration on specific safety issues of these concepts could be extended.

3) A symmetric approach could be envisaged, to initiate a collaboration on safety studies related to water cooled solid blankets, in case of renewal of interest for this blanket concept in EC.

LIQUID METAL TESTING FACILITIES

BACKGROUND

- MHD is a key issue in the development of (self cooled) LM blankets (heat transfer, corrosion, pressure/stress) (20-25% uncertainty on Δ P~5-6 MPa)
- Two objectives for a development program:1) LM Blanket Technology 2) LM Blanket Performance Prediction

EXISTING COLLABORATION

US ALEX (1988/89 $\rightarrow$)

EC (KfK) MEKKA (1989 $\rightarrow$ 94)

(US & EC) Development of analytical tools (89-95)

PLANS FOR FUTURE COLLABORATION

US ALEX II (1992/93 $\rightarrow$ 2000) complex geometry, multiple effects

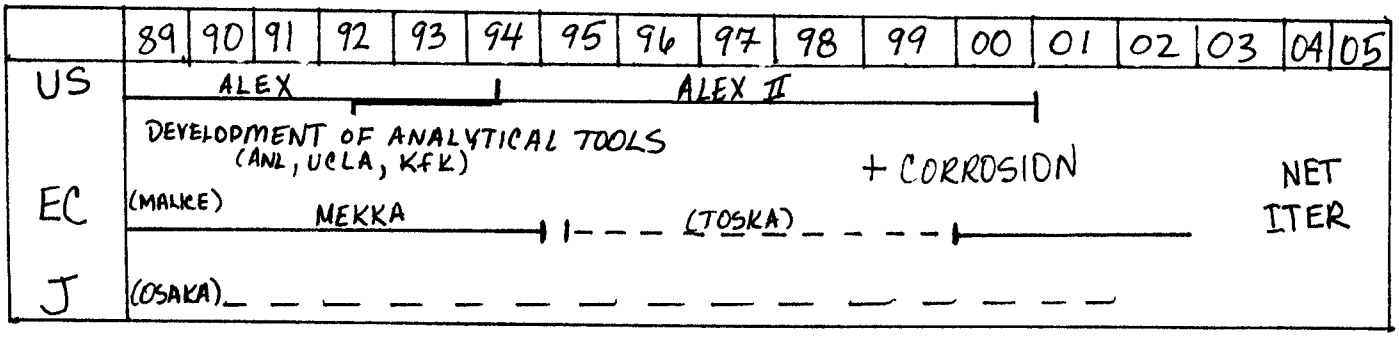
EC (TOSKA) (1995/2000 $\rightarrow$ ITER) multiple effect tests-corrosion

(US & EC) Development of analytical tools

The projected cost of participation of EC in ALEX II is already included in the (1989-94) European LM Blanket development program.

POTENTIALITIES FOR EXTENDED COLLABORATION

Strong interest of Japanese universities. Some expression of interest by JAERI in LM technology, but no declared intention to launch a liquid blanket program in the short term.



LIQUID METAL TESTING FACILITIES

RECOMMENDATIONS TO THE IEA AD HOC GROUP

1) Liquid metal MHD is a suitable subject to be further examined for an IEA Implementing Agreement

   - MHD in the short term
   - Multiple effects, including corrosion in the long term

2) Steps should be taken to explore the interest of Japanese Universities

   - to define their contribution to the international program
   - to discuss the financial agreements

3) Liquid metal corrosion could be an additional suitable area for an extended international collaboration

   - This topic should be addressed in a future workshop

4) In order to develop more detailed proposals for collaboration by January 1990, it is recommended that another meeting of technical experts be held prior to December 1989.

SOLID BREEDER IRRADIATION EXPERIMENT

BACKGROUND

- The tritium extraction from the blanket is a main issue
- This issue was addressed since 1984 by active national and international programs of breeder irradiation and in situ tritium recovery experiments

$\{Li_2O, Li_4SiO_4, Li_2ZrO_3, LiAlO_2\} \times \{\text{Pebble Particle}, \text{Sintered Product}\} \times \{\text{Water (J, US, EC diver)}, \text{Helium (US, EC, J)}\} \times \{\text{Austenitic Steel}, \text{Martensitic Steel}\} \times \{\text{purge gas}, \text{composition}\}$

- Significant progress has been achieved in documenting the solid breeder data base

PAST OR EXISTING EXPERIMENTS

FUBR I	(84-89)	US-EC	EBR II
VOM 23H	( )	J-EC	JRR 2
CREATE V	( )	Canada-EC	NRU
EXOTIC 3	(86)	US-J-EC	HFR
BEATRIX II	(89-90) + (90-91)	US-J-Canada	FFTF
EXOTIC 5	(Planned)	EC-J	HFR
ALICE 2	( )	EC-US	OSIRIS
MOZART	(87-88)	EC-US-J	HELUSINE
SIBELIUS	(89-90)	US-EC	SILOE

PROPOSAL FOR FUTURE COLLABORATION

- Nuclear test of an integrated blanket submodule in a mixed spectrum and/or a fast fission reactor

[integrated T retention, permeation, material integration, thermal performance, BU effects]

FAST 6m → 2.3 y	vs	MIXED SPECTRUM 6 m
Adequate simulation of T production and heat generation		
Helium as coolant High burn up achievable More relevant He/dpa (n, 2n) Be		Possible use of water Low burn up Self shielding ^6Li enrichment < 3%

- Review of the existing irradiation facilities
- Testing strategy to be defined (Nature and number of submodules, schedule compatible with EC programs, test early after 1994)

SOLID BREEDER IRRADIATION EXPERIMENT

RECOMMENDATIONS to the IEA AD HOC GROUP

1) Much of existing activities on solid breeder involve international collaboration

2) Nuclear tests of integrated blanket submodules are a major future step and could be a suitable activity for a broad international collaboration

3) EC does not foresee such test before 1995 (beginning of irradiation)

4) The current national solid breeder programs are focused on development for test modules

5) Fast and thermal reactors are useful for different types of experiments

TRITIUM RECOVERY FROM BREEDING BLANKETS

BACKGROUND

- Demonstration of the fuel processing cycle including the plasma exhaust and the blanket stream is essential before devices like ITER are commissioned
- The performances of the blanket tritium processing line could be considered as one of the selection criteria of the blanket
- Active national programs aim at developing tritium extraction methods from driver and breeding blankets

EXISTING AND PLANNED COLLABORATION

US (LANL)
J (JAERI)
} TSTA (1987-1992) Collaborative agreement (2+2) M$/year

US (LANL, ANL)
J (JAERI)
} Breeding Blanket Interface Design Study (87-92)
Verification of safety, reliability, effectiveness of the processing technology current support from CFFTP and KfK

Phase 1	(87-88)	Characterization of the blanket output stream (Pb-17Li [KfK], Liquid Li, Aqueous salt [CFFTP], solid breeder) (89-93)
Phase 2	(89-91)	Conceptual design of BBI, develop a model to be incorporated to the TSTA operation code
Phase 3	(90-92)	Engineering design of all BBI components and interfaces with TSTA
Phase 4	(92-92)	Hardware procurement and construction (5-8M$)(not approved)
Phase 5	(93-95)	Operation of BBI (2-3 yrs. as an integral part of TSTA) (not approved) Check out with D_2, followed by T_2 operation

POSSIBLE EXPANDED COLLABORATION

Near Term: BBI supports the ITER design activities for tritium systems

Long Term: Open the collaboration to Canada, Europe, ITER....

- In the form of personnel and/or financial support and/or hardware components
- Principle of sharing the generated information among the participants

A collaboration would be welcome even in limited areas of the BBI such as in methods of selecting and analyzing the processing of blanket product streams for integrating with the main fuel stream.

TRITIUM RECOVERY FROM BREEDING BLANKETS

RECOMMENDATIONS TO THE IEA AD HOC GROUP

1) The relative complexity characteristics of the tritium processing of the blanket products are important parameters and could constitute one of the selection criteria for the blanket. (especially for a driver blanket)

2) In view of the large agreement on a strategy of driver blankets for all national and international fusion projects, the tritium recovery from breeding blankets is a suitable area for a broader international cooperation, including integration of the blanket flow into the fuel stream.

3) The ultimate goal and the schedule of the BBI program, does not strictly fit into the present objectives of the European Test Program of DEMO relevant blankets, which does not anticipate the integration of the blanket flow into the fuel stream.

4) The development of tritium extraction methods from blankets is an active field of research:

   - the chemistry of purge gas for solid blankets is in the process of optimization (Internal arrangement OF the blanket (Be, SS) characterization of impurities)

   - various methods are being investigated for Pb-17Li

5) For the above reasons it could be recommended that the international collaboration first be concentrated on the development of tritium extraction methods from the blanket, and the analysis of processes for the integration of the blanket flow into the fuel stream (solid blankets, Pb-17Li blankets, others)

FUSION NEUTRONICS EXPERIMENTS

BACKGROUND

- A reliable prediction of neutron reactions and transport in shield and blanket is a main issue for the design of future D-T fusion devices
- Integral experiments of high intensity 14 MeV neutron flux, are needed to verify and improve the predictability of crucial neutronic issues

PAST AND EXISTING COLLABORATION

{US-DOE & JAERI}	(1984-87-90....)	Collaborative program on Fusion Blanket Neutronics
{KfK & JAERI}	(1987 - 89)	Cooperation on nuclear heating measurements and Be-shell transmission
NEACRP- ((US, C, F, I, S, J,...)	(1989 -)	International comparison of T production and measurement techniques

PROPOSAL OF EXTENDED COLLABORATION

- Integral Benchmark Experiment on Ceramic Breeder Blanket
- Shielding Benchmark Experiment
- Nuclear Heating Measurements
- Long Lived Activation Measurements

Areas of collaboration include, expt. planning, preanalysis of expt., new technique developments

- Intention to upgrade FNS to increase the capability of high fluence irradiation

FUSION NEUTRONICS EXPERIMENTS

RECOMMENDATIONS TO THE IEA AD HOC GROUP

1) A reliable prediction of neutron reaction and transport in shield and blanket, is a main issue for the design of future D-T fusion devices [Radiation protection, tritium production, nuclear heat deposition, induced radioactivity]
Integral experiments at high intensity 14MeV neutron flux, are needed to verify and improve the basic data and the calculational methods of the critical design issues, of all national and international fusion projects [inboard shield, etc.]

2) In view of the high cost of high intensity 14 MeV neutron sources, and of the number of generic neutronic issues, that can be addressed by the existing FNS facility at JAERI, an extended international collaboration should be supported.

3) There are limited available personnel resources in the EC for international collaboration but steps have been taken to implement fusion neutronics experiments in the EC fusion technology program.

4) In view of the development and testing strategy of the next fusion devices, shielding benchmarks are more appropriate to international collaboration. Accuracy of bulk shielding effectiveness, prediction of streaming effects and nuclear heating.

5) Specific details of the experiments would be worked out by a steering committee of specialists. Areas of collaboration include: experiment planning, preanalysis of the experiment, intercomparison, evaluation, development of techniques.

6) It is recommended that the appropriateness of an IEA collaboration on fusion neutronics experiments be further examined by a group of specialists.