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INSIDE

FOURTH AND FINAL MEETING OF QUADRIPARTITE EDA NEGOTIATORS (QEN-4)

The fourth Quadripartite Engineering Design Activities (EDA) Negotiations (QEN) Meeting for ITER was held on November 13 and 14 in Moscow. The meeting was hosted by the Soviet Ministry of Atomic Power and Industry (MAPI) and was held in the new building of the Academy of Sciences.

The four delegations attending the meeting were headed, as in previous negotiating meetings, by Dr. James F. Decker, Deputy Director, Office of Energy Research, Department of Energy for the US, Professor Paolo Fasella, Director-General for Science, Research and Development, Commission of the European Community for the EC, Mr. Hiroto Ishida, Director-General of the Atomic Energy Bureau of the Science and Technology Agency of Japan for Japan, and Dr. Boris V. Nikipelov, First Deputy Minister of MAPI for the USSR.

The meeting was opened with expressions of congratulations to the JET Project, headed by Dr. Paul-Henri Rebut, and to the EC for the recent fusion power experiments reported widely in the press. The four delegations were then pleased to hear from all sides statements with expressions of willingness to conclude the negotiations while continuing further preparatory work for the start of the EDA. (Please see box for selected pieces from the Parties' statements.)

The ITER EDA Agreement was initialled

The Working Group reported on their efforts toward completion of the negotiation as well as the preparations for the start of the EDA. (Please see accompanying article on the Working Group meeting.) After a final review of the draft text of the Agreement, the negotiators initialled the texts of the Agreement and Protocol I signifying acceptance on an ad referendum basis for formal review by their authorities.

The negotiators then confirmed their earlier understandings on the locations and assignment of responsibilities for the Joint Central Team as follows: the Project Integration Co-center will be at San Diego; the Out-of-vessel Components and Related Systems Co-center will be at Naka; and the In-vessel Components and Related Systems Co-center will be at Garching.

Further, the negotiators indicated that the likely nominees for key positions were the following:

Selections from the opening statements by the four Parties

From the Soviet Statement - *"Activities related to ITER are supported by the President of the USSR and the President of Russia."*

From the Japanese Statement - *"We hope ITER-EDA, which will play a central role in our program in the near future, be started as early as possible, and with close collaboration among all the colleagues of the four Parties, ITER-EDA will prove to be a really fruitful and productive project."*

From the EC Statement - *"The EC Delegation considers that the QEN-3 results (texts and negotiations packages) represent a fair and realistic basis for the conclusion of the negotiations."*

From the US Statement - *"Since our last meeting at Reston in July, the Department of Energy has convened two advisory committees that have considered the magnetic fusion program; both reconfirmed the importance of ITER."*

Council Chair	E. P. Velikhov (USSR)
Council Co-chair and Chair of the Management Advisory Committee	M. Yoshikawa (Japan)
Director	P.-H. Rebut (EC)
Chair of the Technical Advisory Committee	P. Rutherford (US)

Home Team Leaders:

EC	R. Toschi	USSR	O. Filatov
Japan	S. Matsuda	USA	A.J. Glass

The expected Council members were identified as follows:

The expected ITER Council members were identified

EC*	Japan	USSR	US
P. Fasella	M. Yoshikawa	E. Velikhov	J. Decker
C. Maisonnier	K. Atarashi	N. Cheverev	N. Davies

* will be accompanied by Chair, CCFP, as an expert

The four delegations agreed to submit to their authorities the initialled text and understandings with a view to concluding as soon as possible the Agreement and Protocol I. They are also organizing further interim work to prepare the start of the EDA. The Working Group is continuing to address the various remaining administrative topics as part of this preparation.

As the EDA will be under the auspices of the IAEA, the negotiators also considered that consultation with IAEA be pursued with a view to defining the domain in which assistance could be provided by the IAEA and the possible modalities of implementation. To that end, the negotiators prepared and sent to Director-General Blix a letter informing him of the progress made at the fourth negotiating meeting. The letter also notes that they have asked the Working Group to continue its explorations with Agency officials in order to prepare for possible arrangments between the IAEA and the four ITER Parties

Appreciation for the IAEA's support was expressed

acting through the Council, once it is established, following signing of the Agreement. The letter ends with appreciation for the Agency's support during the CDA and the EDA negotiations.

The negotiators initialled the texts ending with a champagne toast in honor of the progress made to date.

SEPTEMBER MEETING OF THE ITER NEGOTIATORS WORKING GROUP

by M. Roberts, Chair, Working Group

The Quadripartite Engineering Design Activities Negotiators' (QEN) Working Group met again at International Atomic Energy Agency Headquarters in Vienna on September 11-13, 1991. The purpose of this meeting was to help the negotiators prepare for the fourth QEN meeting scheduled for Moscow in November, and to continue necessary preparations for the actual start of the EDA.

Twenty-one separate topics were discussed during this three-day meeting. On matters relating directly to the completion of the negotiations, the Working Group heard from each delegation that no changes in the draft Agreement text were contemplated, discussed each delegation's view on the Agreement signing process, and also discussed cost issues associated with hosting the three co-centers for the Joint Central Team.

Topics associated with future project implementation were addressed

Most of the other topics addressed were associated with future project implementation. While these topics will clearly be the responsibility of the ITER Council and the Director once the Agreement is signed, the Working Group addressed them in order to prepare for a smooth and timely start of the EDA. These topics included clarification of host support at the three co-centers, information for the selection and establishment of the standards for the communications system, suggested procedures for selecting the staff for the Joint Central Team, and the optional mechanisms for the staffing of the key personnel.

As a result of the efforts of the Working Group, clear information was developed that was provided to the negotiators for their use in preparing for the final negotiating meeting.

ITER WORKSHOP ON RADIATION EFFECTS ON DIAGNOSTIC COMPONENTS

by F. Engelmann, V. Mukhovatov, S. Yamamoto and K. Young

Plasma diagnostics on the ITER device have to provide detailed and reliable information both for physics understanding of the plasma behaviour and for feedback control to ensure device integrity. The most severe constraints on the performance of the plasma diagnostics on ITER are imposed by the nuclear radiation. For this reason an evaluation of the radiation effects on diagnostic components was set by the ITER CDA Diagnostics Group as the highest priority component of the ITER-related diagnostics R&D programme. Drs. V. Chuyanov, A. Glass, Y. Shimomura and R. Toschi, representing home teams, authorized a Workshop on "Radiation Effects on Diagnostic Components" to be held in St. Petersburg, USSR, October 14-17, 1991. The objectives of the Workshop were as follows:

1. Discussion of the ITER-related diagnostic R&D needs for radiation testing with the material scientists:
   - definition of properties, critical for performance;
   - definition of priorities for urgent studies.
2. Evaluation of national capabilities for studying the radiation effects on diagnostic components:
   - review of the status of activities of the home teams;
   - review of capabilities and availability of existing radiation facilities.

Thirty people, i.e., 15 plasma physicists and diagnosticians and 15 material scientists and engineers from the four Parties attended the Workshop.

Radiation issues affecting performance of diagnostic components were clarified

The Workshop clarified the main radiation issues that affect the performance of a broad set of diagnostic components, i.e., mirrors, windows, insulators, optical fibres, cables and various diagnostic sensors. The most critical questions, to be resolved with priority, concern the systems and components in the region adjacent to the plasma or in the neighbourhood of slits. In the first place, magnetic probes, Langmuir probes and signal cables are to be mentioned here. Candidate materials for mirrors, windows and electrical insulators were selected. The conditions for the most urgent irradiation tests were specified.

The key issues in the areas of optical materials and ceramics as specified by the experts at the Workshop are listed below. They all must be resolved before the ITER design finalization.

1. Radiation effects on mirror reflectivity (especially for view mirrors; sputtering and radiation damage by neutral atoms and neutrons; temperature in the range of 100°C to 600°C; mainly post-irradiation testing; fluence of 10^{20} - 10^{25} n/m^2).
2. Optical characteristics of windows during irradiation (luminescence; need to know the location, width, and intensity of excited bands; radiation-induced light absorption; photo-bleaching effects; in-situ testing).
3. Engineering radiation tests of SiO_2 fibreoptics (photo-bleaching luminescence effects, neutron spectrum and H_2 effects; gamma and neutron irradiation; effect of pre-irradiation; temperatures in the range of 25°C - 100°C; fluence up to 10^{18} n/m^2).
4. Mechanical and electrical properties of insulators (Al_2O_3, $MgAl_2O_4$, fused SiO_2); temperature range of 100°C - 1000°C; reactor irradiation to fluence $\approx 10^{26}$ n/m^2 for mechanical tests and accelerator-based irradiation for electrical degradation tests). The test at applied electric field is also important.
5. Neutron irradiation effects on dispersive elements (post-irradiation and in-situ tests).
6. Engineering radiation testing of microwave antenna (graphite, Glid Cop and so on; $\approx$1000°C; $\approx 10^{26}$ n/m^2).

Irradiation studies using fission neutrons 14-MeV, neutrons gamma rays, and energetic ions are required. The fission neutrons are appropriate for most cases. The 14-MeV neutrons are required for spectral-effect and transient-effects studies. Gamma irradiation is sufficient in the study of fluence effects for most SiO_2 studies. Ion irradiation is necessary to investigate surface layer degradation of the view mirrors. Initial screening tests have to be made for a broad set of candidate materials. Time scale for testing is expected to be of 1-2 years for screening tests and of 3-4 years for design-relevant testing on a limited number of materials. There is an extensive data base of fluence effects for SiO_2 which is almost ready to be assembled into the engineering data base. Very little information is available on other materials. Fused SiO_2 was recommended as the reference material for many applications. It was noted that the well developed technical background for nuclear reactors and accelerators in extreme conditions may be applicable to resolve difficulties with some diagnostic elements (i.e., thermocouples, microfission chambers, signal cables), but this must be verified in detail.

The results of ongoing work and near-term plans covering relevant questions in each of the Parties were presented and discussed. Radiation facilities which would be suitable for testing materials for diagnostic components (fission reactors, gamma ray sources, particle accelerators and fusion neutron sources) in various institutions of the ITER partners were reviewed.

Large variety of irradiation facilities could be made available for testing of diagnostic materials

It was confirmed that there was a large variety of irradiation facilities in those institutions which would be suitable for testing of diagnostic materials and components. Radiation enhanced electrical breakdown is being investigated systematically. The substantially reduced threshold levels present a serious challenge to diagnostic (and other) applications where there are applied DC or AC electric fields of even modest values.

It was appreciated that the information presently available on the neutron and gamma fluxes to which the various diagnostic components will be exposed, by now is only preliminary. An iterative approach based on a proceedingly more detailed design analysis and on the results of the testing programme will have to be adopted to define the components and their working conditions in ITER definitely.

The Workshop was very successful in clarifying the issues for the members of the materials science community, while giving the plasma diagnosticians a good view of the status of present-day radiation-effects knowledge. This combination enabled the Workshop to produce many useful recommendations for the future ITER-related diagnostic R&D works.

LIST OF PARTICIPANTS

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ITER MAGNET R&D WORKSHOP

September 23-27, 1991, at Naka Fusion Research Establishment, JAERI, Japan
by A. Kostenko, Chairman

The Workshop was arranged by Drs. V. Chuyanov, A. Glass, Y. Shimomura and R. Toschi on the occasion of the QEN-2 Working Group Meeting in Brussels. According to their recommendation the Workshop should be held in September in Japan and should focus mainly on the Scalable Model coils development and test. It was also recommended to avoid to the extent possible making "recommendations which would have implication on the task assignment. The latter will be the responsibility of a future Working Group".

The Workshop gathered 26 magnet experts: four from the EC, eleven from Japan, six from the USA and five from the USSR. They made about 30 presentations which can be grouped into the following topics:

1. Exchange of views on the ITER magnet R&D plan and information on expected contributions from the Parties.

2. Preliminary design and test programme for Central Solenoid (CS) and Toroidal Field (TF) Model Coils.

3. Model Coil Test Facilities (requirements, national capabilities and availabilities).

4. Status of ongoing R&D in critical areas (conductor development, structural and insulating materials development and testing).

The superconducting magnet systems are among the most critical of ITER subsystems because they represent an advanced technology and should demonstrate highly reliable and safe operation. An extensive magnet R&D programme was developed during the CDA period. The main components of the programme are the Database Development Programme and the Scalable Model Coil Test Programme. The latter one implies the design, fabrication and testing of both the CS and TF Model Coils. Its successful implementation was considered as very important for making decision on ITER magnets construction.

Being cognizant of very tight schedule and high cost of the Model Coil Test Programme the CDA Magnet Group recommended to carry it out on the basis of efficiently co-ordinated international collaboration including task-sharing among the ITER Parties, the use of common test facilities and probably co-operative production of Model Coil modules. For the same reasons and because of the fact that the consensus on several important aspects of the Scalable Model coil test programme was not reached during the CDA it was suggested to the Parties to carry out the model coil design and test programme development during the interim period following the end of CDA and present and discuss them at a joint meeting of the magnet experts.

So the primary objective of the Workshop was the consideration of the results of this work and revision of the CDA magnet R&D plan based on those results. It was anticipated that comparison of the different design proposals would result in the consolidation of the designs allowing to reach agreement on the common specification for the model coils and requirements for the test facilities.

Each of the four Parties reported at the Workshop the preliminary designs and test programmes for both CS and TF model coils.

Preliminary designs and test programmes for CS and TF model coils were reported

All Parties demonstrated very similar views on the CS model testing which come in line with the CDA team proposal. A stack of model coil modules in form of circular coils with inner diameter (≈ 2 m) determined by minimum bending radius of full size conductor was suggested by everybody. The only differences were in the conditions (stress level, critical temperature margin, etc.) at which the nominal operating point would be reached. There was full agreement with the suggestions to use the separate highly instrumented double pancake place in the middle of the coil stack for the detailed measurements of the AC losses, mechanical stresses and stability margin. Such a convergence of opinions permitted without any difficulty to adopt the common specification for the CS Scalable Model Coil and specify main features and requirements for the test facility. There was general agreement that the geometry and main features of the CS model coils are fixed and no significant changes are envisaged.

COMMON SPECIFICATION FOR THE CS SCALABLE MODEL COILS

Nominal Operating current	I_{op} = 40 kA
Maximum Field	B_m = 13 T
Operating Temperature	T = 4.5 K
Temperature Margin	$\Delta T \geq 2$ K
Maximum Voltage	20 kV
Maximum Tensile Stress	σ_θ = 500 MPa
Current Density (Cable Space)	J_{cs} ≈45 A/mm^2
Winding Inner Radius	R_i = 1.0 m
Winding Outer Radius	R_o = 1.65 m
Radial Build for Connection	ΔR = 0.1 m
Maximum Axial Build	$Z \leq 2.5$ m
Number of Coil Modules	N = 4

Various approaches to the TF model coils tests were presented and discussed

A much more difficult situation appeared with regard to the TF model coil tests for which four different approaches were suggested. The USSR Group presented a study on the same geometry as was proposed by the CDA team (a set of three circular coils with one coil offset), but somewhat decreased coil dimensions were considered with the aim to lower the cost and to provide the possibility for a coil home test at any Party test facility. The European view was that it was not needed to construct and test a special TF model coil. Most of the design issues specific for ITER TF magnet could be resolved by testing the TFC conductor in the simple solenoid geometry of the CS model coil set and the design verification of case-winding interaction under assymetric loading could be verified elsewhere, e.g., in the EU-LCT coil tests at 11 T with 1.8 K cooling. The race-track geometry was proposed by the Japanese group. All participants of the Workshop agreed with the main reasons for this geometry that it provides possibility to investigate the manufacturing problems of D-shaped TF coils having transition regions between straight and curved parts. But everybody was aware of the added complexity of coil fabrication, that increases the risk to both the fabrication schedule and the successful performance of the TF model coil.

There were two proposals from the US group. The first approach called a minimum scale TF insert coil was developed by B. Montgomery. It is a non-circular coil with a steel case. The winding pack consists of three double pancakes with minimum bend radius of 0.9 m and a maximum bend radius of

1.5 m. This coil is proposed to be tested in the background field of the PF modules being inserted in the middle of it. The supporting stress analysis had shown that this geometry being much cheaper than that proposed by the Japanese and USSR Groups could provide stress simulation in the conductor and case identical to that in the circular off-set coils proposed during the CDA. The down-sides of the minimum scale TF coil relative to the CDA proposed coils, however, would be the exclusion out of the tests of the conductor options other than react-and-wind types and the potential loss of industrial large coil fabrication experience. The latter drawback could be eliminated if the second USA proposal would be accepted. They suggested to expand the task called MAG 1.5, Full-Scale Winding Development, and include the fabricaton and cold testing of one or more full-scale double pancakes with the aim to develop and confirm reliable manufacturing methods. After rather long and hot discussions involving many participants, both TF coil models, proposed by the USA group, were accepted by all four Parties for recommended further study.

TF MODEL COILS

1. TF Model Module/Coil

Nominal Operation Current	I_{op} = 40 kA
Maximum Field	B_m = 11.2 T
Temperature Margin	$\Delta T \geq 2$ K
Ampere-Turns	$\leq$ 9 MA
Current Density (Cable Space)	$J_{cs} \approx 60$ A/mm^2
Maximum Tensile Stress	Comparable to CDA values
Size and Test Condition	Compatible with KfK facility

2. TF Full Scale Model Coil

   Size ITER Full-size
   - Fabricated according to ITER magnet assembly process
   - Possible configuration:
     a) Double pancake(s).
     b) Double pancake(s) with additional dummy pancakes to complete a winding pack, together with a full-scale case.

When discussing the model coil test programmes, much more attention than previously was paid to the magnets reliability issues. In this respect most of concerns were expressed with regard to the high mechanical cycling of the ITER magnets. The modification of the CDA magnetic R&D plan by including the extensive cyclic testing of the model coil modules was recommended. The estimated time needed for the endurance testing was between four and six months.

The plan for magnet R&D was reviewed

The CDA plan for magnet R&D was reviewed and found to be basically sound, particularly with regard to the CS model coil programme. Several modifications in the plan had been recommende to accommodate the above-mentioned decisions on technical elements. The revised magnet R&D time schedule is shown in the accompanying table.

Parties exchanged information on the proposed test facilities including existing capabilities and planned modifications. To enable the implementation of the Scalable Model coil testing the following was recommended with regard to the major test facilities: Construction of a new test facility at JAERI and modification of two existing facilities at KfK and LLNL. The JAERI facility would carry out the high-power full-performance testing of the CS model coil modules, and the KfK facility would carry out the combined testing of the TF and PF modules and the endurance testing. The LLNL facility could carry out the cold testing of the full-sclale TF winding elements. The main parameters of these major facilities were summarized in the workshop minutes. The same was done for facilities such as Sultan, Sims-2, Fenix, SETF, LTMS-12, which could be used for model pancake and full-scale conductor testing.

The Parties presented the results of the ongoing magnet R&D programme. Since completion of the CDA, there has been significant progress in many areas. The status of this R&D programme and recommendations for focusing the continuing work are given in the minutes. The status of the conductor development allowed agreement by the experts on the following important technical points, simplifying the R&D programm:

a) The internally cooled cable conductor is selected as the baseline conductor for all the ITER coil systems, with variations limited to details of manufacture and coil-specific geometries and material ratios.

b) The baseline conductor concept and any other concepts which may come under consideration must meet the requirements that they be fully qualified in the model coil programme.

c) The ITER CDA goal for the strand critical current density is slightly higher than achievable in the time scale for the fabrication of the model coils. At present, strands with current density 600 A/mm^2 (4.5 K, 12.5 T, no external strain) and 20 μm D_{eff} are available to begin the fabrication of conductors for the Model Coil.

The general atomosphere of the Workshop was characterized by everybody's wish to get consensus on points of divergence through technical discussions, and it was done in most of the technical areas. Everyone recognized needs for early decisions on the content of the magnet R&D programme and task-sharing. But at present the continuation of the work on the model coil design and conductor qualification is essential for the magnet R&D programme. To make efficient use of available resources there is a requirement for collaboration and task-sharing of development tasks.

MAGNET R&D TIME SCHEDULE

Model Coil Components Testing and Development	12/92
Model Coils Construction	12/94
Model Coil Assembly and Testing	12/96
Facility Preparation	12/94
TF Coil Prototype Construction	12/95
TF Prototype Testing	12/96
Facility Preparation	12/95
Component Performance Improvement	12/96

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NEUTRAL BEAM MEETING

Moscow, October 21-23, 1991
by V. Kulygin

An ITER NB meeting was held in Moscow on October 21-23, 1991, being authorized by representatives of the Parties. This article is an edited version of the report of that meeting.

The goal of the meeting was to review the status of the respective neutral beam development programs with emphasis on plans for:

1. Demonstrating proof of principle for the Electro Static (ES) and Electro Static Quadrupole (ESQ) negative ion beams accelerator concepts;

2. Demonstrating a neutral beamline scalable model;

3. Improving the effectiveness of the global program through increased collaboration.

<u>Status of the ongoing NB R&D programs</u>

It was concluded that good progress of R&D has been made by all the Parties with a special commendation to the Japanese for their accomplishments.

Status of the neutral beam development programs was reviewed

In particular, JAERI had provided an essential progress in negative ion sources development by achieving good results in increasing of extracted ion current (10 A, 50 kV, 0.1 s), demonstration 24-hour operation of an ion source at 0.25 A, demonstration of a high-quality beam formation at energy 300 keV. Japan has provided also development of a 2.5 m diameter epoxy insulator for accelerator construction.

Other ion source development efforts: new test stand at LBL has been completed and is now under operation for a new Barium Surface Convertor

Source (BaSCS) testing; test stand at KIAE for Hydrogen-Cesium Plasma Volume Source (HCPVS) testing is under construction.

To develop a steady-state operated ion source with long life is one of the more difficult R&D tasks. Using of RF driven plasma generators instead of usual discharges with filament cathodes appears an attractive way for the task decision. The EC, Japan and the US are carrying out experiments in this field.

Experiments on ion beam formation and acceleration are going on at Culham (DRAGON) with the goal of achieving 200 kV, 4 A D^-, 2 s; at LBL an ESQ accelerator has been demonstrated to design current and voltage 100 mA He^+, 200 keV;, at Moscow (MRTI) where a 300 mA H^-, 350 keV, 1 ms was demonstrated. (The plan is to demonstrate 1 A H^-, 500 keV, 5 ms by the end of 1992.) A Japanese plasma generator, coupled to an accelerator designed and constructed by the CEA (Cadarache), has been tested on the Cadarache test bed. Greater than 2 A of deuterium ions have been accelerated to 100 keV and transmitted to 130 mm wide target 3 m from the source. Pulse length was 2 s.

A good possibility to increase the overall efficiency of the NB system is a creation of a plasma neutralizer. If it can be developed, the efficiency could be increased from 40% to 50-60%. Culham has now designed and is fabricating an RF driven Ar plasma neutralizer for test on DRAGON. In Japan a Xe plasma with density of 10^{12} cm^{-3} was produced with 2.45 GHz microwaves in the field free region of a multicousp plasma generator with 20 cm diameter. Plasma neutralizer tests will be conducted in 1992 with a > 350 keV H^- beam.

ES & ESQ acceleration concepts proof of principle

The meeting participants have a common opinion about necessity of PoP demonstration for both ES and ESQ accelerator concepts. Both accelerators should be tested to 1.3 MeV, > 1A H^-, with neutralization for seconds.

The US proposes to demonstrate the ESQ system (1.3 MeV, 1.4 A H^-, 2 s) during 1995.

For the ES concept:

1. The USSR would demonstrate 1.3 MeV, 4 A H^-, 0.1 s during 1994.
2. Japan would demonstrate 400 keV, 1 A H^-, 5 min, during 1993 (no ITER credit)

While neither of the ES tests satisfy the PoP criteria, together they support the PoP demonstration of the ES accelerator.

Scalable model demonstration

Scalable Model demonstration would be a collaborative effort

It is planned that the EC and USSR Scalable Model Test Stand (SMTS) proposals would be evaluated and it would be recommended by later 1992 which proposal should be pursued. It is important that the detail study of the physics issues has been performed at Cadarache and the design has been revised, adopting a configuration with the ion source at high voltage. The comprehensive design analysis and change in configuration supports the ITER NB common design. Further, the plan is to evolve common designs for both the ES and ESQ concepts and, based on PoP results, select one for construction and test. It is assumed that the Scalable Model demonstration would be a collaborative effort and testing of the Scalable Model hardware might be done in 1996 and 1997.

Collaboration

US/EC may study the feasibility of conducting the ESQ PoP demonstration at Cadarache (in D with long pulses ≈ tenths of seconds) as an alternate to conducting the test in the US as currently planned.

It is necessary to encourage additional collaborations and joint efforts to ensure an integrated NB technology R&D program. Collaboration between the members of all four Parties is needed for using all possibilities either to speed up the schedule or reduce the cost.

Next NB Meeting

Investigation of the practicality of the next NB meeting at Cadarache at the end of May 1992 showed that the meeting would be required for evaluation of the Scalable Model demonstration proposals and evolving the best scenario for further consideration, as appropriate.

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ITER Magnet Workshop, 23-27 September 1991, JAERI-Naka

RESEARCH ACTIVITY ON THE LiPb BLANKET FOR ITER IN THE NUCLEAR RESEARCH INSTITUTE, ŘEŽ, CSFR
by V. Šulc

Activities in the field of utilization of liquid metals in the nuclear power industry have a tradition of 30 years in Czechoslovakia. Problems of heat transfer, technology and corrosion in sodium-cooled fast reactor cores were successfully investigated in the Nuclear Research Institute (NRI) and in co-operating research institutions and industrial plants. As a result, modular sodium-water steam generators and fittings for large diameter piping were designed, produced and put into operation.

Since 1989, activities related to the application of $Li_{17}Pb_{83}$ alloy as a fertile material for the ITER fusion reactor blanket have been carried out. In 1989 Czechoslovakia was accepted as a participant in the ITER project through the USSR and since then has contributed to the ITER Conceptual Design Activities.

An R&D program was prepared on the basis of long existing scientific and technical potential, augmented by the following recently built experimental facilities:

Forced Circulation Circuit,
Autoconvection Corrosion Test Loop,
Technological Channel with a height of 4 m,
Thermomechanical Test Facility.

The experimental research performed in NRI focused on three main areas:

Technology of the $Li_{17}Pb_{83}$ Eutectic Alloy
Heat Transfer and Thermal Hydraulics of Fusion Reactor Blanket
Corrosion of Structural Materials in the LiPb Alloy.

In the following a brief description of the major results achieved in these three areas will be given.

Technology of the $Li_{17}Pb_{83}$ Eutectic Alloy.

The alloy was prepared from domestically produced materials - lead and lithium of 99.98% and 99.4% purity, respectively. In a low-frequency induction furnace a total of 100 kg of the alloy was prepared. Technological procedures enabling the preparation of the alloy in melts of the order of 100 kg were developed. Metallography showed that the structure of the ingots was acicular and lamellar, with a very homogeneous dispersion.

The stability of the alloy in 12-15 m height blanket channels with zero or minimum flow velocity in a cyclic operational regime is one of the basic requirements for the applicability of the alloy in tritium production. The difference in the densities of Pb (11.341 gcm^{-3}) and Li (0.534 gcm^{-3}) is very significant and, therefore, separation of these components might occur along the vertical channel which may adversely affect the coefficient of tritium production.

Therefore, in a technological channel with a height of 4 m the temporal and spatial stability of the eutectic alloy was investigated during 500-hour operation, with cyclic temperature changes in the range of 150-350°C, thus permitting 100 solid-liquid-solid phase changes at 235°C.

Two-dimensional diagnostics of the alloy in the channel were performed

A sampling method developed in the NRI enabling two-dimensional diagnostics of the alloy composition along both channel height and cross-section was used to determine the content of lithium, iron, nickel, chromium and calcium in the entire channel volume. A relationship was established between the increase in lithium concentration taking place in a relatively narrow layer near the alloy surface and the number of solid-liquid-solid cycles. In a major part of the channel (approximately 90% of its height) the lithium depletion of the alloy is negligible.

This method is also applicable to monitoring the displacement of impurities and corrosion products in the alloy.

Heat Transfer and Thermal Hydraulics of Fusion Research Blanket.

The experimental reserach has been focused on the blanket cooled by low-pressure water, with a channel filled with stagnant alloy and batch separation of tritium. In this case the alloy temperature is close to the phase transition temperature and follows the cyclic heat generation. The uneven distribution of the generation along the very long blanket channel contributes to the danger of overloading of the channel wall by heat. In addition, the possible occurrence of local zones with melted alloy leading to natural circulation in limited areas contributes to the complexity of the temperature fields in the channel, as well.

Therefore, to enable the determination of temperature fields in a blanket channel model, the Thermomechanical Test Facility at NRI is equipped with 108 micro-thermocouples as well as with systems for internal and external heating and cooling of the channel.

Corrosion of Structural Materials in the LiPb Alloy.

The research on corrosion of structural materials concentrates on the study of the behaviours of promising austenitic and martensitic steels under conditions characterized by cyclic operation parameters.

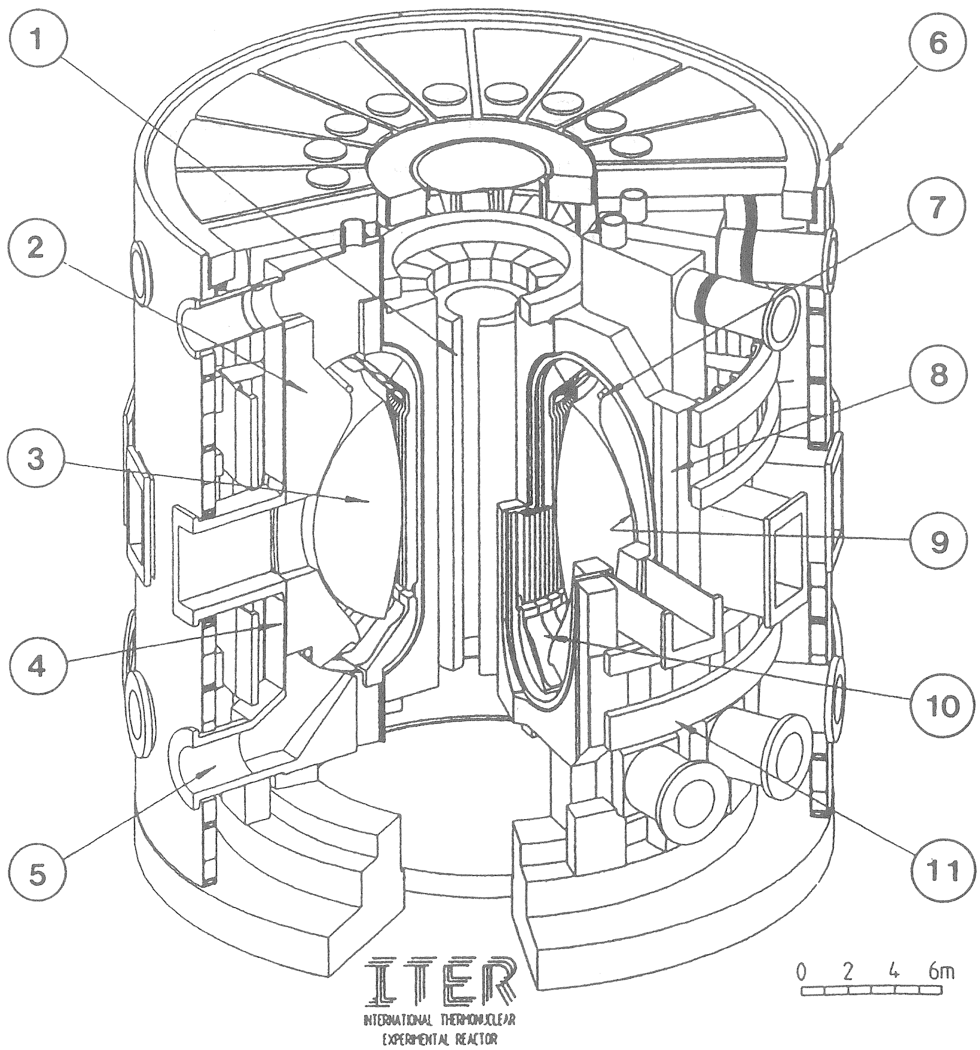
It has been assumed that during the experiments the exposure time for structural materials in the alloy would be in the range of 1000-5000 hours at temperatures from 150°C up to 500°C. The experimental investigation of the following characteristics under cyclic operation conditions is planned:

- total corrosion of structural materials in the alloy flowing with velocities of up to 10 cms^{-1}
- stress corrosion of specimens of the C type with a wedge;
- transfer of chemical elements among the specimens and loop sections of different temperatures

The results of the ITER Conceptual Design Activities (CDA) have attracted much attention from the scientific community. The extensive report "ITER Conceptual Design" was published in the IAEA Journal **Nuclear Fusion**, Vol. 31, No. 6, June 1991 (pages 1135-1224). The Journal is on sale and can be obtained either through local sales agents for IAEA publications or through the Division of Publications, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400, Vienna, Austria.

ITER REFERENCE PARAMETERS

Plasma major radius, R (m)	6.0
Plasma half-width at midplane, a (m)	2.15
Elongation, 95% flux surface	1.98
Toroidal field on axis, B_o (T)	4.85
Nominal maximum plasma current, I_p (MA)	22
Nominal fusion power, P_f (MW)	1000



1- CENTRAL SOLENOID
2- SHIELD/BLANKET
3- PLASMA
4- VACUUM VESSEL-SHIELD
5- PLASMA EXHAUST
6- CRYOSTAT
7- ACTIVE CONTROL COILS
8- TOROIDAL FIELD COILS
9- FIRST WALL
10- DIVERTOR PLATES
11- POLOIDAL FIELD COILS

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