TECHNICAL ADVISORY COMMITTEE
on the Transmutation Experimental Facility (TEF)

Meeting held from 19 to 20 February 2018
Tokai, Japan

T-TAC 2017 REPORT

Contents

EXECUTIVE SUMMARY

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 19th to 20th, 2018 at the J-PARC centre, Tokai. The T-TAC thanks the J-PARC Director Dr N. Saito for providing a comprehensive view of the TEF project through detailed presentations from his staff.

The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during the meeting. Given that an English version of the TEF-T TDR is not yet complete, T-TAC cannot comment on the completeness of the TEF Facility Technical Design. T-TAC notes the efforts of including new chapters regarding instrumentation and waste treatment in the draft TDR.

T-TAC recognizes the funding constraints and the need of reconsidering the strategy of the TEF project. The proposed approach builds on J-PARC's strong expertise in the field of accelerator and target technologies and addresses a scope that encompasses not only the ADS mission but also other high power accelerator applications. T-TAC recommends to preserve the TEF-T experimental LBE target technology as a key element of the proposed proton beam irradiation facility and regrets the unclear path to the realization of TEF-P which may lead to a loss of capability to perform sub-criticality and transmutation experiments that TEF-P can offer.

T-TAC strongly encourages to further enhance collaborations with other organizations involved in ADS projects like MYRRHA and promote the research potential to a wider public audience and commercial entities in order to enhance visibility of the project.

INTRODUCTION

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 19th to 20th, 2018 at the J-PARC centre, Tokai. Appendix I gives the agenda for the meeting while Appendix II indicates the charges that the J-PARC director gave to the committee. The full committee (see Appendix III) participated in the two-day meeting.

The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during the meeting. The draft Technical Design Report (TDR) of TEF-T has not been considered for the reviewing by T-TAC.

1. TEF-P DESIGN AND RELATED R&D

In the TEF-P safety design JAEA performed important investigations for the final stage of basic design; experiment for heat conductivity through lattice, heat transfer analysis in ULOF, structural analysis of the core in ULOF, and safety design report.

Observations and Comments

T-TAC takes note of the availability of a well-documented Safety Design Report on TEF-P and acknowledges the progress made in the understanding of the thermal and structural analysis in the event of an “Unprotected Loss of Flow”. The results of ULOF were presented, but no information for UTOP was given. During the meeting JAEA answered that the UTOP event is not severe for TEF-P, and the UTOP safety analysis is not required in the class B analysis.

T-TAC cannot verify the claim that “TEF-P design is in final stage of preparation for application of construction”. However, T-TAC believes the objectives of the TEF-P project should be re-assessed/re-defined in the light of the recent decisions and developments concerning the fast neutron reactors in Japan. TEF-P has a clear role to play in Japan and the rest of the world when it comes to assess the transmutation efficiency of Minor Actinides or more general the physics of MA fuel. A report on the TEF-P physics program and on the position statement is clearly lacking. How unique, versatile and complete is it as well as how does it compare with the other installations or projects? Also a detailed neutronic characterization of the subcritical/critical core and main reactivity features are missing.

Recommendations

1.1. Add the UTOP analysis results in the TEF-P Safety Design.

1.2. In the heat-transfer analysis of T-TAC4 JAEA showed that the temperature limit was set to 320 °C, and the peak temperature calculated was 303°C. The calculated value is rather close to the temperature limit, and the effects of applied parameters and the uncertainties of various conditions should be considered. Heat conductivity through lattice was significantly improved by filling all lattice with metal like Al, SUS, lead. But it was also shown that the conductivity worsened when there is a gap between metal block and lattice. Careful attention should be paid in constructing such lattices.

2. TEF-T DESIGN

2.1 Overview of TEF-T design progress

Observations and Comments

T-TAC takes note that the draft TDR was updated by introducing recent progress in the TEF-T design including actions taken according to the last T-TAC's recommendations. T-TAC acknowledges that JAEA/MEXT have not approved the project team to proceed with the implementation in the design study of the ISOL facility. Consequently, the detailed design of the ISOL facility and related components was halted. T-TAC strongly encourages to continue to establish collaborations on transmutation technologies with other organizations like universities, MYRRHA, KIT, PSI or INEST/CAS.

2.2 TEF-T LBE spallation target design

Based on the design of the target configuration presented at T-TAC3, new design modifications with respect to :

- minimizing stagnant flow regions,
- designing target head,
- optimizing length of target,
- introducing flow separators in the inlet pipe,
- introducing flow blocks in the annular flow channel,

were presented at T-TAC4.

Observations and Comments

T-TAC recognizes that the modifications which have been made on the original target design improves considerably the performance from the aspects of flow dynamics and generated stresses. This will keep the maximum temperature and the stress level on the beam window below critical values for 316SS and T91. The modifications resulted in a significant reduction of stagnant and re-circulation zones.

Recommendations

2.2.1 Nevertheless, to continue this successful work on optimization of target design, an experimental verification & validation of the new design is absolutely necessary. This is a prerequisite to minimize significantly the technical risk before starting the construction phase of the target system.

2.2.2 The use of LES model is recommended rather than the k-epsilon turbulence model if the result of turbulence, or vortex, behaviors is taken into account for the improvement of TEF-T LBE spallation target design. Since turbulence intensity is nearly equal to the average velocity in the straight part of the annulus, and the effect of turbulence intensity on erosion is not known well, average velocity should be used for the assessment of erosion occurrence.

2.3 IMMORTAL & remote-handling

The IMMORTAL loop is to demonstrate the primary cooling system for the TEF-T target system. Since the 3rd T-TAC Meeting, a thermal balance of the cooling system and a detailed design analysis of HX design has been well addressed.

A detailed design of the heat removal system of IMMORTAL was presented. To remove the high temperature thermal power from the target station, IMMORTAL has a secondary cooling circuit with pressurized water and a third cooling system consisting of a water chiller. Therefore, the purpose of IMMORTAL is to:

- demonstrate the dynamic behavior of heat removal.
- confirm and master the operation procedures.
- show the reliability of individually developed components of target system in an integrated experiment.

Observations and comments

It was proven that the operation temperature reached the desired maximum temperature of 500°C. However, the thermal balance between secondary and third cooling loops was unsatisfactory due to overcooling of the high cooling capacity of the chiller (67 kW). The introduction of valve and bypass line into the chiller solved this problem. A revision of HX design to prevent boundary failure and to increase safety by having an intermediate layer filled with stagnant helium gas has been presented.

All recommendations of T-TAC3 regarding remote handling were reasonably implemented by using prototype support jig.

The design of the whole heat removal system looks “over engineered” and therefore too complicated for a long-term stable operation. Try to simplify the design based on the heat removal system of successfully operating LBE loops like CORRIDA (KIT) or CRAFT (SCK•CEN), KYLIN-II (INEST).

Recommendations

2.3.1 Evaluate the utility of a counterflow heat exchanger (economizer) as central part to transfer the heat from the high temperature downstream (coming from the target) to the low temperature upstream LBE (coming from the EM-pump), followed by an air cooler to bring the LBE temperature below the critical temperature of the EM-pump. This design is called “figure-of-eight design”.

2.3.2 Consider water mist-steam annular flow cooling with simple tubes at atmospheric pressure.

2.3.3 Not all the necessary issues of the remote handling system could be investigated during this fiscal year. Nevertheless, during the lifetime of the target, many remote cutting and welding processes have to be made. Therefore, it is mandatory to continue investigating issues of proper cleaning process and appropriate heat treatment capability after welding.

2.4 Rad-waste management and treatment in TEF-T

Observations and comments

Gaseous, liquid, and solid waste streams have been characterized and the amount generated of each has been estimated. These estimates have been used to size the treatment facilities needed. Liquid and gaseous effluents are purified to the extent practical, or held in storage to allow for radioactive decay, in order to meet regulatory requirements for release to the environment. Tritiated water is collected and solidified for disposal as solid waste. Due consideration is given to the need for local shielding of decay tanks and absorption beds.

All three radioactive waste streams appear to be appropriately treated using the same methodology as MLF target system and other J-PARC facilities apart for cover gas which contains Po. An experimental campaign to evaluate Po release is planned, using Te as a surrogate for Po.

Recommendations

2.4.1 Even if a rather complete study supported by experimental verification with Te as representative of Po is proposed, launch a collaboration with SCK•CEN in case of test campaigns with Po.

2.4.2 Reassess the risks in case of fire for the separated volatile spallation products managed through the off gas process system.

2.4.3 The study of LBE chemistry and transport of impurities, i.e., control of impurities, is recommended to precede the study of gas exhaust management in TEF-T.

2.5 Instrumentation

This chapter is newly introduced as a recommendation of the last T-TAC3 meeting. The monitoring parameters for the control of the LBE target system presented at T-TAC4 are related to temperature, pressure, liquid level, flow rate/velocity, oxygen concentration and leakages.

Observations and comments

All kinds of monitoring systems are well addressed. For the use of pressure gauges at high temperatures, solutions are available in the literature. For the liquid level detection, both types of meters together give more reliability if operating together in one tank.

The long-term operation ability of both plug immersion and contactless types of flow meters have to be carefully evaluated. The proposed design of leak detector, based on the MEGAPIE experience, seems very reasonable.

The progress regarding instrumentation development shows a high level of competence. To further minimize the risk of target system failures, the efforts in studying the long-term reliability of LBE monitoring systems have to be continued and intensified.

Recommendations

2.5.1 For the test and calibration of diaphragm type pressure sensor for LBE as well as plug immersion and contactless types of flowmeters, rely on existing expertise of KIT.

2.5.2 Consider the use of induction type level indicator for continuous readings together with electrode type sensor for signal indication of e.g. over- and/or under-filling of tank level.

2.5.3 Check the capability of leak detector under gamma-ray irradiation.

2.5.4 Provide applicability range and resolution for the different instrumentation.

2.5.5 Build on the operational experience from MLF.

2.6 Safety issues including FMEA

Observations and comments

A risk register has been developed based on both the potential for radiation release to the environment (semi-quantitative) and on the impact on operations (i.e., operating days lost). A Failure Mode and Effect Analysis has identified an LBE pipe break as the worst-case accident. The accident progression assumes all LBE leaks from its primary containment and ends up in the catcher tray on the target trolley. A dose assessment concludes that the maximum dose to a member of the public under this scenario is 0.6 mSv, which is just over the allowable limit of 0.5 mSv.

Caution should be used when considering public safety concurrently with operational impact in the FMEA. It is common practice to separate these two impacts into separate analyses as a means of recognizing the much more important impact of protecting the public versus lost operating days.

When assessing accident consequences, it is normal practice to consider unmitigated consequences prior to crediting active systems that mitigate consequences. In this way, the measure of the degree of a credited system as “important to safety” may be quantified.

Recommendation

2.6.1 The PRA (Probabilistic Risk Assessment) figures used in the calculations are based on the operational experience of water cooled reactors. Consider to adapt the data to the LBE case.

3. R&D for TEF-T

3.1 LBE technology

High Temperature Corrosion Test Loop - OLLOCHI

A response to the recommendations from the T-TAC3 meeting was given in the presentation.

Observations and comments

The detailed CFD analysis of the test sections reveals a very uniform flow pattern in the center line. This will help in the exploitation of the corrosion test results.

A scheme is presented for the exchange of corrosion test samples from the test sections during loop operation. The alternative austenitic steel JPAC 15-15Ti is one candidate for corrosion test samples. There is not yet any method decided for gas mixing in OLLOCHI. First tests with JLBL-4 loop indicate that the reducing process with Ar-H2 takes longer than expected. The consequences for OLLOCHI are not yet clear.

A clear statement was given regarding the separate use of corrosion test and implementation of mechanical test machine. An updated time schedule based on budgetary conditions was presented. The modification for implementation of mechanical testing machine is set on the expansion tank and the test jig is inserted to the 3rd test section. A risk assessment for LME of SS316 and T91 was given.

Recommendations

3.1.1 The detailed CFD analysis of the expansion tank, has to be absolutely performed. Present a strategy how to perform the gas mixing in the expansion tank to maintain the desired oxygen concentration in the OLLOCHI loop. Consider the experience of other existing loops.

3.1.2 Specify more clearly the kind of mechanical tests to be performed with the existing machine.

3.1.3 Reconsider the risk of LME for T91 even at high temperature operation. Have SS316 as an alternative solution in mind!

3.1.4 Reduce the delay in the corrosion testing. The operation of OLLOCHI must start as soon as possible!

Freeze valve development

Observations and Comments

The recommendation of the last T-TAC3 meeting to maintain the cooling rate of LBE always below 3°C/min was carefully investigated. A concept for maintaining this low cooling rate, even in the case of station blackout, was given. It could be shown that by introducing a dwell time of 3 hours at the melting/freezing temperature of 125°C, during cool down from 150°C, the maximum stress level in the steel samples was uncritical all the time. A CFD analysis of 3 mm thick SS316 tube confirmed low stress values for this thermal cycle, too.

Recommendation

3.1.5 Evaluate the strain levels for faster cooling conditions.

Oxygen sensor and potential control

The development of oxygen sensor development was further successful continued.

Observations and comments

A redesign of the sensor head by removing all plastic parts showed no sensitivity to gamma-ray irradiation for 5000 h. The calibration of oxygen sensor by using Pb/PbO saturation was implemented. The introduction of steel sheath to the sensor design as a protection against ceramic debris in the LBE was successfully shown. Mid-term test of oxygen sensor tests up to 2,300 h were presented.

Recommendations

3.1.6 Real long-term tests (>10,000 h) have to be performed to identify weaknesses of the current sensor design. Continue the reliability of the sensor development.

3.1.7 To be able to decide for the start of the TEF-T construction, the availability of a strategy and the components of the oxygen control system (mixing hardware and sensors) is necessary. This will reduce the risk of target failure during operation of TEF-T. Therefore, the efforts in the area of development of oxygen control system for LBE of the target system have to be largely increased within the next fiscal year.

3.2 Design and study for L-TEF BT and neutronics

Observations and comments

T-TAC acknowledge the progress made with the proton beam window design, the remote handling qualification tests and shielding design for the transport cask. T-TAC believes that the dpa cross-section measurement campaign will benefit the ADS community.

Recommendations

3.2.1 Consider to move the proton beam window closer to the target in order to reduce the effect of beam scattering.

3.2.2 Continue to collaborate with ESS and SNS on the development of luminescent coating for beam profilometry.

3.2.3 Demonstrate the stable H+ beam extraction for long pulse operation.

3.3 R&D for evaluation of nuclear property for TEF-T

Observations and comments

T-TAC support this activity that benefits all spallation source designs. It is a good example of cost optimization activity by means of improvement of basic nuclear data.

4. J-PARC’S APPROACH TO THE JAEA’S NEW ROADMAP

Observations and comments

T-TAC recognizes the funding constraints and the need of reconsidering the strategy of TEF. The proposed approach builds on J-PARC’s strong expertise in the field of accelerator and target technologies and addresses a scope that encompasses not only the ADS mission but also other high power accelerator application. T-TAC recommends to preserve the TEF-T experimental LBE target technology as a key element of the proposed proton beam irradiation facility.

T-TAC regrets the unclear path to the realization of TEF-P which may lead to a loss of capability to perform sub-criticality and transmutation experiments that TEF-P can offer. T-TAC hopes in the future that such capabilities can be clarified due to the worldwide lack of fast spectrum critical assemblies.

T-TAC acknowledges J-PARC’s approach can provide the experimental data needed for the Verification & Validation of the computer simulation studies to be conducted within JAEA’s new roadmap.

CONCLUSIONS

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 19^{th} to 20^{th}, 2018 at the J-PARC centre, Tokai.

The T-TAC members acknowledge the high commitment of the team involved to this project and the progress that has been made since the last T-TAC meeting in December 2016 as well as note that the project has carefully considered the recommendations made during the previous T-TAC meeting.

The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during the meeting. Given that an English version of the TEF-T TDR is not yet complete, T-TAC cannot comment on the completeness of the TEF facility Technical Design. T-TAC notes the efforts as previously recommended of including new chapters regarding instrumentation and waste treatment in the draft TDR.

T-TAC recognizes that in the light of delayed TEF construction budget a re-scoping of the TEF facility project becomes necessary. The proposed approach builds on J-PARC's strong expertise in the field of accelerator and target technologies and addresses a scope that encompasses not only the ADS mission but also other high power accelerator application. T-TAC recommends to preserve the TEF-T experimental LBE target technology as a key element of the proposed proton beam irradiation facility and regrets the unclear path to the realization of TEF-P. An action plan, manpower plan, list of activities to do in priority and a staging strategy to bring the revised project to a "ready to go" stage needs to be worked out.

T-TAC acknowledges the collaborative efforts deployed by J-PARC for the Japanese ADS program with other organizations like Japanese universities, MYRRHA, KIT, PSI, INEST/CAS, ESS and encourages growth in it. It also recognizes the promotion of the research potential and industrial applications of the TEF facility to a wider public audience and commercial entities.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

1. TEF-P DESIGN AND RELATED R&D

1.1. Add the UTOP analysis results in the TEF-P Safety Design.

1.2. In the heat-transfer analysis of T-TAC 4 JAEA showed that the temperature limit was set to 320 °C, and the peak temperature calculated was 303°C. The calculated value is rather close to the temperature limit, and the effects of applied parameters and the uncertainties of various conditions should be considered. Heat conductivity through lattice was improved very much by filling all lattice with metal like Al, SUS, lead. But it was also shown that the conductivity worsened when there is a gap between metal block and lattice. Careful attention should be paid in constructing such lattices.

2. TEF-T DESIGN

2.2 TEF-T LBE spallation target design

2.2.1 Nevertheless, to continue this successful work on optimization of target design, an experimental validation of the new design is absolutely necessary. This is a prerequisite to minimize significantly the technical risk before starting the construction phase of the target system.

2.2.2 The use of LES model is recommended rather than the k-epsilon turbulence model if the result of turbulence, or vortex, behaviors is taken into account for the improvement of TEF-T LBE spallation target design. Since turbulence intensity is nearly equal to the average velocity in the straight part of the annulus, and the effect of turbulence intensity on erosion is not known well, average velocity should be used for the assessment of erosion occurrence.

2.3 IMMORTAL & remote-handling

2.3.1 Evaluate the utility of a counterflow heat exchanger (economizer) as central part to transfer the heat from the high temperature downstream (coming from the target) to the low temperature upstream LBE (coming from the EM-pump), followed by an air cooler to bring the LBE temperature below the critical temperature of the EM-pump. This design is called “figure-of-eight design”.

2.3.2 Consider water steam cooling with simple tubes at atmospheric pressure.

2.3.3 Not all the necessary issues of the remote handling system could be investigated during this fiscal year. Nevertheless, during the lifetime of the target, many remote cutting and welding processes have to be made. Therefore, it is mandatory to continue investigating issues of proper cleaning process and appropriate heat treatment capability after welding.

2.4 Rad-waste management and treatment in TEF-T

2.4.1 Even if a rather complete study supported by experimental verification with Te as representative of Po is proposed, launch a collaboration with SCK•CEN in case of test campaigns with Po.

2.4.2 Reassess the risks in case of fire for the separated volatile spallation products managed through the off gas process system.

2.4.3 The study of LBE chemistry and transport of impurities, i.e., control of impurities, is recommended to precede the study of gas exhaust management in TEF-T.

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2.5.1 For the test and calibration of diaphragm type pressure sensor for LBE as well as plug immersion and contactless types of flowmeters, rely on existing expertise of KIT.

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2.5.4 Provide applicability range and resolution for the different instrumentation.

2.5.5 Build on the operational experience from MLF.

2.6 Safety issues including FMEA

2.6.1 The PRA (Probabilistic Risk Assessment) figures used in the calculations are based on the operational experience of water cooled reactors. Consider to adapt the data to the LBE case.

3. R&D FOR TEF-T

3.1 LBE technology

<u>High Temperature Corrosion Test Loop - OLLOCHI</u>

3.1.1 The detailed CFD analysis of the expansion tank, has to be absolutely performed. Present a strategy how to perform the gas mixing in the expansion tank to maintain the desired oxygen concentration in the OLLOCHI loop. Consider the experience of other existing loops.

3.1.2 Specify more clearly the kind of mechanical tests to be performed with the existing machine.

3.1.3 Reconsider the risk of LME for T91 even at high temperature operation. Have SS316 as an alternative solution in mind!

3.1.4 Reduce the delay in the corrosion testing, the operation of OLLOCHI must start as soon as possible!

<u>Freeze valve development</u>

3.1.5 Evaluate the strain levels for faster cooling conditions.

<u>Oxygen sensor and potential control</u>

3.1.6 Real long-term tests (>10,000 h) have to be performed to identify weaknesses of the current sensor design. Continue the reliability of the sensor development.

3.1.7 To be able to decide for the start of the TEF-T construction, the availability of a strategy and the components of the oxygen control system (mixing hardware and sensors) is necessary. This will reduce the risk of target failure during operation of TEF-T. Therefore, the efforts in the area of development of oxygen control system for LBE of the target system have to be largely increased within the next fiscal year.

3.2 Design and study for L-TEF BT and neutronics

3.2.1 Consider to move the proton beam window closer to the target in order to reduce the effect of beam scattering.

3.2.2 Continue to collaborate with ESS and SNS on the development of luminescent coating for beam profilometry.

3.2.3 Demonstrate the stable H+ beam extraction for long pulse operation.

Appendix I – Agenda for 4th T-TAC Meeting

Date:	19 – 20, Feb., 2018
Venue:	Main Conference Room, J-PARC Center Research Building 2F, Tokai, JAEA

<u>19, Feb. (Mon.)</u>

8:30 Shuttle bus from Terrace Inn Katsuta 9:30

Welcome (Closed, N. Saito)

9:35 Mission of T-TAC (Closed, N. Saito)

9:45 Closed session

10:00 Overview

- Overview of J-PARC (N. Saito)
- Overview of J-PARC TEF program (M. Futakawa) 11:00

TEF-P design and related R&D

- TEF-P safety design (K. Nishihara)

12:00 Photo & lunch

13:00 Overview of TEF-T design progress (F. Maekawa) 13:15

TEF-T design

- TEF-T LBE spallation target design (T. Wan)
- IMMORTAL & remote-handling (H. Obayashi)
- Rad-waste management and treatment in TEF-T (H. Kinoshita)
- Instrumentation (H. Obayashi)
- Safety issues including FMEA (T. Sasa)

15:00 Break

15:15 R&D for TEF-T

- LBE technology (2) (S. Saito)
- Design and study for L-TEF BT and neutronics (S. Meigo)
- R&D for evaluation of nuclear property for TEF-T (H. Matsuda) 17:00

Closed session

17:15 Adjourn, shuttle bus to Tokai-Bunshitsu 18:30

Dinner at Tokai-Bunshitsu

20, Feb. (Tue.)

8:30	Shuttle bus from Terrace Inn Katsuta
9:30	JAEA's new roadmap for ADS development (K. Tsujimoto)
	J-PARC's approach to the JAEA's new roadmap (F. Maekawa) 10:00
	Answer for pending questions (if needed)
	Closed session
12:00	Lunch
13:00	Closed session
15:45	Break
16:30	Summary Talk
16:50	Closing
17:00	Adjourn, shuttle bus to Terrace Inn Katsuta

Appendix II – Charges to T-TAC 2017 from J-PARC

by Dr N. Saito

T-TAC was required to advice primarily on the following items:

- Validity of base-line parameters to meet the primary purpose of TEF including both TEF-T and TEF-P that is contributing to nuclear transmutation technology development
- Feasibility of proton beam transport, LBE target system and related systems for TEF -T including safety policy, operation and maintenance scheme
- Adequacy of time line (resource and schedule)

In addition to usual recommendations on facility design and R&D activities, T-TAC 2017 is requested especially to evaluate the completeness of the TEF design, and to advise on J-PARC's approach to the JAEA's new roadmap on ADS nuclear transmutation technology development.

Appendix III - T-TAC Committee members for 2017

Name		Affiliation	Field
1	Marc Schyns (chair)	SCK•CEN	ADS Technology
2	Yacine Kadi	CERN	ADS and Spallation Target Technology
3	Yoshiaki Kiyanagi	Nagoya University	Spallation Target Technology
4	Jürgen Konys	KIT	Lead Bismuth Application Technology
5	Eric Pitcher	LANL	ADS and Spallation Target Technology
6	Minoru Takahashi	Tokyo Tech.	Lead Bismuth Application Technology
7	Toshikazu Takeda	Fukui University	Nuclear Reactor Technology