TECHNICAL ADVISORY COMMITTEE
on the Transmutation Experimental Facility (TEF)

Meeting held from 14 to 15 February 2019
Tokai, Japan

T-TAC 2018 REPORT

Contents

EXECUTIVE SUMMARY

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 14th to 15th, 2019 at the J-PARC centre in Tokai and toured the Materials & Life Science Experimental Facility as well as the LBE loop facilities in the High Temperature Engineering laboratory.

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 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 2018 as well as note that the team has carefully considered the recommendations made during the previous T-TAC meeting.

T-TAC acknowledges the availability in English of a well documented Technical Design Report on TEF-T and considers that the conceptual design of TEF-T is completed and that its basic design is sufficiently advanced. 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 program but also other high power accelerator applications. T-TAC finds that the proposed applications are sound and technically feasible. However, in order to realize it in a reasonable timeframe, T-TAC recommends to allocate more manpower to the project.

T-TAC strongly encourages to further enhance collaborations with other organizations involved in similar projects like MYRRHA in Belgium and promote the TEF project to the potential user communities.

INTRODUCTION

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 14th to 15th, 2019 at the J-PARC centre in Tokai and toured the Materials & Life Science Experimental Facility as well as the LBE loop facilities in the High Temperature Engineering laboratory. 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, as listed in (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.

1. Overview of TEF-T

1.1 LBE target system

Observations

The envisioned ADS features a vertical beam to target. In contrast to this the TEF-T has a horizontal beam to target. Differences e.g. gravity effects have been taken into account by the team.

Also the differences in the beam energy between the ADS (1.5 GeV) and the TEF-T (400 MeV) have been considered for investigating radiation damage effect and transferring knowledge to be gained by TEF-T to the future ADS project.

Even if the design of the target head looks symmetric, the flow pattern has been designed to be slightly asymmetric in order to avoid flow detachment in the center and thus areas of highest cooling needs.

Sensitivity of temperatures in target due to beam offset has been considered by the team.

Weld tests under prototypical geometrical conditions have led to very encouraging weld seam results.

Comments

T-TAC acknowledge the efforts to optimize the flow pattern in order to improve the flow at the hot spot and thus reduce temperature and thermal stress to the target beam entrance window. However T-TAC considers that further optimization is still possible.

Transients as well as flow instabilities in LBE still have to be calculated. Experience with the old ESS mercury target design shows that theoretical symmetric flow pattern can lead to instable flow conditions.

Recommendations

1.1.1. Weld test should be conducted under more realistic conditions including remaining LBE on the inner surface of the pipe as well as taking spallation products into account leading to unwanted alloying or inclusions in the weld seem, that potentially lower the weld seam quality.

1.1.2. Activation of piping and remains of LBE could lead to a gamma background making x-ray quality check of the pipe weld difficult. Amount of gamma background should be estimated in order to verify that x-ray can be used for quality check.

1.1.3. A vacuum vessel is used as a barrier in case of a target leakage. Methods should be worked out on how to recover in case LBE spills into vacuum vessel.

1.2 Target station, beam transport and building

Observations

T-TAC recognizes the use of the existing knowledge at MLF.

Comment

T-TAC is worried about a quadrupole failure that might lead to a focused beam damaging the TEF-T target. Countermeasures to ensure safe beam transport will rely on fast and reliable detection systems. The development of such systems was presented by the talk of Meigo-san 'Displacement cross section measurement and proton beam related instrument' (see section 3.3).

1.3 Technical design report and cost evaluation

Comments

T-TAC notes the effort of completing the compilation and the translation of the Technical Design Report. It has been distributed to the members in January 2019. T-TAC acknowledges that a chapter concerning 'dismantling' is postponed to a latter moment. As indicated in the introduction chapter, the report summarizes the facility design as of 2016.

T-TAC recognizes from the table of the content that all the aspects (scope, design parameters, component description, safety issues, ….) have been addressed and considers that the conceptual design of TEF-T is completed and that its basic design is sufficiently advanced.

Recommendations

1.3.1. T-TAC recommends to keep the TDR updated and in case of significant changes to assess the impact on project organization, schedule and costs once these elements are defined.

1.3.2. The methodology to evaluate the construction costs of TEF-T was presented. The comparison with costs of similar high power accelerator indicates that the bottom up calculation is realistic. T-TAC takes note that the announced cost does not including contingencies. It is recommended for external communication to always clearly indicate the year of the cost assessment in order to avoid issues due to price escalations.

2. R&D activities-1 : LBE spallation target technologies

2.1 Instrumentation and operation of IMMORTAL - Thermal-hydraulic simulation of IMMORTAL

Observations

T-TAC appreciates the answers to the recommendation of the previous T-TAC. The construction and operation of IMMORTAL were successfully achieved. Congratulations to the team. The first data for the operation of the mock up system were well obtained. The performance of the liquid metal loop, the water loop and the heat exchanger was well investigated. The simulation works with RELAP code on the heat exchanger are very helpful to understand the heat transfer phenomena.

Safety related instrumentation was not presented. T-TAC reminds that in such case redundancy and diversity needs to be addressed.

Comment

T-TAC notes that radiation hardness of Oxygen sensor has been evaluated. For the remaining instrumentation information was not presented.

Recommendations

2.1.1. T-TAC would like to advise to continue to accumulate operational experience. In parallel, start to consider the future operation focusing on the chemical aspects on the Pb-Bi system. The target vessel of IMMORTAL which has a unique shape and geometry may be useful to investigate the corrosion and the mass transfer around the target area. The methodology on the chemical control of metallic and non-metallic impurities should be investigated by IMMORTAL system.

2.1.2. Consider to obtain heat transfer coefficient versus the oxygen concentration.

2.2 High temperature corrosion study and freeze valve development

Observation

The corrosion test facility “OLLOCHI” was constructed. Various tests on chemical compatibility and mechanical characteristics of various materials are going to be performed soon. Some experimental works for the development of freezing valve have started. T-TAC recognizes the passive operation of this solution.

Recommendations

2.2.1. The conditions of corrosion tests with OLLOCHI should be well considered based on the operation condition of TEF-T system and ADS system. The flow condition should be determined from the view point of corrosion and mass transfer behaviors. Some non-dimensional numbers relating to the mass transfer behaviors should be considered as same as the averaged flow velocity.

2.2.2. The experiments to monitor the stress around the freezing valve should be performed at the condition simulating the actual use of the freezing valve.

2.2.3. Measurements of solidification process by using the neutron imaging was already performed. To see the solidification process, in-operand neutron transmission measurements coupled with strain gauge measurements will give direct information. Feasibility of such experiments should be discussed. Possibility of a strain measurement using Bragg edge transmission may be also one of discussion items for further studies.

2.3 Flow-accelerated corrosion (FAC) of type 316L SS caused by turbulent LBE flow

Observation

Simulation works on FAC behaviors of 316L austenitic steel in flowing LBE were performed. Some first results were obtained. The results indicated that some trends of the corrosion behaviors are predictable by the numerical simulation. The corrosion and mass transfer behaviors in small area were simulated up to now.

Recommendation

2.3.1. T-TAC would like to recommend to perform the simulation for larger area where temperature gradient exists.

2.4 Behavior of impurities in LBE

Observation

Spallation products were calculated, and volatile compounds are picked out. The chemical behaviors of impurities in LBE were theoretically evaluated.

Comments

The reliability of the amount of the spallation product is important and more precise data are necessary.

The mass transfer behaviors of some major radioactive elements such as Po and Hg are also important topics. T-TAC recognizes the effort to launch collaboration with SCK•CEN.

Recommendations

2.4.1. The change of the oxygen potential according the production of some elements by the neutron irradiation may be evaluated in the future work.

2.4.2. T-TAC strongly supports the experimental verification of spallation product using J-PARC.

3. R&D activities-2: Proton beam related research

3.1 Laser charge exchange for long pulse extraction

Observation

On the 3MeV beamline, the H+ beam was extracted successfully for long pulse by using laser charge exchange technology.

Comment

T-TAC recognized the fundamental technology was established for beam direction control required for TEF-P and takes note that no other activities are planned in this domain.

3.2 Improvement of spallation model for ADS and TEF neutronic design

Observation

This work is considered by T-TAC as very useful. Code inter-comparison is always advisable.

Comments

Experimental data exist, e.g. Titarenko (IAEA, report "Experimental and theoretical study of the yields of residual product nuclei produced in thin targets irradiated by 100-2600 MeV protons") against which it is possible to benchmark codes.

Continue to improve GEM fission model for improved agreement of experimental data.

The CSNS spallation neutron source has a backward beam line. This will be one of useful reference for this backward neutron study.

Recommendations

3.2.1. Model improvements to increase yield of low Z elements (Be, B, ..,Na), implementation of "fragmentation"/ emission of light to medium mass isotopes during INC and evaporation phase.

3.2.2. Think of implementing ABLA v.7 into PHITS to have an alternative evaporation model to GEM.

3.2.3. Experimental program to measure spallation products shall be continued. Evaluate the necessity of extending analysis to non-gamma emitting isotopes (Cl-36, Fe-55, Fe-60 ...)

3.3 Displacement cross section measurement and proton beam related instruments

Observations

It is absolutely vital that the proton beam profile @ the target is very well known. Several different proton beam monitors concepts are currently being studied for TEF-T in collaboration with other projects and facilities (ESS, SNS ..)

Displacement cross section were measured and comparison with calculation models was presented.

Comments

The BPM concept based on luminescent material coatings shall be continued. Consider to install as many beam profile monitors in the TEF-T beam line as possible; try to be redundant to ensure knowledge of beam parameters even in case of failure of one monitor.

DPA is a key parameter to decide beam window life-time. Experimental study is recommended.

Recommendations

3.3.1. Use BPMs based on different physical principles (harp monitors, luminescent coating, thermo-couples) . If the degradation of luminescent coatings are found to be too high to receive clear signals after some irradiation period, harp monitors, or VIMOS like Beam monitors should be employed.

3.3.2. A flatter beam profile over a sensor area will give less error of a proton flux.

4. Future plan

4.1 Material research activities for ADS development

Observation

The needs of the material qualification programme have been presented and a request for a new irradiation facility has been suggested. A multi-physics modelling work has been launched starting with ab initio work.

Recommendations

4.1.1. Relationship between modelling activities and the requirements of the design of TEF needs to be clarified.

4.1.2. A roadmap for the material research activities should be worked out.

4.2 Concept of the proton irradiation facility at J-PARC

Observation

A multipurpose usage of TEF-T has been presented including irradiation around the LBE target, semiconductor testing, ISOL radioactive beam production. T-TAC acknowledges the new approach presented by J-PARC claiming the need for a new irradiation facility equipped with PIE means.

Recommendation

4.2.1. Please ensure the uniqueness of the new TEF facility by comparison with similar existing or planned facilities.

T-TAC CONCLUDING REMARKS

T-TAC acknowledges the high commitment of the team involved in the TEF project and the progress accomplished since the last T-TAC meeting as well as notes that the team has carefully considered the recommendations made during the previous T-TAC meeting. T-TAC members congratulate the team for the obtained data during the operation of the IMMORTAL LBE loop, as demonstrated during the tour in the High Temperature Engineering laboratory.

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. T-TAC acknowledges the availability of a well documented Technical Design Report on TEF-T and considers that the conceptual design of TEF-T is completed and that its basic design is sufficiently advanced.

T-TAC recognizes that it is intended to enlarge beyond the ADS program the overall scope of the TEF project on the basis of J-PARC's existing strong expertise in the field of accelerator and target technologies. T-TAC finds that the proposed new applications are sound and technically feasible. Uniqueness and viability of the new applications of the TEF facility should be considered by comparison with similar existing or planned facilities.

In order to realize it in a reasonable timeframe, T-TAC recommends to allocate more manpower to the TEF project and to further deploy the collaborative efforts with organizations involved in similar projects like MYRRHA in Belgium as well as to promote the TEF project to the potential user communities.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

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1.1 LBE target system

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1.1.2. Activation of piping and remains of LBE could lead to a gamma background making x-ray quality check of the pipe weld difficult. Amount of gamma background should be estimated in order to verify that x-ray can be used for quality check.

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1.3. Technical design report and cost evaluation

1.3.1. T-TAC recommends to keep the TDR updated and in case of significant changes to assess the impact on project organization, schedule and costs once these elements are defined.

1.3.2. The methodology to evaluate the construction costs of TEF-T was presented. The comparison with costs of similar high power accelerator indicates that the bottom up calculation is realistic. T-TAC takes note that the announced cost does not including contingencies. It is recommended for external communication to always clearly indicate the year of the cost assessment in order to avoid issue due to price escalations.

2. R&D activities-1 : LBE spallation target technologies

2.1 Instrumentation and operation of IMMORTAL - Thermal-hydraulic simulation of IMMORTAL

2.1.1. T-TAC would like to advise to continue to accumulate operational experience. In parallel, start to consider the future operation focusing on the chemical aspects on the Pb-Bi system. The target vessel of IMMORTAL which has a unique shape and geometry may be useful to investigate the corrosion and the mass transfer around the target area. The methodology on the chemical control of metallic and non-metallic impurities should be investigated by IMMORTAL system.

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2.4.1. The change of the oxygen potential according the production of some elements by the neutron irradiation may be evaluated in the future work.

2.4.2. T-TAC strongly supports the experimental verification of spallation product using J-PARC.

3. R&D activities-2: Proton beam related research

3.2 Improvement of spallation model for ADS and TEF neutronic design

3.2.1. Model improvements to increase yield of low Z elements (Be, B, ..,Na), implementation of “fragmentation”/ emission of light to medium mass isotopes during INC and evaporation phase.

3.2.2. Think of implementing ABLA v.7 into PHITS to have an alternative evaporation model to GEM.

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3.3.1. Use BPMs based on different physical principles (harp monitors, luminescent coating, thermo-couples) . If the degradation of luminescent coatings are found to be too high to receive clear signals after some irradiation period, harp monitors, or VIMOS like Beam monitors should be employed.

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4. Future plan

4.1 Material research activities for ADS development

4.1.1. Relationship between modelling activities and the requirements of the design of TEF needs to be clarified.

4.1.2. A roadmap for the material research activities should be worked out.

4.2 Concept of the proton irradiation facility at J-PARC

4.2.1. Please ensure the uniqueness of the new TEF facility by comparison with similar existing or planned facilities.

Appendix I – Agenda for 5th T-TAC Meeting

Date: *14 – 15, Feb., 2019*

Venue: *Main Conference Room, J-PARC Center Research Building 2F, Tokai, JAEA*

14 Feb., 2019 (Thu.)

8:30 Shuttle bus departure from the hotel

9:20 Welcome (N. Saito)

9:25 Mission of T-TAC (N. Saito)

9:35 Overview

Overview of J-PARC (N. Saito)

10:00 Closed session

10:45 Site tour

MLF (10:45-11:25)

LBE loop facilities (11:30-12:00)

12:00 Lunch

13:00 Group photo

13:10 Overview (continued)

Overview of nuclear transmutation research at J-PARC (M. Futakawa)

13:30 Overview of TEF-T

LBE target system (T. Sasa, 35 min.)

Target station, beam transport & building (S. Meigo, 35 min.)

Technical design report & cost evaluation (F. Maekawa, 20 min.)

15:00 Coffee break

15:20 R&D activities-1 LBE spallation target technologies

Instrumentation and operation of IMMORTAL (H. Obayashi, 25 min.)

Thermal-hydraulic simulation of IMMORTAL (N. Watanabe, 10 min.)

High temperature corrosion study and freeze valve development (S. Saito, 20 min.)

Flow-accelerated corrosion (FAC) of type 316L SS caused by turbulent LBE flow (Tao Wan, 15 min.)

Behavior of impurities in LBE (N. Ohdaira, 15 min.)

16:45 Closed session

17:15 Adjourn, shuttle bus to hotel

15 Feb., 2019 (Fri.)

8:30 Shuttle bus departure from the hotel

9:20 R&D activities-2 Proton beam related research

Laser charge exchange for long pulse extraction (H. Takei, 10 min)

Experiments for improvement of spallation reaction model (H. Iwamoto, 25 min)

Displacement cross section measurement and development of proton beam monitors (S. Meigo, 25 min)

10:20 Future plan

Material research activities for ADS development (N. Okubo, 15 min.)

Concept of the proton irradiation facility at J-PARC (F. Maekawa, 25 min.)

11:00 Closed session

12:00 Lunch

13:00 Closed session

16:30 Summary talk (chair)

16:50 Closing (M. Futakawa)

17:00 Adjourn, shuttle bus to the hotel

Appendix II – Charges to T-TAC 2018 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, that is, contributing to nuclear transmutation technology development
- Feasibility of the proton beam transport, LBE target system and related systems for TEF 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 2018 is requested especially to evaluate the completeness of the TEF-T design, and to advise on the direction of the revised TEF concept.

Appendix III - T-TAC Committee members for 2019

Name		Affiliation
1	Marc SCHYNS	Belgian Nuclear Research Centre
2	Michael BUTZEK	Forschungszentrum Jülich
3	Yoshiaki KIYANAGI	Graduate School of Engineering, Nagoya University
4	Masatoshi KONDO	Institute of Innovative Research, Laboratory for Advanced Nuclear Energy, Tokyo Institute of Technology
5	Georg MÜLLER	Karlsruhe Institute of Technology
6	Keishi SAKAMOTO	National Institutes for Quantum and Radiological Science and Technology
7	Michael WOHLMUTHER	Paul Scherrer Institut