TECHNICAL ADVISORY COMMITTEE # 6
on the Transmutation Experimental Facility (TEF)

Meeting held from 6-7 February 2020
J-PARC Center, Tokai, Japan

T-TAC 2019 REPORT

Contents

EXECUTIVE SUMMARY

The 6th Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 6th to 7th, 2020 at the J-PARC centre in Tokai and toured the Neutrino 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 2019 as well as note that the team has carefully considered the recommendations made during the previous T-TAC meeting.

T-TAC recognizes the collaborative efforts deployed by J-PARC for the Japanese ADS program with other organizations and encourages growth in it.

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 feels concerned by the fact that some of the on-going activities are focused on more fundamental R&D works. Collaborations with universities could be considered in order to free manpower for the exploitation of the existing infrastructure that has to deliver relevant data to the designers.

As specially requested for this T-TAC meeting, the presented work plan up to 2028 of the 'Nuclear Transmutation Division' has been reviewed. T-TAC considers that this planning is feasible provided that particular attention is given to the alignment between the deliverables to be provided by the Target Technology developments and the needs of the design works for the Irradiation Facility.

Finally, T-TAC noticed that no planning for the safety assessment for the 'irradiation facility' has been presented. To better recommend, T-TAC suggest for the next meeting to get an overview of the global planning for ADS development.

INTRODUCTION

The 6th Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from February 6th to 7th, 2020 at the J-PARC centre in Tokai and toured the Neutrino Experimental Facility as well as the LBE loop facilities in the High Temperature Engineering laboratory.

T-TAC thanks J-PARC/JAEA for providing outstanding hospitality and excellent meeting organization. The efforts of the speakers during the meeting to address the comments & recommendations of previous T-TAC are much appreciated.

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, except Michael WOHLMUTHER (PSI) who could not attend.

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. R&D activities and future plan of Target Technology Development

1.1 Remote handling technologies

Observations

- T-TAC recognizes that most of the T-TAC 2018 recommendations have been well addressed.
- R&D on the remote handling technologies for exchanging a target vessel was reported. The pipe cutting device and the TIG welding machine were developed for the remote handling. The on-line inspection method to detect the internal defects was also explained. The selected RX-camera can measure in an radiation environment of dose rate 50 Gy/h following the specification of the manufacturer.

Comments

- Cleaning specifications and technique for LBE before welding have not been presented. As stated previously, the LBE on the inner surface of the pipe can lead to unwanted alloying in the weld seem, potentially lowering the weld seam quality.
- No information was provided up to now concerning the weld quality.

Recommendations

1.1.1. Consider the radiation hardness of the motors and some irradiation sensitive parts of the machine.

1.1.2. Clarify all the procedures necessary for the TIG welding (preheating and/or Post Weld Heat Treatment – PWHT, inspection, leakage check)

1.1.3. Identify and consider the failure modes of the remote handling systems (for example the blocking of a motor in such a position that further operation by remote handling is no longer possible)

1.1.4. Make sure to comply with the rules or standards for weld inspection that are applicable for PWR.

1.2 Oxygen potential measurement and control

Observation

- The developed automatic oxygen control system was implemented in OLLOCHI and IMMORTAL loops. To improve the thermal shock resistance the team started a new development of Laminated Thin Plate (LTP) oxygen sensors based on a product manufactured for the automotive industry. First results obtained so far shows promising results.

Comments

- Reduction in active area of the new LTP sensor is beneficial for local measurements of the oxygen concentration.
- The very short lengths of the new sensor could prove to be a disadvantage for measurements deep inside the LBE (if required). Some additional developments can however overcome this situation.
- Shock resistance of the new LTP-sensor is assumed but not proven yet.

Recommendation

1.2.1 Improved shock resistance must be evaluated by dedicated experiments so that quantitative numbers for maximum heating/cooling rates can be estimated.

1.3 Electro-magnetic flow probe development

Observation

- The research on the development of EM flow probe was introduced. Preliminary results on the performance of the EM flow probe in liquid metal were explained.

Comment

- Additional electrodes to the 2 existing ones may be considered to measure the flow velocity and flow direction.

Recommendations

1.3.1 Check that the flow perturbations induced by the probe are sufficiently small in order get valuable data to validate the results of the CFD code.

1.3.2 The corrosion of the electrode and the geometrical stability should be assessed.

1.3.3 Assess the effect of the temperature of the liquid metal (metal resistivity and magnetic permeability) on the sensor output.

1.4 Influence of irradiation on the corrosion behavior of steels in LBE

Observation

- First results on the influence of irradiation on corrosion behavior of steels in LBE have been achieved for specimens after ion irradiation and ex-situ corrosion tests in LBE. After irradiation an enhanced oxidation rate was observed in the initial state of exposure.

Comment

- The started investigations are of great importance to study the influence of spallation products on corrosion behavior. Only limited data are available so far, therefore the extension of these activity is very much recognized.

Recommendation

1.4.1 To check, whether the enhanced oxidation after irradiation is limited to the initial state, additional experiments with longer time exposure should be performed (>1000 h).

1.5 Future R&D for LBE technologies

Observation

- T-TAC noticed that the activities concerning Remote Target Exchange technologies is suspended in the future R&D plan.

Comment

- T-TAC considers that the works concerning Remote Handling is an important input for the design of the TEF facility.

Recommendations

1.5.1 Reconsider the planning of the works related to Remote Handling in order to at least provide the necessary input to set-up the design of the facility.

1.5.2 Provide the necessary R&D results in order to update the safety assessment file for the intended construction of the irradiation facility.

2. R&D and future plan of Facility and Application Development

2.1 R&D of superconducting LINAC for ADS

Observations

- Baseline design of JAEA-ADS linac is re-designed by adopting the superconducting linac. Conceptual design was completed and R&D plan was presented.
- The presented schedule for cavity prototyping is rather long. As stated in the presentation, the duration cannot be shortened due to limited budget and manpower.

Comments

- The design of the Superconducting Cavity (SC) is conventional. But this concept is reasonable taking into account the specification of the JAEA-ADS (completely CW operation, high current, high reliability and high availability.)
- The R&D plan to proceed the SC test under a collaboration with KEK is adequate to save investment cost and human resources.

Recommendation

none

2.2 Study of accelerator reliability

Observation

- Operational experience and reliability of J-PARC was reviewed. This is very important and interesting study. It is clearly shown that the reliability increased with time.

Comment

- Please keep in mind that the specifications concerning beam trips in the ADS case can be more challenging than the ones that have been presented. As, the cladding material will be in contact with LBE and will be placed in a radiation environment, appropriate material properties data that take into account radiation and contact with LBE, have to be used. The values of these relevant properties are different compared to the material properties in normal conditions.

Recommendation

2.2.1 T-TAC would like to recommend to arrange the reliability data for different currents, duty cycle, etc. for each year. It is expected that additional interesting findings can be obtained by refining the data analysis in this proposed way.

2.3 Neutronics experiment at J-PARC toward realizing ADS

Observation

- T-TAC recognizes big progress of nuclear cross section measurements. Nuclide production cross section and displacement cross sections were successfully measured and gave new important data. The results of nuclide production cross section indicated large discrepancy between calculation and experiment. A plan to measure double differential cross section, thick target neutron yield and inelastic scattering cross section was introduced.

Comment

- The obtained data of the nuclide production cross section clearly indicate their usefulness and necessity of improvement of simulation calculation codes although they are only for two natural elements. The future plan is expected to give useful data not only for ADS but also many other spallation neutron sources such as J-PARC-Target2. T-TAC acknowledges the efforts to proceed this kind of nuclear data measurements.

Recommendations

2.3.1 Further measurements on mono-isotopes are required for the nuclide cross section measurement to improve the cross-section model and close collaboration with nuclear theorist(s) is recommended.

2.3.2 The planning of the experiments is ambitious regarding the available resources. It is recommended for the team to extend the international collaborations while keeping the focus on ADS needs.

2.4 R&D of ADS target experimental facility in J-PARC

Observation

- More and more systems (e.g. satellites, avionics, cars, trains & communication systems) integrate a constantly increasing number of electronic components, increasingly complex, where soft errors can lead to important damage. So Soft Errors testing can be a solid business case for the accelerator as intended to be built by J-PARC.

Comments

- T-TAC acknowledges the efforts for finding new commercial application for the neutron source like soft errors testing. However, ADS should take advantage of this opportunity.
- Different Beam monitors have been evaluated and will be available in the future. T-TAC encourages the continuation.

Recommendation

2.4.1 Explore possible advantages of the neutron facility for the ADS program. As an example, consider the use of a LBE type target for the neutron source.

3. T-TAC CONCLUDING REMARKS

T-TAC congratulates the TEF team for the progress accomplished and acknowledges the high commitment of the team involved in the TEF project as well as it notes that the team has carefully considered the recommendations made during the T-TAC meeting in 2019. T-TAC recognizes the collaborative efforts deployed by J-PARC for the Japanese ADS program with other organizations and encourages growth in it.

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 feels concerned by the fact that some of the on-going activities are focused on more fundamental R&D works and moreover that developments of Remote Handling for target exchange are suspended. If the construction of the irradiation facility has to start in 2024 as indicated in the planning of the 'Nuclear Transmutation Division', the right focus should be given to needs of the designers. Collaborations with universities could be considered in order to tackle the more fundamental R&D activities. In this way more manpower can be freed for the exploitation of the existing infrastructure that has to deliver relevant data to the designers.

As specially requested for this T-TAC meeting, the presented work plan up to 2028 of the 'Nuclear Transmutation Division' has been reviewed (see figure 1 hereunder). T-TAC considers that this planning is feasible provided that enough resources are made available. Particular attention should however be given to the alignment in this planning between the deliverables to be provided by the 'Target Technology' (2-c) developments and the needs of the design works for the 'Irradiation Facility' (1). T-TAC is convinced that the planned work for 'accelerator' (2-a) and 'beam technology' (2-b) can both be in 2028 at a level to start designing the ADS accelerator. T-TAC acknowledges that the planned R&D works for 'target technology' (2-C) can in 2028 be sufficient advanced to support the ADS conceptual design.

Finally, T-TAC noticed that no planning for the safety assessment for the 'irradiation facility' and the 'ADS system' has been presented. To better recommend, T-TAC suggest for the next meeting to get an overview of the global planning for ADS development.

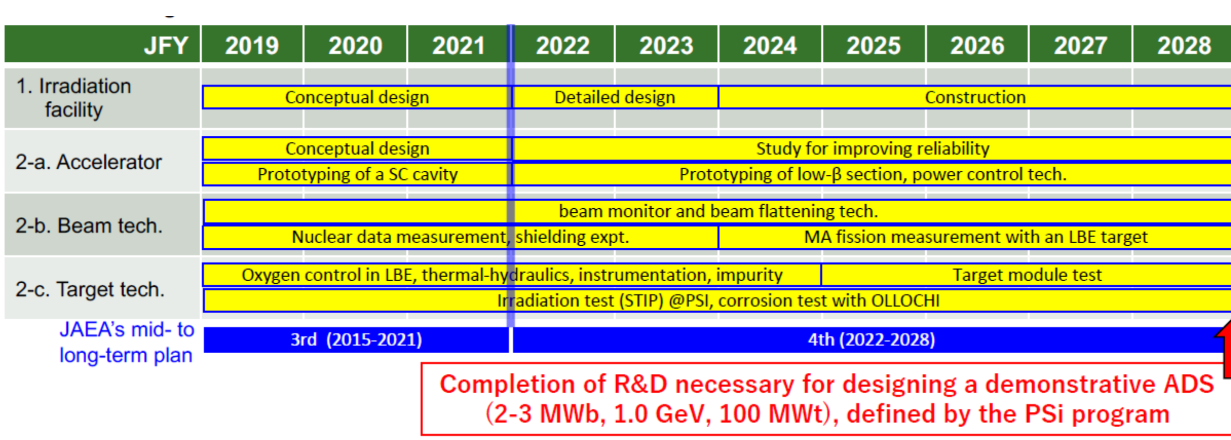

Figure 1 : Work plan of the Nuclear Transmutation Division

(source: T-TAC 6, Overview of the Nuclear Transmutation Division, slide # 12)

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

1. R&D activities and future plan of Target Technology Development

1.1. Remote handling technologies

1.1.1. Consider the radiation hardness of the motors and some irradiation sensitive parts of the machine.

1.1.2. Clarify all the procedures necessary for the TIG welding (preheating and/or Post Weld Heat Treatment – PWHT, inspection, leakage check)

1.1.3. Identify and consider the failure modes of the remote handling systems (for example the blocking of a motor in such a position that further operation by remote handling is no longer possible)

1.1.4. Make sure to comply with the rules or standards for weld inspection that are applicable for PWR.

1.2. Oxygen potential measurement and control

1.2.1. Improved shock resistance must be evaluated by dedicated experiments so that quantitative numbers for maximum heating/cooling rates will be estimated.

1.3. Electro-magnetic flow probe development

1.3.1. Check that the flow perturbations induced by the probe are sufficiently small in order get valuable date in order to validate the results of the CFD code.

1.3.2. The corrosion of the electrode and the geometrical stability should be assessed.

1.3.3. Assess the effect of the temperature of the liquid metal (metal resistivity and magnetic permeability) on the sensor output.

1.4. Influence of irradiation on the corrosion behavior of steels in LBE

1.4.1. To check, whether the enhanced oxidation after irradiation is limited to the initial state, only, additional experiments with longer time exposure should be performed (>1000 h).

1.5. Future R&D for LBE technologies

1.5.1. Reconsider the planning of the works related to Remote Handling in order to at least provide the necessary input to set-up the design of the facility.

1.5.2. Provide the necessary R&D results in order to update the safety assessment file for the intended construction of the irradiation facility.

2. R&D and future plan of Facility and Application Development

2.1. R&D of superconducting LINAC for ADS

none

2.2. Study of accelerator reliability

2.2.1. T-TAC would like to recommend to arrange the reliability data for different currents, duty cycle, etc. for each year. It is expected that by refining the data analysis in this proposed way, additional interesting findings can be obtained.

2.3. Neutronics experiment at J-PARC toward realizing ADS

2.3.1. Further measurements on mono-isotopes are required for the nuclide cross section measurement to improve the cross-section model and close collaboration with nuclear theorist(s) is recommended.

2.3.2. The planning of the experiments is ambitious regarding the available resources. It is recommended for the team to extend the international collaborations while keeping the focus on ADS needs.

2.4. R&D of ADS target experimental facility in J-PARC

2.4.1. Explore possible advantages of the neutron facility for the ADS program. As an example consider the use of a LBE type target for the neutron source.

Appendix I – Agenda for 6th T-TAC Meeting

Date: 6 – 7, Feb., 2020

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

6 Feb., 2020 (Thu.)

8:20 Shuttle bus from the hotel

9:30 Welcome (N. Saito)

Mission of T-TAC (N. Saito)

Overview of J-PARC (N. Saito)

10:10 Group photo

10:30 Closed session

10:50 Overview

- Overview of Nuclear Transmutation Division (M. Futakawa & F. Maekawa)

11:20 R&D activities and future plan of Target Technology Development Section

- Remote handling technologies (S. Saito)
- Oxygen potential measurement and control (H. Obayashi)
- Electro-magnetic flow probe development (G. Ariyoshi)

12:20 Lunch

13:30 R&D activities and future plan of Target Technology Development Section

- Influence of irradiation on the corrosion behavior of steels in LBE (N. Okubo)
- Future R&D for LBE technologies (T. Sasa)

14:30 Coffee break

15:00 R&D activities and future plan of Facility and Application Development Section

- R&D of superconducting LINAC for ADS (Kondo)
- Study of accelerator reliability (H. Takei)
- Neutronics experiment at J-PARC toward realizing ADS (H. Matsuda)
- R&D of ADS target experimental facility in J-PARC (S. Meigo)

17:00 Closed session

17:15 Adjourn, shuttle bus to a restaurant

19:00 Dinner at a restaurant

7 Feb., 2020 (Fri.)

8:20 Shuttle bus from the hotel

9:30 Site tour (Neutrino Experimental Facility, LBE loop facility)

10:30 coffee break

10:40 Closed session

12:00 Lunch

13:00 Closed session

16:00 Summary talk

16:20 Closing

16:30 Adjourn, shuttle bus to the hotel

Appendix II – Mission and charge to T-TAC 2019 from J-PARC

by Dr N. Saito

Mission of T-TAC

To advise primarily to 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)

Note that the "TEF" does not mean the Transmutation Experimental Facility consisting of TEF-T & TEF-P designed in the past but the revised TEF concept.

Charge of T-TAC 2019

In addition to the recurrent request described in its mission, T-TAC 2019 is especially asked to advice on the R&D plan of activities proposed by the Nuclear Transmutation Division.

Appendix III - Committee members for T-TAC 2019

	NAME	AFFILIATION	POSITION
1	Marc SCHYNS	SCK CEN	Manager of the Advanced Nuclear Systems Institute
2	Michael BUTZEK	Forschungszentrum Jülich	Team leader automation, magnet bearing and gears
3	Michael WOHLMUTHER	Paul Scherrer Institut	Group Leader Radiation Transport and Multiphysics
4	Yoshiaki KIYANAGI	Graduate School of Engineering, Nagoya University	Professor, Graduate School of Engineering
5	Keishi SAKAMOTO	National Institutes for Quantum and Radiological Science and Technology	Director of Nuclear fusion reactor materials research and development
6	Georg MÜLLER	Karlsruhe Institute of Technology	Deputy Director, Head of Department Professor
7	Masatoshi KONDO	Tokyo Institute of Technology, Institute of Innovative Research, Laboratory for Advanced Nuclear Energy	Associate professor