TECHNICAL ADVISORY COMMITTEE # 9
on the Transmutation Experimental Facility (TEF)

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Meeting held on 3rd February 2023
Online meeting

T-TAC 2023 REPORT

Final

Contents

EXECUTIVE SUMMARY

The 9th Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project held their meeting online on 3rd February 2023.

The T-TAC thanks the J-PARC Director Dr T. Kobayashi 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 as well as note that the team has carefully considered the recommendations made during the previous T-TAC meeting.

A new format was used for the T-TAC 2023 meeting. The presentations including audio comments have been available to the T-TAC members in advance and discussed during an on-line Questions & Answers session after a short reminder of the key messages by means of selected slides. The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during this unique session.

T-TAC noted a further reduction in the course of 2022 of the human resources allocated to the ADS program at J-PARC. Consequently, some of the R&D tasks had to be put on-hold and deferred to a later stage in the frame of the prioritisation of the on-going activities. This situation will significantly hamper the transition from the R&D phase to the realisation TEF-T.

Four areas of applications have been identified: material irradiation, soft error testing of semi-conductor devices, radioisotope production and proton beam applications. A first workshop was organised mid-2022 to capture the needs of the potential user communities and the facility plan was submitted to the Science Council of Japan that called for proposals to be included in mid-to-long term academic research strategies.

T-TAC considers the R&D works carried out by J-PARC as highly valuable contributions to the international ADS community and acknowledge the continuous efforts deployed by J-PARC to set-up collaborations with other organisations on national and international level in the frame of the Japanese ADS program.

INTRODUCTION

T-TAC thanks J-PARC/JAEA for the excellent meeting organization. T-TAC appreciated the time and diligence all the presenters have invested in order to convey a high density of information and material. Also, the efforts of the speakers during the meeting to address the comments & recommendations of previous T-TAC meeting are much appreciated.

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

- Validity of the design concept to meet the primary purpose of the proton irradiation facility, that is, contributing to nuclear transmutation technology development and versatile needs to the facility

- Direction and technical aspect of R&D activities on high-power accelerator, proton beam and target technologies for the primary purpose

In addition to the recurrent request described in its mission, T-TAC in this year is especially asked **to give technical comments and recommendations to the on-going R&D activities.**

1. Report by J-PARC

1.1 Overview of Nuclear Transmutation Division & J-PARC Transmutation Experimental Facility Program and future Direction

Observations

- JAEA's mid to long term plan (FY2022-2028) includes R&D on nuclear transmutation technology by using ADS. Regarding the J-PARC TEF program, JAEA reframes the facility plan based on the results of related R&D and versatile needs to the facility in addition to nuclear transmutation research. In total, 4 areas of applications have been identified: material irradiation, soft error testing of semi-conductor devices, radioisotope production and proton beam applications. A first workshop was organized mid-2022 to capture the needs of the potential user communities and the facility plan was submitted to the Science Council of Japan.

- On-going activities, including domestic and international collaborations, for the design of the spallation target & the development of the key LBE technologies needed for the realization of TEF-T and ADS, have been presented.

Comments

- The human resources allocated to the ADS program decreased significantly in 2022. This situation will hamper the transition from the R&D phase to the realization TEF-T. Prioritization of R&D tasks taking into account the reduction of financial and human resources took place and are commented in the next sections.

- The characteristics of the beam and target station as proposed for the complementary program in the parasitic mode are not presently covered in other accelerator centers in Japan, notably for the proposed medical radionuclide programme. It also matches the characteristics of other accelerators (cyclotron or linacs) already active in medical isotope production, such as BLIP, LANSCE, TRIUMF, PSI or SPIRAL 2. The combination of the proposed parasitic scheme of operation with expertise available in isotope mass separation, would allow J-PARC becoming one of the major facilities in this field.

Recommendations

1.1.1 T-TAC encourages to further capture on a regular base the needs of potential user's communities as well as to involve these communities in the advancement of the realization of the whole facility. Consider to carry out in addition and to keep updated a separate context analysis for every of the 4 presently identified applications. And try to identify complementarity or even uniqueness (niche) of the facility regarding other existing or projected infrastructures on domestic and international level.

1.1.2 Consider to exploit synergies in J-PARC, notably with the strong expertise in radiochemistry and isotope mass separation already present at ARSC-JAEA.

1.1.3 Strive to internationalize the user's communities. This could be achieved in the frame of existing collaboration at J-PARC like RaDIATE.

1.1.4 Continue to set-up collaborations on domestic and international level in the frame of the Japanese ADS program.

1.2 OLLOCHI and Corrosion Study

Observations

- Stable OLLOCHI-loop operation was successfully demonstrated for 11,000 hours under controlled parameters regarding temperature, flow rate and oxygen concentration.
- First corrosion results of two different steels of T91-type (with and without pre-oxidation) after 2000 h of exposure at 450 °C were presented. Strong oxide scale peeling was observed on T91-steel without Si addition. Proper pre-oxidation suppresses flaking of oxide layers to a certain extend.
- Based on these results, the original plan to conduct high-temperature long-term corrosion test was revised. In particular, it is planned to conduct pre-oxidation at higher oxygen concentration and to increase the oxygen concentration in OLLOCHI during the corrosion test.

Comments

- First of all, T-TAC congratulate the team for all the effort made leading to a such successful long-term operation of OLLOGHI, since November 2020.
- Meanwhile, three test campaigns have been conducted in OLLOCHI resulting in large number of specimens of different steels exposed to flowing LBE. Unfortunately, only a small number of post-exposure samples have been investigated to date. Results of these investigations are very important for the further pre-selection of candidate materials and for streamlining the next experimental campaigns in OLLOCHI.
- Observed oxide scale spallation on non-Si-containing T91 steel may result from locally higher flow velocity at sample surface (turbulent flow?). Because, precise measurements of the local flow distribution are not really achievable, the results should be compared with consideration of the flow conditions from thermal-hydraulic simulations.

Recommendations

1.2.1 Before fixing the next corrosion campaign in OLLOCHI put more effort on the post-exposure investigation of relevant samples from previous corrosion experiments (OLLOCHI campaigns 1-3)

1.2.2 Try to relate experimental observations regarding oxide scale peeling to expected flow distribution results from hydraulic simulations.

1.2.3 The current strategy for improved pre-oxidation process is to increase the oxygen concentration. It should be also considered whether better results could be achieved by increasing the pre-oxidation temperature (550-600 °C).

1.3 Status of LBE handling technologies

Observations

- The activities related to LBE handling technologies were affected by significant budget reductions. Important research topics and associated facilities for remote handling, natural convection and the development of velocity measuring devices were suspended.
- Reduced activities are now focus on oxygen control technologies and issues related to impurity control of dissolved steel elements and spallation products.
- Procedures for impurity measurements were established. First results on impurity monitoring of Ni, Cr and Fe in LBE were presented.

Comments

- T-TAC recognizes the valuable cooperation with Fukui University on the further development of the “TRAIL code” for impurity prediction in LBE.
- There should be some description about the technique to improve the Cr and Fe detection in future measurement.

Recommendations

1.3.1 To compensate as much as possible for suspended research topics, try to extend further national and international collaborations with partners in these fields (SCK-CEN, KIT…)

1.3.2 The future experiment plan must be examined carefully to obtain useful data, especially for ling-term experiments.

1.4 Neutronics study

Observations

- T-TAC recognizes steady progress in systematic measurements of proton-induced nuclide production cross sections and reaction rate measurement of ^{209}Bi(n,xn) for back-streaming neutrons at J-PARC.
- Measurements of double-differential neutron production cross sections and thick target neutron yields for Fe, Pb, and Bi, and new measurement of ^{237}Np fission rates were carried out using 107-MeV proton beam from the FFAG accelerator at Kyoto University.

Comments

- The INCL4.6/GEM calculation underestimates the experimental nuclide production cross sections for Bi target in the mass region of fission fragments. If the similar trend is found for the other heavy targets, the fission model in GEM should be improved in collaboration with the PHITS developer group.
- The energy spectrum of back-streaming neutrons can be derived from the measured ^{209}Bi(n,xn) reaction rates by means of an unfolding method with evaluated cross section data. It is interesting to apply such an unfolding method to the newly measured reaction rate data and to compare the unfolded neutron spectrum with the previous TOF measurement and PHITS simulation.
- The presentation actually extends beyond neutronics studies with fundamental data comparison with eg, proton-induced reactions.

Recommendations

1.4.1 A series of nuclear data measurements at the FFAG facility were completed at the end of JFY2022. It is desirable to proceed with data analysis of high-energy fission as well as TTNY and DDX and provide these results as soon as possible.

1.4.2 A proton-induced nuclide production database should be developed in collaboration with JAEA's Nuclear Data Group, using an evaluation method based on machine learning with GPR.

1.4.3 Elaborate on the plans for secondary reaction measurements, as it could provide interesting rates directly in the LBE targets for e.g. (alpha,2n) for another very important alpha emitters, At-211.

1.5 Accelerator development for ADS

Observations

- The reference JAEA-ADS linac design was updated. A fault compensation study was completed for many failure patterns. The maximum required power is 30% extra to compensate failures and the power requirement has been fixed.
- The progress of the development of the Single Spoke Resonator (SSR) is reported. The body part was fabricated and the frequency was measured. There were slight differences between the measured and CST simulation results. The error source is not fully understood, but this is in a tunable range.
- End-drift-tube assembly will be expected to complete in this FY2022.
- JAEA/J-PARC joined the Test Technology Collaboration.

Comments

- T-TAC notes that the reference linac design is almost completed.
- It is useful to collaborate with MYRRHA in a failure compensation study.
- T-TAC is concerned about the slow pace of the cavity development due to the limited budget. T-TAC is also concerned about keeping the resources until it's completion.
- At the development of the SSR, instead of relying on a large company, direct contract to processors is significant in terms of cost reduction and consolidation of staff member's skills.
- There is a concern about thermal distortion of a flange surface during welding. T-TAC encourages an actual process after sufficient determination of the welding conditions.
- Joining the TTC is welcomed for learning superconducting technology and exchanging information.

Recommendations

1.5.1 The requirement of the RF power is more consolidated. Then T-TAC repeats the recommendation at the last meeting; study the 648 MHz RF source choices in terms of the cost, operation and maintainability to establish the reference design and cost estimation.

1.5.2 As a next step of the linac design, T-TAC recommends to consider the ion source and LEBT design based on the startup and operating scenario.

1.5.3 Proceed steadily the development of the spoke cavity. The result of end-drift- tube assembly is expected to report at the next T-TAC.

1.6 Study of accelerator reliability

Observations

- The beam trip rate was studied for the SNS superconducting linac in the period from February to October 2020. The neutron production hours is 2,872 and operational hours is 2,856. The evaluated availability is 99.4%.
- There are some differences between SNS and J-PARC for minimum unit on record of the beam trip time.
- The Mean Time Between Trips is used to compare the SRF(SNS) and NC(J-PARC). The MTBT is 683 hours at SNS while 480 hours at J-PARC.
- The main causes of the beam trips were cavity discharges both for SNS and J-PARC.

Comments

- In response of the T-TAC#8 recommendation, the beam trip rate is well studied for the SNS superconducting linac.
- Although the minimum unit on record of the beam trip time is different for two facilities, T-TAC recognizes that the MTBTs for the two facilities are not large differences in 40 %. T-TAC notes that both facilities are the top level stable machines for SRF and NC structures.

Recommendations

1.6.1 T-TAC recommends to deepen objective evaluation such as statistical processing and to publish a paper as a summary of this work.

1.6.2 Consider to reduce the time window of small beam trips presently set from 0 to 6 minutes in order to document beam trips in-line with the requirements of ADS accelerator configurations.

1.7 Beam monitor development

Observations

- R&D of SiC wire monitor has been continued since FY2021. In FY2022, the SiC wire as a profile monitor showed good tolerance for the 3 GeV proton beam irradiation.
- A displacement test was conducted by using TIARA heavy ion to accelerate the displacement. Secondary electron was observed as a function of displacement.
- Due to the short range (about 2um) at 10MeV Nickel-ion, damage is introduced only on the surface of the SiC wire.

Comment

- Comments and recommendations from T-TAC#8 have been properly addressed.
- The SiC wire is a good candidate for the high-intensity beam.
- The only plan of the FY2023 activity is the development of the SiC wire monitor. T-TAC is concerned about the drastic reduction of activities due to the lack of resources such as man-power and budget.

Recommendations

1.7.1 Study further for the SiC wire monitor to clarify the beam depth profile dependence by using higher energy heavy ions, for example, the JAEA-TANDEM accelerator.

2. T-TAC #9 CONCLUDING REMARKS

T-TAC congratulates the team for the progress accomplished and notes that the project has considered the recommendations from the previous T-TAC.

A new format was used for the T-TAC 2023 meeting. The presentations including audio comments have been made available to the T-TAC members in advance and discussed during an on-line Questions & Answers session after a short reminder of the key messages by means of selected slides. The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during this unique session. The first feedback about the new format discussed by the T-TAC members during the 'closed session' pointed out that the efficiency of the on-line meeting is indeed increased by the shorter and more focused presentations. However, the interactions between the J-PARC team and the T-TAC members have diminished to a level that a continuation in such a format is no longer deemed to be appropriate by the T-TAC members.

T-TAC noted that JAEA's mid to long term plan (FY2022-2028) includes R&D on nuclear transmutation technology by using ADS and, regarding the J-PARC TEF program, it reframes the facility plan towards versatile applications in addition to nuclear transmutation research. In total, 4 areas of applications have presently been identified: material irradiation, soft error testing of semi-conductor devices, radioisotope production and proton beam applications. A first workshop was organised mid-2022 to capture the needs of the potential user's communities and the facility plan was submitted to the Science Council of Japan. T-TAC encourages to further capture on a regular base the needs of potential user's communities also at a international level as well as to involve these communities in the progess of the realization of the whole facility while continuously analysing the complementarity of the facility regarding other existing or projected infrastructures. As the scope of the T-TEF facility may extend to other users, as well as serving other groups in J-PARC, T-TAC recommends that the project integrates early on new constraints in the design, licensing or mode of operation vs the present baseline.

As announced in last T-TAC meeting, the human resources allocated to the ADS program at J-PARC decreased significantly in 2022. This situation will hamper the transition from the R&D phase to the realization of TEF-T. Prioritization of R&D tasks taking into account the reduction of financial and human resources took place. T-TAC recommends to keep the R&D efforts in-line with the needs for constructing TEF-T as well as to secure the needed hands-on experience required for the safe and efficient operation of the TEF facility.

T-TAC recognizes the collaborative efforts deployed by J-PARC for the Japanese ADS program with other organizations on national and international level and encourages its further growth.

T-TAC considers the R&D works carried out by J-PARC as highly valuable contributions to the international ADS community.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

1.1. Overview of Nuclear Transmutation Division & J-PARC Transmutation Experimental Facility Program and future Direction

1.1.1. T-TAC encourages to further capture on a regular base the needs of potential user's communities as well as to involve these communities in the advancement of the realization of the whole facility. Consider to carry out in addition and to keep updated a separate context analysis for every of the 4 presently identified applications. And try to identify complementarity or even uniqueness (niche) of the facility regarding other existing or projected infrastructures on domestic and international level.

1.1.2. Consider to exploit synergies in J-PARC, notably with the strong expertise in radiochemistry and isotope mass separation already present at ARSC-JAEA.

1.1.3. Strive to internationalize the user's communities. This could be achieved in the frame of existing collaboration at J-PARC like RaDIATE.

1.1.4. Continue to set-up collaborations on domestic and international level in the frame of the Japanese ADS program.

1.2. OLLOCHI and Corrosion Study

1.2.1. Before fixing the next corrosion campaign in OLLOCHI put more effort on the post-exposure investigation of relevant samples from previous corrosion experiments (OLLOCHI campaigns 1-3).

1.2.2. Try to relate experimental observations regarding oxide scale peeling to expected flow distribution results from hydraulic simulations.

1.2.3. Current strategy for improved pre-oxidation process is to increase the oxygen concentration. It should be also considered whether better results could be achieved by increasing the pre-oxidation temperature (550-600 °C).

1.3. Status of LBE technologies

1.3.1. To compensate as much as possible for suspended research topics, try to extend further national and international collaborations with partners from these fields (SCK-CEN, KIT…).

1.3.2. The future experiment plan must be examined carefully to obtain useful data, especially for ling-term experiments.

1.4. Neutronics study

1.4.1. A series of nuclear data measurements at the FFAG facility were completed at the end of JFY2022. It is desirable to proceed with data analysis of high-energy fission as well as TTNY and DDX and provide these results as soon as possible.

1.4.2. A proton-induced nuclide production database should be developed in collaboration with JAEA's Nuclear Data Group, using an evaluation method based on machine learning with GPR.

1.4.3. Elaborate on the plans for secondary reaction measurements, as it could provide interesting rates directly in the LBE targets for e.g. (alpha,2n) for another very important alpha emitters, At-211.

1.5. Accelerator development for ADS

1.5.1. The requirement of the RF power is more consolidated. Then T-TAC repeats the recommendation at the last meeting; study the 648 MHz RF source choices in terms of the cost, operation and maintainability to establish the reference design and cost estimation.

1.5.2. As a next step of the linac design, T-TAC recommends to consider the ion source and LEBT design based on the startup and operating scenario.

1.5.3. Proceed steadily the development of the spoke cavity. The result of end-drift- tube assembly is expected to report at the next T-TAC.

1.6. Study of accelerator reliability

1.6.1. T-TAC recommends to deepen objective evaluation such as statistical processing and to publish a paper as a summary of this work.

1.6.2. Consider to reduce the time window of small beam trips presently set from 0 to 6 minutes in order to document beam trips in-line with the requirements of ADS accelerator configurations.

1.7. Beam monitor development

1.7.1. Study further for the SiC wire monitor to clarify the beam depth profile dependence by using higher energy heavy ions, for example, the JAEA-TANDEM accelerator.

Appendix I – Agenda for 9th T-TAC Meeting

3rd February, 2023			
Japan	EU		
16:00	08:00	Welcome, Mission of T-TAC, J-PARC Overview	T. Kobayashi
16:20	08:20	Closed session (decision of individual charge)	
16:30	08:30	Overview of Nuclear Transmutation Division	F. Maekawa
16:45	08:45	Transmutation Experimental Facility Program and Future Direction	S. Meigo
17:00	09:00	OLLOCHI and corrosion Study	S. Saito
17:15	09:15	Status of LBE handling technologies	H. Obayashi
17:40	09:40	Break	
18:00	10:00	Neutronics study	H. Iwamoto
18:15	10:15	Accelerator development for ADS	Y. Kondo
18:30	10:30	Study of accelerator reliability	H. Takei
18:45	10:45	Beam monitor development	S. Meigo
19:05	11:05	Closing words	S. Wakimoto
19:10	11:10	Closed session	
20:00	12:00	Adjourn	

Appendix II – Mission and charge to T-TAC 2023 from J-PARC

by F. MAEKAWA

Mission of T-TAC

To advise primarily to the following items,

- Validity of the design concept to meet the primary purpose of the proton irradiation facility, that is, contributing to nuclear transmutation technology development, and versatile needs to the facility
- Direction and technical aspect of R&D activities on high-power accelerator, proton beam and target technologies for the primary purpose

Charge of T-TAC 2023

In addition to the recurrent request described in its mission, T-TAC in this year is especially asked **to give technical comments and recommendations to the on-going R&D activities.**

Appendix III - Committee members for T-TAC 2023

	NAME	AFFILIATION	POSITION
1	Marc SCHYNS	SCK CEN	Institute Director Advanced Nuclear Systems
2	Michael BUTZEK	Forschungszentrum Jülich	Team leader automation, magnet bearing and gears
3	Kazuo HASEGAWA	National Institutes for Quantum Science and Technology (QST)	Director of Nuclear fusion reactor materials research and development
4	Kei ITO	Institute for Integrated Radiation and Nuclear Science, Kyoto University	Associate professor
5	Georg MÜLLER	Karlsruhe Institute of Technology	Deputy Director, Head of Department Professor
6	Thierry STORA	The European Organization for Nuclear Research (CERN)	Senior Physicist, PRISMAP coordinator
7	Yukinobu WATANABE	Interdisciplinary Graduate School of Engineering Sciences, Kyushu University	Professor