TECHNICAL ADVISORY COMMITTEE # 10
on the Transmutation Experimental Facility (TEF)

Meeting held on 29 & 30 January 2024
J-PARC, Tokai, Japan

T-TAC 2024 REPORT

Final

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EXECUTIVE SUMMARY

The 10th Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project held their meeting from January 29-30 2024 at the J-PARC centre in Tokai and toured the Materials and Life science experimental Facility, 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 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.

T-TAC also appreciated the presented efforts to define the Technical Readiness Level (TRL) and suggest to further work it out in a structured way by keeping track of the rationale and the evidence to assign TRL to the different identified technologies as well as by associating a development plan to increase the TRL levels.

T-TAC acknowledges the intent to reframe the facility plan towards applications in addition to ADS. A clear scope (re)definition of TEF and an associated implementation strategy with a realistic planning should be worked out. T-TAC reminds that the transition from the present R&D phase of TEF to its realisation with the present (sub-critical and ageing) allocated human resources is questionable. An increase of human and financial resource is mandatory to keep the programme viable.

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 as well as to capture the needs of the potential user communities.

INTRODUCTION

The 10th Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project held their meeting from January 29-30 2024 at the J-PARC centre in Tokai and toured the Materials and Life science experimental Facility, 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.

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. Facility Design Update

1.1. Proton Irradiation Facility

Observations

- The committee acknowledge the present layout of the proton irradiation facility. This layout is similar to the one presented during the last committee meeting. It has reached a certain maturity level.
- The project members have undertaken actions to enlarge the user community
- They successfully identified 4 communities in total, and started to very preliminary identify the state of the art, possible implementation in the previous design
- Focus shifted from a ADS research uniquely driven facility to a multipurpose facility with medical RI production as well as soft error and other irradiation possibilities
- A schedule was presented mostly inspired from previous developments

Comments

While some maturity level can be associated to present design, it is pointless to associate a TRL with regard to following comments:

- New scope of the projects, and subsequent staging related to design, budget, resources and feasibility analysis will totally affect the overall TRL of this work package

- The vision and goal for the project should be defined to the new focus to make sure that the work done matches the goals. The new vision and goal should be clearly formulated, documented and properly communicated after agreement with the project sponsors and major stakeholders.

- The committee urges the project to organize a scoping project meeting with relevant bodies to endorse new phases and community possibly involved ASAP : this is critical to keep the team federated and the project well perceived outside.

- While some items were presented with highest TRL qualification, eg TRL9 for BNL RI production, inclusion and parallel operation of TRL9 technologies does not mean the proton irradiation facility will rapidly reach readiness for construction.

- The JPARC presents unique features and competences (high power target, LBE technology, accelerator, Hot Cell expertise, expertise of standalone isotope mass separation) that needs to be exploited for the fine-tuning of the scope of the TEF-T with regard to new additional axes of research.

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.

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

1.2. Hot Laboratory for PIE

Observations

- A quite detailed and ambitious layout is presented

- Yet some basic features were not presented, eg flow diagram of irradiated materials, people and waste, …Process of PIE flow was not presented but has a big impact on the design.

- Schedule and cost is missing for the moment

Comments

- The scope and priorities were not presented to define associated layout (footprint for waste likely too small) especially for RI production and purification. Make sure you fully define the PIE process of the work that will be performed in this facility.
- Similar to the irradiation facility, it is of utmost importance to get support from the sponsors (supporting the project) and clear line to follow after scope is fixed.
- It is important that teams believe in new proposed plans with project oriented management (occasion to empower/recruit new young staff)
- Interfaces are critical, eg transfer with proton irradiation facility and import/export of eg Thorium

Recommendations

1.2.1. Update budget and timeline and if necessary reiterate the scoping exercise.

1.2.2. Look the full value chain for medical isotope production and the required infrastructure

1.2.3. Consider the licensing aspects in function of the target material (Th or U) as it can have impact on the security measures on J-PARC site

2. R&D Activities on LBE Technology Development

2.1. Oxygen concentration control

Observations

- Improved procedure to measure impurities in the LBE of OLLOCHI loop were applied allowing to estimate Fe and Ni amount. Cr, Fe and Ni contents in LBE were measured and confirmed that their contents were small compared to their solubility except for Fe content in DT. Cr concentration still below detection limit. Detection limit improved by one order of magnitude.
- Oxygen consumption during OLLOCHI loop operation was successfully measured for the first time for all three campaigns. An unknown increase in Oxygen consumption was detected after loop shutdown.
- Trail code was successfully applied to MEGAPIE target resulting in fair agreement with PIE results

Comments

- Oxygen control system is meanwhile elaborated well and fulfills requirements to handle the target. Not much additional effort required.
- T-TAC recognize the effort made in further upgrading the TRAIL code and the planning to integrate an element dissolution model.

- T-TAC also recognize the planning to start sensitivity analyses on corrosion product deposition for cold-trap design. But no information was provided about the content of this work

Recommendations

2.1.1. Focus mainly on TRAIL code upgrade as well as impurity measurements and control

2.2. Results of corrosion tests

Observations

- Data shown was not compared to existing data from other/older tests.
- Weight loss and oxygen layer thickness of specimens, 316L, T91, ODS and T91-Si, in LBE flow were measured and 316L, ODS and T91-Si showed good corrosion resistance compared to T91.
- The effectivity of pre-oxidization, i.e. steam-oxidization and/or oxygen saturation, was confirmed to reduce the corrosion amount though the corrosion resistance effect of steam-oxidization can decreases with time.

Comments

- The data shown is based on one investigated sample per setup. It would be nice get some more samples for the same setup to have some statistics
- How does data compare to existing data? Even if the existing data is with different structural material.
- Is slit corrosion an issue because of the small gap for the LBE flow along the sample?

Recommendations

2.2.1. Reuse already exposed samples in the planned new campaigns to increase the exposure time.

3. R&D Activities on Proton Beam Technology Development

3.1. Beam monitor development

Observations

- As R&D on profile monitors using SiC wires, study has been conducted to see if they could withstand proton irradiation. For this purpose, the electron emission rate by heavy ions irradiations has been measured.

- The dpa was evaluated at the Bragg peak position using 10.5 MeV Ni and 200 MeV Xe beams. The dpa differs greatly between the surface and the Bragg peak positions. The results have been showed that the SiC wire is expected to last up to 30 dpa. Since the expected damage on the surface is 2.5 dpa, SiC wire is a robust solution for beam monitoring and is compatible with maintenance of the accelerator scheduled on a yearly base.

Comments

- The previous T-TAC advice to study the behavior of the beam with high-energy ions is well reflected.

- The experiments and results are appreciated even under the conditions with limited manpower and budget.

- The obtained SiC wire results are useful for the accelerator community not only for the ADS community and T-TAC encourages to continue the work.

- The lifetime or duration of actual monitors is not only determined by displacement damages, but is affected by temperature, mechanical behavior, and other factors. It is necessary to consider technical feasibility including these factors. In particular, the large 450mm aperture monitor is challenging.

- Evaluation of radiation damages for support frames is important for practical use.

- The development of monitors using SiC wire is scheduled to terminate by 2024, but the final achievement is not clear.

Recommendations

3.1.1. To conclude the campaign, list up the whole issues with SiC wire monitors, then indicate what has been resolved, and what needs to be resolved in the future.

3.1.2. Regarding the development of IPM starting from 2025, clarify the development items and annual plan.

3.2. Neutronics experiment

Observations

- Works were done in the neutronic design of the proton irradiation facility. One of them show that it is possible to extend the area of the irradiation field according to user's request by increasing the aperture of the neutron beamline and improving shielding performance.

- Production of ^{99}Mo using the ^{100}Mo(p,pn) reaction at the proton irradiation facility was proposed. The simulation result indicates that the production capacity is comparable to the currently planned capacity at the JRR-3 facility.

- All measurements conducted with 107-MeV proton beam at Kyoto University were successfully completed. The spallation models used in in the particle transport simulation codes were validated using the measured data including neutron production DDXs, the mass number distribution of fission fragments, and fission neutron yields.

Comments

- T-TAC acknowledges the steady progress made in experiments at J-PARC, including systematic measurements of nuclide production cross sections, application of the unfolding method to estimate thick target neutron yield, and preliminary measurement of Al(p,xp) reaction.

- The new data of fission neutron yields for Pb and Bi will be useful to investigate the contribution of neutrons caused by fission from the experimental total neutron production yield.

- If the Al(p,xn) data are available, comparison of the DDX data between (p,xn) and (p,xp) reactions would be helpful to investigate the cause of the discrepancy between the measured DDX data and the spallation model calculations.

- T-TAC repeats that improvements to the reaction models and the nuclear data library used in PHITS code should continue in collaboration with the nuclear data group and the PHITS developer group in JAEA as well as with researchers outside JAEA.

Recommendations

3.2.1. Verify the 100Mo(p,pn) cross section used in the simulations, it will be possible to measure the 99Mo production cross section from a Mo target irradiated with a 0.4 GeV proton beam in future nuclide production experiments at J-PARC.

3.2.2. Look to other reaction channels to evaluate the specific activities in the 99Mo production.

3.2.3. A series of measurements at J-PARC have systematically accumulated a variety of nuclide production cross sections. Systematic comparisons of the measured nuclide production cross sections with various spallation models used in ADS neutronics simulation are very useful for understanding of the current predictive power of the models and their improvement. A review paper on the nuclide production cross sections should be published.

4. R&D Activities on Super-conducting Accelerator Development

4.1. Beam Design of Super-conducting linac for JAEA-ADS and prototyping of a spoke

Observations

- The beam power of the ADS accelerator (30 MW) and the required electric power have been evaluated, and the achievement of target efficiency of 30% has been shown.
- The 648MHz RF source accounts for 86% of the total power, so its selection is important. The RF sources of klystrons and semiconductor have been compared, and semiconductor amplifiers have been selected by considering cost, operational issues, and maintainability.
- The ion source by using a 2.45GHz ECR with three electrodes has been designed.
- A low energy beam transport system has been investigated with two solenoid magnets and a chopper, with considering space charge effects.
- The chopper is to use control the pulse width and ramp-up control of the beam power.
- In collaboration with other facilities using superconducting linacs, compensation methods and beam dynamics have been studied in case of cavity failure.
- The production of a spoke cavity is continued. In FY2022, electron beam welding of the beam ports and measurement of the frequency were conducted, and in FY2023, the EBW of the spoke was tested and the beam ports were manufactured.

Comments

- T-TAC9's recommendations and comments have been appropriately responded.
- Although there were concerns about thermal distortions during welding, T-TAC appreciates that it was manufactured within specifications.
- The selection of the 648MHz RF source and the design of the ion source and LEBT have been done appropriately.
- The controlling the beam current at the ramp up by the chopper is generally reasonable, but compatibility with the target side is needed to be checked in order to confirm the method.
- T-TAC acknowledges that the production of the spoke cavity is progressing steadily.
- T-TAC recognize that the reference design for the ADS accelerator is almost completed, and should be described a document in order to shift to the next step.

Recommendations

4.1.1. Progress steadily towards the production of the spoke cavity prototype.

4.1.2. Prepare a report on the Reference Design of the ADS accelerator (Conceptual Design Report)

4.2. Study of Accelerator Reliability

Observations

- Two papers have been progressing for publication on the statistical evaluation results, one of which has been published and the other will be submitted in March 2024.
- The superconducting linac operation statistic data have been obtained and the trip rate has been evaluated. For beam trips higher than 5 minutes, data shows significant deviations from the acceptable beam trip frequency.
- From the trip frequency data of the superconducting linac, the trip frequency and the ratio to the allowable beam trip frequency have been analyzed.
- From the operating experience, the frequency of beam trips has been essentially the same for both J-PARC and SNS.

Comments

- T-TAC considers that the series of reliability monitoring tasks for accelerator operation have been almost completed, and the task should be relaunched after attempt of corrective actions (component exchange, major maintenance, …).

Recommendations

4.2.1. T-TAC recommends that the statistical data will be considered in the ADS accelerator design in order to improve the situation.

5. T-TAC #10 CONCLUDING REMARKS

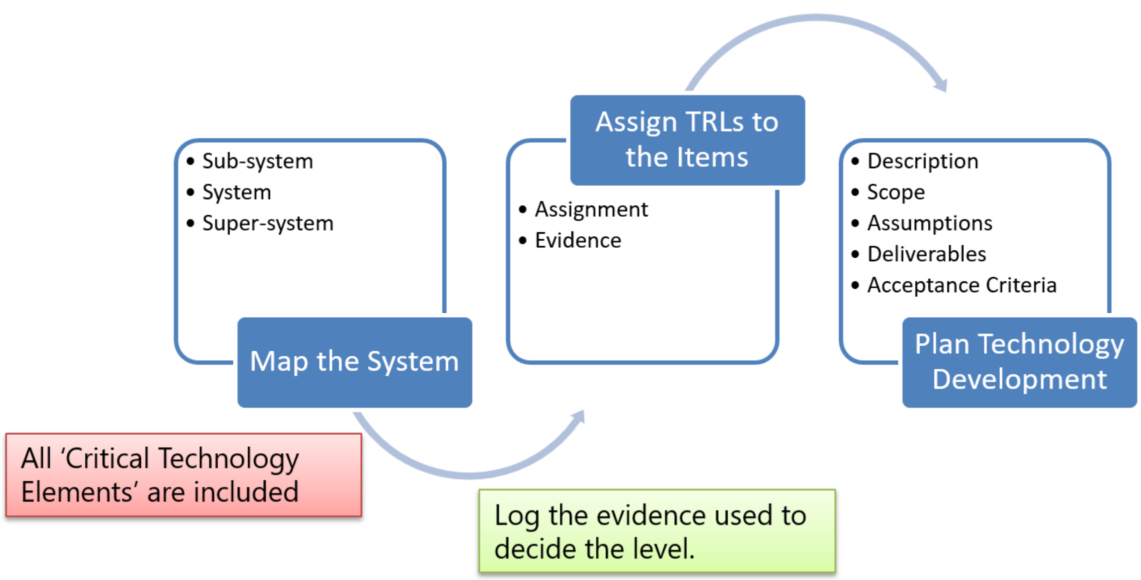
T-TAC congratulates the team for the progress accomplished and notes that the project has considered the recommendations from the previous T-TAC's

T-TAC acknowledges the intent to reframe the facility plan towards applications in addition to ADS. In total, 4 areas of applications have presently been identified: material irradiation, soft error testing of semi-conductor devices, radioisotope production and proton beam application. A clear scope (re)definition of TEF and an associated implementation strategy with a realistic planning should be worked out.

A workshop was organised mid-2023 to capture the needs of the potential user's communities and the facility plan was cited the Science Council of Japan. T-TAC encourages to further capture on a regular basis the needs of potential user's communities also at an international level.

T-TAC reminds that the transition from the present R&D phase of TEF to its realisation with the present (sub-critical and ageing) allocated resources is questionable. An increase of human and financial resource is mandatory to keep the programme viable. Meanwhile, T-TAC recommends to keep the R&D efforts in-line with the needs of the ADS programme as well as to secure the needed hands-on experience required for the safe and efficient operation of the existing TEF facilities.

T-TAC appreciates the presented efforts to define the Technical Readiness Level (TRL) and suggest to further work it out in a structured way by keeping track of the rationale and the evidence to assign TRL to the different identified technologies as well as by associating a development plan to increase the TRL levels.



T-TAC recognizes the collaborative efforts already deployed by J-PARC for the Japanese ADS program with other organizations on national and international (SCK CEN, ESS, KIT, PSI) level and further encourages growth in it.

T-TAC recognizes that the R&D topics are in-line with the needs for designing and constructing TEF for ADS.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

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1.1. Proton Irradiation Facility

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.

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

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

1.2. Hot Laboratory for PIE

1.2.1. Update budget and timeline and if necessary reiterate the scoping exercise

1.2.2. Look the full value chain for medical isotope production and the required infrastructure

1.2.3. Consider the licensing aspects in function of the target material (Th) as it can have impact on the security measures on J-PARC site

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4.1.1. Progress steadily towards the production of the spoke cavity prototype.

4.1.2. Prepare a report on the Reference Design of the ADS accelerator (Conceptual Design Report).

4.2. Study of Accelerator Reliability

4.2.1. T-TAC recommends that the statistical data will be considered in the ADS accelerator design in order to improve the situation.

Appendix I – Agenda for 10th T-TAC Meeting

(Main Conference Room, J-PARC Center Research Building 2F)

January 29, 2024 (09:30) – January 30, 2024 (8:00 PM)			
First day - January 29, 2024			
08:30	09:30	Shuttle bus departure from the hotel	
09:30	10:10	Welcome, Mission of T-TAC, Overview J-PARC	T. Kobayashi
10:10	10:30	Group photo	
10:30	10:50	Closed session (decision of individual charge)	
10:50	11:20	Overview of Nuclear Transmutation Division	F. Maekawa
		Facility Design update	
11:20	12:00	Proton Irradiation Facility	S. Meigo
12:00	12:20	Hot Laboratory for PIE	S. Saito
12:20	*13:20*	*Lunch*	All
		R&D Activities on LBE Technology Development	
13:20	13:55	LBE-related activities in J-PARC – R&D Activities on LBE Technology development	H. Obayashi
13:55	14:20	Results of corrosion tests	N. Okubo
		R&D Activities on Proton Beam Technology Development	
14:20	14:40	Beam Monitor Development	S. Meigo
14:40	15:20	Neutronics Experiment	H. Iwamoto
15:20	*15:40*	*Coffee break*	*All*
		R&D Activities on Superconducting Accelerator Development	
15:40	16:20	Design of Superconducting Linac for JAEA-ADS and Prototyping of a Spoke	B. Yee-Rendon
16:20	16:40	Study of Accelerator Reliability	H. Takei
16:40	17:15	Closed session	
17:15	19:00	Adjourn: Shuttle bus to the hotel	
Second day – January 30, 2024			
08:30	09:30	Shuttle bus departure from the hotel	
09:30	11:30	Site tour: Materials and Life Science Experimental Facility, Neutrino Experimental Facility and LBE testing apparatuses	
11:30	*11:40*	*Coffee break*	
11:40	12:00	Closed session	
12:00	*13:00*	*Lunch*	
13:00	15:00	Closed session	
15:00	15:20	Summary Talk	M. Schyns (??)
15:20	15:30	Closing words	S. Wakimoto
15:30	16:30	Adjourn, shuttle bus to Tokai and Katsuta stations and the hotel	

Appendix II – Mission and charge to T-TAC 2024 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

Specific charge of T-TAC 2024

In addition to the recurrent request described in its mission, T-TAC in this year is especially asked **to review progress in the facility design with considering the Technical Readiness Level (TRL).**

As recommended in the T-TAC held 2 years ago, we created the TRL for the facility. We will show the TRL in this T-TAC. Hence we think the charge is appropriate for this T-TAC.

Appendix III - Committee members for T-TAC 2023

	NAME	AFFILIATION	POSITION
1	Marc SCHYNS	SCK CEN Belgian Nuclear Research Centre (SCK CEN)	Institute Director - Innovative Nuclear Systems
2	Michael BUTZEK	Forschungszentrum Jülich	Team leader automation, magnet bearing and gears
3	Kazuo HASEGAWA	National Institutes for Quantum Radiological 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 (KIT)	Deputy Director, Head of Department Professor
6	Thierry STORA	The European Organization for Nuclear Research (CERN)	Senior Physicist, PRISMAP coordinator, ISOLDE target expert
7	Yukinobu WATANABE	Department of Interdisciplinary Engineering Sciences, Kyushu University	Professor