TECHNICAL ADVISORY COMMITTEE
on the Transmutation Experimental Facility (TEF)

Meeting held from 12 to 14 December 2016
Tokai, Japan

T-TAC 2016 REPORT

Contents

EXECUTIVE SUMMARY

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from December 12th to 14th, 2016 at the J-PARC centre, Tokai and toured the LINAC building, the Safer building as well as the laboratory in the High Temperature Research Building and, finally, the site for the planned construction of TEF. 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 TEF program was presented as part of the roadmap towards the Accelerator Driven System (ADS) proposed by JAEA for waste transmutation. The key issues on the support R&D, design and licensing of the “ADS target test facility” TEF-T as well as of the critical/subcritical reactor “Transmutation Physics Experimental Facility” TEF-P to study the reactor physics with Minor Actinide (MA) fuel, have been addressed during the meeting. T-TAC formulated a list of observations, comments and recommendations for these topics. Both systems TEF-T and -P are outstanding and unique in the world and T-TAC is convinced that given the proper resources the TEF program will greatly contribute to the development of ADS for the transmutation of high level waste at an engineering level and create important scientific, technological as well as societal benefits.

To close the conceptual design phase of TEF-T, T-TAC recommends to complete the draft Technical Design Report (TDR) by including additional sections about instrumentation, waste characterization and dismantling.

T-TAC strongly encourages to enhance collaborations as well as joint Education & Training programs with other organizations involved in ADS projects like MYRRHA and to promote the potential of the TEF facility to different communities (e.g. nuclear physics, nuclear astrophysics, nuclear medicine) for the implementation of research programs as well as for commercial applications.

INTRODUCTION

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from December 12th to 14th, 2016 at the J-PARC centre, Tokai and toured the LINAC building, the Safer building as well as the laboratory in the High Temperature Research Building and, finally, the site for the planned construction of TEF. Appendix I gives the agenda for the meeting while Appendix II indicates the charges that the J-PARC director gave to the committee. The full committee (see Appendix III) participated in the three-day meeting, except Eric Pitcher (ESS) 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. The draft Technical Design Report (TDR) of TEF-T has not been considered for the reviewing by T-TAC.

1. OVERVIEW OF J-PARC TEF PROGRAM

The Transmutation Experimental Facility program was presented as part of the roadmap towards the ADS proposed by JAEA for waste transmutation. The structure of the involved R&D sections in J-PARC as of April 1st 2016 as well as the updated schedule for the Target (-T), the Beam Transport (-BT) and Physics (-P) of the TEF project have been shown.

Observations and Comments

Even if additional staff joined the Nuclear Transmutation Division since the last T-TAC meeting in 2015, T-TAC estimates that a further reinforcement of the TEF team as well as the set-up of a construction team is required in order to complete the detailed design, the licensing file and the launch of the construction phase of TEF-T and TEF-BT as presently under discussion.

T-TAC recognizes that a rescheduling of the project is necessary in the light of delayed grant of the TEF construction budget. It should be made clear how the final construction cost will vary if the project is recurrently delayed. Until now, such a risk analysis has not been presented and the impact of not allocating the requested manpower is not assessed.

T-TAC strongly encourages to enhance collaborations and Education & Training programs with other organizations in the form of a “ADS P&T task Force” involving ADS projects like MYRRHA or organizations (e.g. universities, research centers, industry) with relevant expertise and to promote the potential of the TEF facility to different communities for the implementation of research programs (e.g. nuclear physics, nuclear astrophysics, nuclear medicine) as well as for commercial applications (e.g. semiconductors testing).

Recommendation

1.1 Continue the Public Relation campaigns in order enhance visibility of the TEF project: presentation of the project to Japanese Nuclear and non-Nuclear Industry clusters or associations, convince experts of other communities (Fast Reactor, geological repository, …) in order to maintain credibility of the project and avoiding conflicts between experts during public debates, revisit the TEF website for the public (make content less scientific, add an application catalogue of public interest, add a media gallery, …)

2. TEF-T DESIGN DETAILS

2.1 Target System and Maintenance

A new design of the target system, based on the conceptual design presented at T-TAC 2 and introducing additional, new components to simplify the target system, was presented. In particular, the target head design, the target loop and the design of the target trolley was re-designed for increased safety in case of e.g. a LBE leakage.

Observations and Comments

Concerning the target head unit, the basic design was not changed. The connections to other system components were located just after the target head. The support for the target head is designed to minimize the curvature during filling of LBE into the target head.

A major design change is the introduction of a movable vacuum vessel to keep the target head under negative pressure condition. Furthermore, the vacuum vessel also acts as a “safety hull” to enclose reaction products in an accidental case. The vacuum vessel was designed as a separate component to simplify the target head design (decrease the risk of malfunction) and improve the re-usability after target exchange. The center of the target head can be automatically aligned to the beam window center by the support structure in the vacuum vessel. The primary LBE loop is located on the target trolley. The functional tests of the loop components will be performed with IMMORTAL loop (see section 3.1). The LBE flow is set to 1 m/s whereas in an ADS, typically 2 m/s are applied. No reason for the limitation (corrosion, erosion etc.) was given.

The new state of the automatic cutting, cleaning of tube ends from sticking LBE and re-welding of connecting target tubes to avoid most of the joints/flanges, discussed already during the T-TAC2 meeting, was presented. For the re-welding of T91 tubes an annealing heat treatment of the welding zone at 760°C for about 2 hours to avoid embrittlement is therefore absolutely necessary.

Recommendations

2.1.1 Prove a proper cleaning process of the cutted target tubes from sticking LBE before re-welding to a new target.

2.1.2 Development of measures for the cleaning quality before re-welding of pipes.

2.1.3 Prove the capability of external movable heater systems to perform the required heat treatment, including air-cooling afterwards to room temperature.

2.2 Target Design

In response to a recommendation of the T-TAC 2 meeting, to strengthen the flow stability and to reduce the stress level, three types of target head designs with additional flow slits and modified shape of inner tube, wing-type flow guides and change in beam window shape are being investigated.

Observations and comments

In the target head design, the avoidance of a stagnation point of the LBE flow in the centre of the Beam Window to decrease the thermal stress level is of great importance. Therefore, the variation of the curvature of Beam Window has resulted in significant minimization of stagnation volume and stress level. An offset of the proton beam might keep the maximum temperature and the stress level below critical values for SS 316 and T91 steels. Few information is provided concerning the instrumentation of the target (vivration monitoring, stress measurements, ultrasound velocimeters, …)

Recommendations

2.2.1 Prove the functioning of the chosen target design for 316 and T91 steels in a full 3D fluid analysis before testing in IMMORTAL loop.

2.2.2 Consider the risk of liquid metal embrittlement for T91 steel in comparison to SS 316. What would be the consequences for the target design?

2.2.3 Consider as “plan B” the use of a bypass flow in the target to avoid stagnation point in the center of Beam Windows if designs A, B and C are not giving appropriate results.

2.3 Target Station

The target system including the LBE target, the vacuum vessel and the target trolley is located at the center of TEF-T. The target station is a complex of components including the target system and as well as the inner vessel with water cooled shielding blocks, the outer vessel with shield blocks containing steel, the concrete biological shield surrounding the outer vessel. The 4 main design criteria (shielding, confinement, heat removal, interfaces) have been detailed and the layout of the target station resulting from the application of these criteria was presented.

Observations and Comments

Several tasks have been listed that are necessary to carry out in order to advance the present design of the target station to the level of 'detailed design' with the contribution of design companies.

Recommendations

2.3.1 Assess the window effect on the proton beam distribution (energy deposition, beam emittance,…)

2.3.2 The integration of the neutron beam line and the multipurpose target should be assessed. What is the impact on the shielding?

2.4 Irradiation and PIE Plan

Observations and Comments

The adequacy of different sample preparation processes after TEF-T irradiation has been assessed. Pros and Cons of Electrical Discharge Machining (EDM), lathe machining and the combination of both machining techniques have been listed. Some clarification is requested concerning the method for monitoring and maintaining the irradiation conditions a. o. temperature, LBE flow as well as the shape of the DPA field (neutron versus proton).

Recommendations

2.4.1 Assess flow pattern and check erosion of the samples

2.4.2 Set-up the detailed irradiation condition and PIE plan (target and samples) when target design is fixed.

2.5 User Applications

In addition to the R&D of the ADS, it is intended to build a 'multipurpose' equipment near the target in order to make effective use of the fast and high-energy neutrons produced from the LBE target in TEF-T. The additional devices (pneumatic tube, neutron beam port, ISOL facility) to achieve this additional objective have been presented. Also, some examples of targeted research fields were listed.

Observations and Comments

The ISOL facility is an independent beam line and is still in its basic design phase. Also the insertion mechanism of the secondary target trolley was shown and needs to be further developed.

Single Effect Event's & Single Event Upset's test will be performed commercially with the use of a private company neutron source since such tests have to respect international standard. Please pay attention to such development for considering the application fields.

Recommendations

2.5.1 About spatial distribution the neutron distribution on the target should be taken into account.

2.5.2 Consider the energy spectrum at the detecting position as another important information for the applications.

2.5.3 The organization of workshops gathering potential users working in the intended research topics would be of benefit to assess their needs. The outcomes of these workshops can lead to the definition of a detailed applications catalogue for the multipurpose equipment in the TEF facility and, maybe, to some basic design changes of it (or parts of it) in order to fulfil the identified user's requests.

2.6 Facility Design

Observations

The layout of the facility and the electricity required were presented. The space for the ISOL accelerator is rather narrow. The electricity for ISOL is about half of the total electricity. Procedure to store the activated materials was not presented. The recommendations proposed in T-TAC 2 were well reflected.

Recommendations

2.6.1 Consider to build ISOL facility on a different level than Target station

2.6.2 Ensure easy access for the users

2.6.3 Storage area(s) of spent targets and activated materials should be designed carefully taking into account the detailed experimental plans and the number of the targets stored during the life time of the facility. Furthermore, detailed storage procedure should be considered.

2.6.4 ISOL strongly affects the layout and the services. Therefore, it is important to carry out a detailed design of the ISOL facility in order to fix its location including space for scientific instruments (spectrometers) and cryogenic plant for the RIB post-accelerator

2.6.5 Electrical Power requirements for the Multipurpose Area (ISOL Facility) are clearly underestimated (one should target x 2 higher ~ 4.5 MW). They should be revised based on list of equipments (cryo plant, LINAC, beam lines, experimental devices, ISOL target system, RF system, cooling and ventillation, etc…). Indicative figures are; for cryogenics 1.5 MW, power converters 1.2 MW, cooling and ventilation 1 MW, electrical systems 0.3 MW, RF 0.4 MW, vacuum system 0.1 MW.

2.7 Control System

The outline of TEF-T General Control System (GCS) and its subsystems including the Personnel Protection System (PPS) have been presented.

Recommendations

2.7.1 Assess the time delay between detection and beam stop. Such information is necessary to consider the recovery scenario or the safety analysis.

2.7.2 Define control requirements for the user application part

3. EXPERIMENTS AND RESULTS FOR TEF-T DESIGN

3.1 TEF-T Target Mockup Loop – IMMORTAL

The TEF-T target mockup loop was re-named to IMMORTAL! IMMORTAL is a test loop to demonstrate the feasibility of the primary cooling system of TEF-T target system. The recommendations of the T-TAC 2 Meeting concerning the temperature margin of old fin-type Heat Exchanger (HX) and revision of HX design (minimizing risk of water hammer) has been well addressed by starting a detailed revision of the HX design. Furthermore, also a RELAP5 model of IMMORTAL has been made to assess the transient behavior of LBE target system, as also recommended in the last T-TAC meeting.

Observations and Comments

The commissioning and integration tests have already been performed. The development of ultrasonic flowmeter as an absolute instrument, compared to EM flow meter, is of great importance. The enormous sound speed of HLM´s requires extremely fast acquisition and data processing systems to obtain reliable velocity information. Besides these quite sophisticated demands on the data transmission recording and processing units, several constraints regarding the environmental conditions have to be matched. Because of the elevated temperature of more than 200°C, wave guides have been developed to decouple the temperature from the sensor. Such an integrated probe can operate in liquid metal temperatures up to 620°C. Secondly, an acoustic coupling of the sensor and the fluid has to be ensured which means that the probe has to be physically wetted. This is partially achieved by applying a sacrificial nickel layer on the probe surface before inserting it into the fluid. Within the lead-bismuth, this nickel layer is dissolved and ensures the wetting of the surface for a certain time. However, the wetting of the sensor surface gets lost after a few days of operation.

For the heat exchanger, the secondary medium is pressurized water. Outlet temperature is 200°C and water pressure is 2 MPa. Saturation pressure of pressurized water at 200°C is about 1.45 MPa. However, at 2 MPa the boiling point is 213 °C. There is only a small margin in temperature. Subcooled boiling can quickly occur, and the boiling bubble collapse in the water bulk flow. If a certain amount of generated steam is surrounded by subcooled water periodically, water hammer may occur because of quick condensation of the steam, and as a result the heat exchanger is damaged by the water hammer. As a countermeasure, the presented revision of HX design with a double-wall tube with an intermediate gap filled with He gas looks reasonable.

Recommendations

3.1.1 Prove the accuracy and long-term stability of ultrasound flow meter in comparison to electromagnetic-type flow meter.

3.1.2 Check if high temperature oil could be an additional alternative to He gas?

3.1.3 Prove the revised HX design in IMMORTAL loop tests.

3.2 High Temperature Corrosion Test Loop – OLLOCHI

The High-temperature test loop was re-named to OLLOCHI! The status for OLLOCHI as end of 2016 (step 1) is that the erection of the loop and the conditioning operation without LBE, including OCS, have been finished. The next steps to finalize the remote monitoring system (steps 2 and 3) and to incorporate a mechanical testing machine in the 3rd test section are foreseen until end of 2017.

Observations and Comments

The purpose and objectives of the test loop are well addressed since the 1st and 2nd T-TAC meetings. Nevertheless, the presented new flow scheme considers not all the recommendations, given in the last T-TAC meeting in October 2015!

- The incorporation of the two ultrasonic flow meters into both test sections is nearly finished (step 2). Later on, their output can be compared with the signal from the newly installed EM flow meter after the pump.
- The careful CFD analysis of the flow pattern of the test sections have not been made up to now. This is necessary due to the design of the outflow of LBE from the holes in the specimen holder inside the expansion tank.
- The alternative austenitic steel JPAC 15-15Ti to SS316 for the low temperature pipes could be accepted.
- A third test section connected to a mechanical test machine for tensile and fatigue testing was introduced since the last design revision. Because of the incorporation and the fact how it is connected to the main LBE flow, a strong influence on the operation of OLLOCHI loop to perform long-term corrosion testing is expected! Furthermore, the conditions for the test samples regarding oxygen concentration and LBE flow velocity at the surface seems to be, at least, difficult to estimate and to control.
- There is no equipment currently existing for the automatic gas mixing to control the oxygen in the OLLOCHI loop.

Recommendations

3.2.1 The detailed CFD analysis of the two test sections, including the flow into the expansion tank, has to be absolutely performed.

3.2.2 Present a scheme/plan how to insert and exchange corrosion test samples from the test sections while operating the loop.

3.2.3 Present a strategy how to perform the gas mixing in the expansion tank to maintain the desired oxygen concentration in the OLLOCHI loop.

3.2.4 Due to the different requirements for the loop operation, consider the operation of OLLOCHI firstly without connecting to a test machine, at least in the next years, until enough experience in the loop operation exists. Prepare a "plan B".

3.2.5 Update and/or modify the experimental plan (schedule) based on the budgetary conditions.

3.3 Oxygen Sensor and Potential Control

The purpose and the objectives of the oxygen concentration measurement with electrochemical oxygen sensor, including oxygen control process, are well addressed. Most of the recommendations of the 1st and T-TAC 2 Meeting are fulfilled.

The presented calibration method is in principal appropriate, but:

Observations and Comments

The use of Fe/Fe_3O_4 reference potential for sensor calibration is not biunique due to the existence of different Fe-oxides, resp. their potentials.

The sensibility of the sensor signal to gamma –ray irradiation is probably due to the degradation of plastic material used inside the sensor (e.g. isolation material of BNC plug etc.).

Recommendations

3.3.1 For the calibration of Pt/air sensor, rely only on Pb/PbO (saturation) and e.g. on Co/CoO as reference points.

3.3.2 Consider a re-design or shielding of the oxygen sensor head.

3.3.3 Long-term tests (>> 1 year) of oxygen sensor signal stability are still pending.

3.3.4 Consider the use of a protecting steel sheath around the ceramic electrolyte tube of the oxygen sensor when using in flowing LBE.

3.4 Freeze Valve Development

Because of leakages with needle-type bellow valves, the number of mechanical valves have to be reduced to a minimum number which is also in agreement with the experience of the T-TAC. Nevertheless, to incorporate a so-called freeze-seal valve into the target loop will have an impact on the reliability and safety of the whole loop system. Because LBE is time-dependent expanding after solidification, high mechanical stresses can result in structural failures of the piping system when the strength of structural steels is exceeded. The level of mechanical stresses depends on the cooling rate, onset temperature of cooling and time in the solid state.

The recommendation of the 2nd T-TAC meeting to perform thermal expansion tests of LBE during freezing as a function of cooling rate by means of strain gauge-instrumented capsules has been successfully implemented. The excellent results are in good agreement with earlier data from PSI during the MEGAPIE campaign. With 3°C/min cooling rate from 150°C as starting temperature, the induced strain/stress remains below the allowable values for SS 316 at 400°C.

Recommendations

3.4.1 Guarantee that the “real” cooling rate of LBE will never be higher than about 3°C/min to maintain the stress level in the pipe steel below its UTS. This must be true also in the case of “station blackout” where no external electrical power is available for controlled operation of heating/cooling systems.

3.4.2 Perform a stress analysis for the piping geometry of freeze valve to confirm its feasibility.

4. PROTON BEAM TRANSPORT

4.1 Design and Study on L-TEF-BT and Neutronics

Observation

Recommendations of previous T-TAC report are correctly addressed and the remaining issues are clearly identified.

Recommendations

4.1.1 Make sure that there is enough space to locate ancillary equipments (laser room, power supplies, RF equipment for ISOL)

4.1.2 Promote collaboration with ESS for the design of the Beam profile monitor

4.1.3 Develop the LCE technique for short bunched beam applications

4.1.4 Perform systematic validation of PHITS code through cross section measurements and comparisons

4.2 Beam Extraction by Laser to TEF-P

Observation

Congratulations to the team for the achievement. Very good experimental results of LCE test have been obtained by using the 3-MeV H^- beam. Weak point of the technique is the window for the laser.

Recommendations

4.2.1 Consider to carry out systematic beam emittance measurements

4.2.2 Either select a different material for the window or develop appropriate monitoring system

5. SAFETY ISSUES

5.1 Basic Policy & FMEA

The safety policy and the procedure of safety analysis including examples of FMEA (Failure Mode and Effect Analysis) have been presented. The Safety Protection System for J-PARC MLF will serve as a model. The safety analysis is still in progress.

Comments

It is necessary to distinguish common troubles from accidents although the recovery scenarios have to be considered for both cases. Some of the scenario's depend on the timing of the beam stop after the accident detection. Therefore, close collaboration with the accelerator group seems necessary.

Recommendations

5.1.1 Establish the risk register (risk identification and mitigation)

5.1.2 Identify all relevant 'initiating events'

5.2 Analysis for an LBE Leakage Incident

The impact of an LBE leakage accident in the circulation system has been assessed at 250 kW operation and at maximum LBE temperature (550°C). Internal and external doses at the site boundary have been calculated on the basis of conservative assumptions.

Observations

The total dose obtained is about 300 μSv at the highest LBE temperature. This value decreases significantly if the considered LBE temperature is lower (300 °C). The yearly dose limit for persons who are not nuclear energy workers (referred as members of the public) is 1 mSv, as set out in the Radiation Protection Regulations.

Recommendations

5.2.1 The gamma ray data included in the JENDL or ENDF are sometimes inconsistent with real ones. Check the energy and intensity compared with other gamma ray data.

5.2.2 Accuracy of the number of the produced nuclei by spallation should be mentioned in order to indicate reliability.

5.3 Shielding Design for TEF-T

Observations

The status of the shielding design for TEF-T including target station, hotcell and beam transport has been shown confirming that an effective dose rate lower than 10 uSv/y can be achieved at the site boundary for a 250 kW operation.

Operation of the ISOL facility (sizeable source of radiation) has not been considered in this analysis. This will require considerable shielding.

Recommendations

5.3.1 Consider storage of activated waste (spent ISOL target) and activation of cooling water and ground water (path to external boundary)

5.3.2 Consider shielding of ISOL components (ISOL target, mass separators, LINAC post accelerator)

6. TEF-P OVERVIEW

Observations and Comments

TEF-P has a clear role to play in Japan and the rest of the world when it comes to assess the transmutation efficiency of Minor Actinides (MA) or more general the physics of MA fuel.

Such a general purpose test facility could easily attract interest from other groups worldwide and secure the funding and continuation of the project, by making TEF -P more “versatile” in order to be able to assess transmutation efficiency for different configuration of fuels and neutron spectra, like for instance:

- Pure MA fuels
- Pu-loaded MA fuels
- Individually loaded MA fuels (Np targets, Am targets, Cm targets, Np+Am, etc…)
- Under fast neutron spectrum, slightly moderated spectra (10-100 keV), ultra hard neutron spectra, epithermal/resonant neutrons, etc…
- Th-Ma fuels in fast spectrum

It would be interesting to assess the variations of reactivity coefficients with the change of the neutron spectra. After getting those fundamental data one can proceed to the full core experiments with MA pins in the test zone. In some cases, the measurement of reaction rate ratios, e.g. capture and fission of Am-241, Am-243, Cm-244 relative to Pu- 239 or U- 235 fission, using the foils and samples, even if it seems difficult to load a lot of Minor Actinides like Cm in the test zone. Similar tests should be carried out for the long-lived fission products (Tc-99 and I-129)

The inner pressure and temperature rise rate are indeed important parameters for the cladding tube rupture experiments. However, a safety assessment for MA fuel which has been stored 30 or 50 years is very conservative.

Recommendations

6.1 Redefine the experimental program and redefine time schedule accordingly.

6.2 Reinforce the reactor physics team.

6.3 Simulate all possible configurations for optimizing ADS parameters and transmutation efficiency.

6.4 Consider irradiation of the fuel by charge particle as this will affect He production and release.

6.5 Consider in the modelling work that temperature of pin will not be uniformly distributed as presently assumed.

6.6 Nuclear instrumentation: review all known techniques (BFS in Russia, PFR in UK) and consider axial (instead of transverse) insertion of the Micro fission Counter in order to simplify the remote handling system.

6.7 Fuel handling system: assess the sensitivity to radiation (optics, camera, electronics), evaluate if there is a need for a diverse and/or redundant system that does not rely on reading barcode, avoid organic material on the robotic arm, design the remote handling machine to handle all types of core components (nuclear instrumentation, fuel, targets pins, control rods, …)

CONCLUSIONS

The Technical Advisory Committee T-TAC for the Transmutation Experimental Facility (TEF) project met from December 12th to 14th, 2016 at the J-PARC center, Tokai and toured the LINAC building, the Safer building as well as the laboratory of the in the High Temperature Research Building and, finally, the site for the planned construction of TEF.

The T-TAC members acknowledge the high commitment of the involved J-PARC team to this project and the progress that has been made since the last T-TAC meeting in October 2015. As demonstrated during the tour of T-TAC in the LINAC building, excellent results of the preliminary Laser Charge Exchange (LCE) experiment have been obtained by using the 3-MeV beam. The stripped H+ beam with a power of about 5 W equivalent was obtained under the J-PARC LINAC beam condition. This value is compatible with the power requirement of the proton beam for the TEF-P.

Even if additional staff joined the Nuclear Transmutation Division since the last T-TAC meeting, it estimates that a further reinforcement of the TEF team as well as the set-up of a construction team is required in order to complete the detailed design, the licensing file and the launch of the construction phase of TEF-T and TEF-BT as presently under discussion.

The observations, comments and recommendations included in this report are based on the presentations and information that have been provided to T-TAC during the meeting. The draft Technical Design Report (TDR) of TEF-T has not be considered for the reviewing by T-TAC. To close the conceptual design phase of TEF-T, T-TAC recommends to complete the draft TDR by including additional sections about instrumentation, waste characterization and dismantling.

T-TAC strongly encourages to enhance collaborations as well as joint Education & Training programs with other organizations involved in ADS projects like MYRRHA, to promote the potential of the TEF facility to different communities for the implementation of research programs and/or for commercial applications and, finally, to pursue the Public Relation campaigns in order enhance visibility of the TEF project.

T-TAC is convinced that the issues for the construction of the ADS target test facility TEF-T and the study of the reactor physics with Minor Actinide fuel for the subcritical reactor TEF-P are correctly addressed by the involved J-PARC team. Both systems are outstanding and unique in the world and will significantly contribute to the development of physical, material and engineering data necessary for the construction of a ADS able to transmute high level waste at large-scale.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

1. OVERVIEW OF J-PARC TEF PROGRAM

1.1 Continue promoting Public Relation campaigns in order enhance visibility of the project: presentation of the project to Japanese Nuclear and non-Nuclear Industry clusters or associations, assure agreements with experts of other communities (Fast Reactor, geological repository, …) in order to maintain credibility of the project and avoiding conflicts during public debates between experts, revisit the TEF website for the public (make content less scientific, add an application catalogue of public interest, add a media gallery, …)

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2.4.2 Set-up the detailed irradiation condition and PIE plan (target and samples) when target design is fixed.

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2.5.2 Consider the energy spectrum at the detecting position as another important information for the applications.

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2.6.5 Electrical Power requirements for the Multipurpose Area (ISOL Facility) are clearly underestimated (one should target x 2 higher ~ 4.5 MW). They should be revised based on list of equipments (cryo plant, LINAC, beam lines, experimental devices, ISOL target system, RF system, cooling and ventilation, etc…). Indicative figures are; for cryogenics 1.5 MW, power converters 1.2 MW, cooling and ventilation 1 MW, electrical systems 0.3 MW, RF 0.4 MW, vacuum system 0.1 MW.

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3.2 High Temperature Corrosion Test Loop - OLLOCHI

3.2.1 The detailed CFD analysis of the two test sections, including the flow into the expansion tank, has to be absolutely performed.

3.2.2 Present a scheme/plan how to insert and exchange corrosion test samples from the test sections while operating the loop.

3.2.3 Present a strategy how to perform the gas mixing in the expansion tank to maintain the desired oxygen concentration in the OLLOCHI loop.

3.2.4 Due to the different requirements for the loop operation, consider the operation of OLLOCHI firstly without connecting to a test machine, at least in the next years, until enough experience in the loop operation exists. Prepare a “plan B”.

3.2.5 Update and/or modify the experimental plan (schedule) based on the budgetary conditions.

3.3 Oxygen Sensor and Potential Control

3.3.1 For the calibration of Pt/air sensor, rely only on Pb/PbO (saturation) and e.g. on Co/CoO as reference points.

3.3.2 Consider a re-design or shielding of the oxygen sensor head.

3.3.3 Long-term tests (>> 1 year) of oxygen sensor signal stability are still pending.

3.3.4 Consider the use of a protecting steel sheath around the ceramic electrolyte tube of the oxygen sensor when using in flowing LBE.

3.4 Freeze Valve Development

3.4.3 Guarantee that the "real" cooling rate of LBE will never be higher than about 3°C/min to maintain the stress level in the pipe steel below its UTS. This must be true also in the case of "station blackout" where no external electrical power is available for controlled operation of heating/cooling systems.

3.4.4 Perform a stress analysis for the piping geometry of freeze valve to confirm its feasibility.

4. PROTON BEAM TRANSPORT

4.1 Design and Study on L-TEF-BT and Neutronics

4.1.1 Make sure that there is enough space to locate ancillary equipments (laser room, power supplies, RF equipment for ISOL)

4.1.2 Promote collaboration with ESS for the design of the Beam profile monitor

4.1.3 Develop the LCE technique for short bunched beam applications

4.1.4 Perform systematic validation of PHITS code through cross section measurements and comparisons

4.2 Beam Extraction by Laser to TEF-P

4.2.1 Consider to carry out systematic beam emittance measurements

4.2.2 Either select a different material for the window or develop appropriate monitoring system

5. SAFETY ISSUES

5.1 Basic Policy & FMEA

5.1.1 Establish the risk register (risk identification and mitigation)

5.1.2 Identify all relevant accident scenario's

5.2 Analysis for an LBE Leakage Incident

5.2.1 The gamma ray data included in the JENDL or ENDF are sometimes inconsistent with real ones. Check the energy and intensity compared with other gamma ray data.

5.2.2 Accuracy of the number of the produced nuclei by spallation should be mentioned in order to indicate reliability.

5.3 Shielding Design for TEF-T

5.3.1 Consider storage of activated waste (spent ISOL target) and activation of cooling water and ground water (path to external boundary)

5.3.2 Consider shielding of ISOL components (ISOL target, mass separators, LINAC post accelerator)

6. TEF-P OVERVIEW

6.1 Redefine the experimental program and redefine time schedule accordingly.

6.2 Reinforce the reactor physics team.

6.3 Simulate all possible configurations for optimizing ADS parameters and transmutation efficiency.

6.4 Consider irradiation of the fuel by charge particle as this will affect He production and release.

6.5 Consider in the modelling work that temperature of pin will not be uniformly distributed as presently assumed.

6.6 Nuclear instrumentation: review all known techniques (BFS in Russia, PFR in UK) and consider axial (instead of transverse) insertion of the Micro fission Counter in order to simplify the remote handling system.

6.7 Fuel handling system: assess the sensitivity to radiation (optics, camera, electronics), evaluate if there is a need for a diverse and/or redundant system that does not rely on reading barcode, avoid organic material on the robotic arm, design the remote handling machine to handle all types of core components (nuclear instrumentation, fuel, targets pins, control rods, …)

Appendix I – Agenda for 3rd T-TAC Meeting

Date: 12 – 14, Dec., 2016
Venue: Main Conference Room, J-PARC Center Research Building 2F,
Tokai, JAEA

12, Dec. (Mon.)

8:30	Shuttle bus from Terrace Inn Katsuta (Guide: H. Takei)
9:30	Site tour (including photo near the TEF site)
	Linac Building (9:30-10:00, Guide: H. Takei)
	Safer Building (10:05-10:35, Guide: T. Sugawara)
	High Temperature Research Building (10:40-11:30, Guide: S. Saito)
	Photo near the TEF site (11:35-11:45, Guide: T. Sasa)
12:00	Lunch
13:30	Welcome (Closed, N. Saito)
13:35	Mission of T-TAC (Closed, N. Saito)
13:45	Closed Session for T-TAC Member
14:10	Overview of J-PARC (14:10-14:35, N. Saito)
	Overview of J-PARC TEF Program (14:35-15:00, M. Futakawa)
15:00	Break
15:20	TEF-P Overview
	Over view of TEF-P design (15:20-16:00, T. Sugawara and M. Fukushima)
16:00	Closed Session for T-TAC Member
17:00	Adjourn
17:00	Shuttle bus to Terrace Inn Katsuta
18:30	Dinner at Katsuta Area

13, Dec. (Tue.)

8:30	Shuttle bus from Terrace Inn Katsuta (Guide: H. Takei)
9:30	TEF-T Overview and TDR (F. Maekawa)
9:45	TEF-T Design Details (1)
	Target System and Maintenance (9:45-10:05, T. Sasa)
	Target Design (10:05-10:25, T. Wan)
	Target Station (10:25-10:45, H. Kinoshita)
10:45	Break
11:00	TEF-T Design Details (2)
	Irradiation and PIE plan (11:00-11:15, N. Okubo)
	User Applications (11:15-11:30, H. Iwamoto)
	Facility Design (11:30-11:50, H. Kinoshita)
	Control System (11:50-12:10, K. Sakai)
12:10	Lunch

13:30	Experiments and results for TEF-T design
	IMMORTAL (13:30-13:50, H. Obayashi)
	OLLOCHI (13:50-14:10, S. Saito)
	Oxygen sensor and potential control (14:10-14:30, T. Sugawara)
	Freeze valve development (14:30-14:50, S. Saito)
14:50	Break
15:10	Proton Beam Transport
	Design and Study for L-TEF BT and Neutronics (15:10-15:30, S. Meigo)
	Beam Extraction by Laser to TEF-P (15:30-15:50, H. Takei)
15:50	Safety Issues
	Basic Policy & FMEA (15:50-16:15, T. Sasa)
	Analysis for an LBE Leakage Incident (16:15-16:35, H. Iwamoto)
	Shielding Design for TEF-T (16:35-17:00, H. Iwamoto)
17:00	Closed Session for T-TAC Member
18:00	Adjourn
18:00	Shuttle Bus to Terrace Inn Katsuta

14, Dec. (Wed.)

8:30	Shuttle Bus from Terrace Inn Katsuta (Guide: H. Takei)
9:30	Closed Session for T-TAC Member
	Including Answer for Pending Questions if Needed
12:00	Lunch
13:30	Summary Talk by T-TAC member
14:20	Closing
14:30	Adjourn
14:30	Shuttle Bus to Terrace Inn Katsuta

Appendix II – Charges to T-TAC 2016 from J-PARC

by Dr N. Saito

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

- Validity of base-line parameters to meet the primary purpose of TEF including both TEF-T and TEF-P that is contributing to nuclear transmutation technology development
- Feasibility of proton beam transport, LBE target system and related systems for TEF -T including safety policy, operation and maintenance scheme
- Adequacy of time line (resource and schedule)
- In addition to usual recommendations on facility design and R&D activities, it is asked to point out left issues for completing the TEF design, and to advice on approaches to solve the issues including international collaboration and PR campaigns, etc.

Appendix III - T-TAC Committee members for 2016

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