TECHNICAL ADVISORY COMMITTEE
on the Transmutation Experimental Facility (TEF)

Meeting held 10-11 July 2014
Tokai, Japan

T-TAC 2014 REPORT

July 31th, 2014

Contents

EXECUTIVE SUMMARY

The T-TAC (Technical Advisory Committee for the Transmutation Experimental Facility (TEF) project) met on July 10th and 11th, 2014 at the J-PARC centre, Tokai and toured the Linear Accelerator Tunnel, the Material & Life Science Experimental facility as well as the site for the future construction of TEF on the 11th. The T-TAC thanks the J-PARC Director Dr. Y. Ikeda for providing a comprehensive view of the TEF project through detailed presentations from his staff.

Nuclear transmutation by Accelerator Driven System (ADS) has been one of the important goals of J-PARC for many years. After the accident at Fukushima-Daiichi Nuclear Power Plant public interest to nuclear waste management increased significantly. Now, JAEA has increased its commitment to construct new TEF facilities using the higher energy LINAC successfully upgraded to 400 MeV. The T-TAC finds that the future scientific opportunities offered by TEF are world-class and given that the appropriate resources, it can contribute in a meaningful way to Japan's new strategic energy plan.

In the context of international participation, an attractive program can be mounted with the ADS project MYRRHA in Belgium that can have a complementary role to accelerate the realisation of the ADS transmutation roadmap of J-Parc.

INTRODUCTION

The TEF-Technical Advisory Committee (T-TAC) for the Transmutation Experimental Facility (TEF) project met on July 10th and 11th 2014 at the Ibaraki Quantum Beam Research Center (IQBRC) building of J-PARC, Tokai and toured the Linear Accelerator Tunnel, the Material & Life Science Experimental facility as well as the site for the construction of the intended TEF on the 11^{th}. 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 two-day meeting, except Dr Minoru Takahashi (Tokyo Institute of Technology) who could not attend, but participated through written input submitted prior to meeting.

1. ADS DEVELOPMENT PROGRAM

The Transmutation Experimental Facility program was presented as part of the roadmap towards the ADS proposed by JAEA for waste transmutation. The positions in the JAEA organisation chart of the involved R&D sections in J-PARC and the R&D groups in the Nuclear Science and Engineering Center have been shown.

From the strategic point of view concerning the Accelerator Driven System (ADS) program at JAEA, it has been reported of the work completed by the Working Party of MEXT to Review Partitioning and Transmutation (P&T) Technology. This Working Party was set under the Nuclear Energy Science and Technology Committee of MEXT and delivered its preliminary report in November 2013 giving a. o. the following recommendations for P&T and ADS development:

- To further develop the ADS Target Test Facility (TEF-T) under J-PARC to verify the feasibility of the beam window which is a big challenge for ADS and to consider it as a material test facility,
- To further develop the Transmutation Physics Experimental Facility (TEF-P) under J-PARC to overcome difficulties in reactor physics issues such as for a subcritical core and a MA-loaded one,
- To consider a participation of Japan in the MYRRHA Program, as the intermediate step between the TEF-T/TEF-P stages and the ADS industrial transmuter. The Working party indicates that it is appropriate to proceed with negotiation about JAEA’s participation at a reasonable level and mutual collaboration with Belgium and other relevant countries.
- To shift the R&D to the next stage of engineering scale. Although, further check and review is required on the status of the achievement for underlying R&D, technical feasibility including operation and maintenance, consistency to regulations etc.

The International Advisory Committee (IAC) for the J-PARC project met on March 10^{th} and 11^{th}, 2014 at the J-PARC centre, Tokai. The IAC 2014 acknowledged the following facts in its report issued on April 15, 2014:

- The global strategy on Partitioning and Transmutation (P&T) and ADS development recommended by the Working Party of MEXT to Review P&T Technology is rational and sound, in particular the decision to move from lab-scale demonstration towards “Engineering level prototyping”,
- The internationalisation of the project has been started and should be expanded through cross-participation and exchange of experts and teams with other organisation active in the field of P&T and ADS development,
- The designs of TEF-P and TEF-T facilities look promising but the IAC members can’t judge on their technical value based on the short presentation they were exposed to.

Based on these findings, the IAC 2014 proposed the following recommendations:

- The TEF-T and TEF-P designs and their safety approach should be submitted to an International reviewing panel. (IAC 2014 Recommendation #9)
- The Users group for the TEF-T facility should be consulted to assess more specific demands on irradiation conditions in order to define the characteristics of the facility accordingly. (IAC 2014 Recommendation #10)
- The upgrading the Technological complex of the HLM at Tokai laboratories should be conducted in synergy with other laboratories in the world active in this field to avoid duplication leading to saving money. (IAC 2014 Recommendation #11)
- Safety rules and management to be applied for the ADS facilities in J-PARC need to be carefully developed in agreement with nuclear facilities regulation. (IAC 2014 Recommendation #12)
- Personnel and expertise available at J-PARC (for ex-targetry) or at JAEA (Monju) should now be engaged in the ADS programme. (IAC 2014 Recommendation #13)

According to Chapter 3, 4.4 of "Strategic Energy Plan" of Japan issued in April 2014, "nuclear transmutation technology using fast reactors and accelerators, will be promoted by utilizing global networks for cooperation."

Observations and Comments:

- The necessity to compare the merits and demerits of nuclear transmutation technologies including critical Fast Reactor (FR) type and different ADS types with each other was considered by T-TAC. There are two aspects:
  a. A strategic comparison: Critical FR versus ADS (be it window or windowless target based), this is an independent question from the future of TEF-T
  b. A technological option for realizing the ADS: window versus windowless, where the relevance of TEF-T can be questioned

  Concerning the first aspect (a), there are various studies conducted internationally at OECD/NEA level and at EU level in Framework Projects like ADOPT, PATEROS and ARCAS (see Cordis website of the European Commission http://cordis.europa.eu/projects/home_en.html) that show the merits of each technology FR vs ADS and concluded that ADS can lead to more efficient and concentrated treatment of High Level Waste.
  Coming to the second aspect (b), this option will not affect the intrinsic transmutation performance of the ADS but the overall efficiency as indeed the technological choice could lead to high or low availability of the facility to do the job. In Europe both spallation target designs were considered for experimental ADS (windowless: MYRRHA, XT-ADS, Window: EA-80, XT-ADS-Gas) and industrial ADS scale (EFIT with both options).
  The technological choice of window or windowless target is driven by technical specification and safety considerations, namely:
  b. Beam current density on the window: should be not exceeding 50 $\mu A/cm^2$ (for proton energies ranging between 300 and 800 MeV)
  c. Proton Energy, the lower the proton energy the higher the energy deposition in the window material is thus leading to window breaking
  e. In case of window breaking or windowless design the safety issue related to the release of volatile spallation products and consequently the proton beam line and the accelerator contamination with these products can become an issue and should be correctly addressed.

In the particular case of MYRRHA where until 2005 the proton energy beam was limited to 350 MeV, the windowless design was the only technical feasible solution due to the beam current density (> 150 µA/cm²) and the energy deposition in the window material. After having extended the proton energy beam in MYRRHA to 600 MeV and taking into account the feedback experience from the MEGAPIE project (1 MW spallation window target experiment, with a proton beam intensity of 1,8 mA with an energy of 590 MeV), the MYRRHA project moved also towards a window target.

Concerning the 3rd issue mentioned above and related to the safety aspects due to the volatile spallation products and the associated beam line and accelerator eventual contamination, this remains to be technically addressed in both targets design: window or windowless.

As such and taking into account that the industrial ADS will be going towards a window design target, the TEF-T facility will be contributing to its main objective of demonstrating at engineering scale the feasibility of such a window target and its operability at demonstration time durations needed for the strategic decision to embark for ADS technology for industrial transmutation of High Level Waste.

- The objective of the present ADS program should not be the promotion of research activities such as Radio Isotope production, physics, HLM technology, … but the development of nuclear transmutation technology for enhancing the safety of processing and disposal of radioactive waste as written in "Strategic Energy Plan". The program should be strictly reviewed to achieve the objective.
- The classification of studies shown in the roadmap could be simplified as follows:
  - (1) Accelerator technology
  - (2) Reactor core technology
    - MA, Fuel; Neutronics (Core design, Nuclear data); Cladding; Thermal-hydraulics
  - (3)Target technology
    - Beam window technology (Irradiation effect, etc.); Windowless technology
  - (4) Plant technology
    - Whole system; Primary system; Balance of plant (BOP); Safety system
  - (5) Coolant/target Technology
    - Material/compatibility/Oxygen control; Impurity control; Instrumentation & Control for Po; TH
  - (6) Fuel cycle/Waste management
    - Pyroprocessing
  - (7) Safety evaluation and management

Recommendations

1.1 The ADS program should be planned based on the candidate concept of ADS with preferably some variety of design and certain ranges of design parameters so that the results of R&D can be applicable to the various future ADS design flexibly.

1.2 In addition to the recommendation of the International Advisory Committee 2014 of J-PARC (IAC 2014 Recommendation #13) to engage in the ADS program the personnel and expertise available at J-PARC (for ex-targetry) or at JAEA (Monju), T-TAC recommends to consider the involvement of the Monju staff in the ADS program in terms of design for the industrial ADS and in terms of realization for the TEF-T. The experience gained by key members of the Monju team during the LFR design is an asset to consider during for reassignment.

2. READINESS OF TEF-T CONSTRUCTION

2.1 Feasibility of the Target Head Design

Consistent with many ADS programs worldwide, LBE has been selected as the spallation target material and subcritical core coolant. The review committee endorses this selection.
The target must verify the feasibility of the spallation target beam window for the ADS application. It accomplishes this in two ways:

- The target window can be designed as a prototype to an ADS spallation target window and tested in beam
- Materials samples can be placed in the high flux region of the target to test the behavior of candidate alloys under prototypic conditions.

Three target types were presented. Target A is proposed primarily for irradiation of materials specimens, and is designed with a sample holder. Target B is of a prototype ADS geometry but made of SS316L and operated at lower than prototypic temperature. Target C is the same geometry as Target B, but made of prototypic alloy (T91) and operated at prototypic temperature (up to 550°C). The presentation material focused on Target A, which is the proposed first target (presentation by Kogawa et al.). The target employs a coaxial flow geometry, a concave beam window, and the proposed alloy is SS316FR. A water-cooled safety hull envelopes the target. For an assumed maximum beam current density of 20 μA/cm^2 on target, finite element analyses show the design satisfies design criteria related to static and dynamic stresses, as well as fatigue limits, for the unirradiated alloy. The proposed design satisfies the additional design criteria of limiting the LBE vessel temperature to less than 500 °C and the LBE flow rate at the vessel wall to less than 2 m/s. An analysis indicates the dynamic pressures within the LBE are well below those which cause cavitation. The design of the safety hull is such that the maximum stresses and operating temperatures are well below those experienced by the LBE vessel. This should assure that its structural integrity is more reliable than that of the LBE vessel.

Heat is transferred from the LBE primary loop to a water secondary loop that operates at 2 MPa with an outlet temperature of 200 °C. This is 12 °C below the boiling point of water at 2 MPa.

Observations:

- Calculated damage rates in the beam window and in the region where materials samples will be placed are in the range that are useful for providing irradiated materials data for ADS applications.
- Design study on Target A for the irradiation experiment is well performed. The results showed the LBE flow rate, pressure, stress. It is indicated the effect of the pressure wave, the cavitation damage are very small and cyclic thermal stress are under the allowable level.
- The maximum acceptable current is around 30 μA/cm^2.
- The coaxial flow arrangement produces a zero-flow point at the center of the beam window, just where the deposited power density is greatest. Other designs (e.g. the MEGAPIE target) have avoided this “dead” zone.
- Operating temperature in the beam window is higher than the operating temperature in the materials samples.

Comments:

- The materials irradiation program may be well served by a target design that allows materials samples to be irradiated at temperatures beyond the allowable temperature limit of the beam window.

- Assess lifetime limits of the target based on the degradation of allowable stress limits due to radiation damage to confirm reasonable target lifetime limits.
- There is little margin to avoid two-phase flow in the secondary loop.
- The design study was performed under the condition of the proton beam profile with average current of 20 μA/cm^2. On the other hand it was indicated that the beam profile can be varied from 10 μA/cm^2 to 50 μA/cm^2. Therefore, it is better to perform design studies at different beam profile considering the radiation damage requirement. For the design the power-up schedule should be also taken into account.
- Type B and C targets should be designed after clarifying the conditions such as flow rate, temperature and so on.
- The number of the target to be stored within the hot cell will decide the life of the facility. Therefore, evaluation of the target life is very important and after then the storage capacity should be decided.

Recommendations:

2.1.1 Clearly establish the range of design parameters (flow rates, wall and sample temperatures, flow velocities, beam current density, dpa and He production levels) needed to address all viable ADS candidate concepts.

2.1.2 Carefully evaluate the applicability of the CFD codes to predict flow and heat transfer conditions at the zero flow point arising from the coaxial flow arrangement, and confirm sufficient margin in the design such that there is high confidence in the predicted beam window temperature.

2.1.3 Irradiation scenario relating to the target performance should be considered and expected dpa values should be evaluated.

2.1.4 Assess the response of the secondary loop to off-normal events, e.g., loss of site power, loss of flow in the secondary, etc.

2.2 Feasibility of the basic design of LBE-primary loop

The presentation clearly showed the “lessons learned” during the last years at the Transmutation Section of J-PARC Center, in the area of material research in LBE. Many stagnant and flowing test facilities have been built and operated with the emphasis to rate the compatibility behavior of relevant structural materials at different temperatures, flow velocities and oxygen concentrations.

Observations and Comments:

- Tests at “no oxygen control” seems not to be very meaningful for an authoritative statement or are at least difficult to interpret.
- Besides the corrosion testing, the investigation regarding the use of joints, flanges and valves as part of flowing test loops, was a large effort during the last ten years. Nevertheless, the own results of the reviewer with these components in the operation of a large-scale HLM lab at KIT let him come to the conclusion that for a safe running of HLM loops, the numbers of joints and flanges should be at the absolute minimum. Their risk to contribute to system failures is rather high for a reliable operation.
- For the future design and construction of TEF-T, the current facilities are no longer appropriate for testing materials in LBE under relevant conditions. Therefore the planning of a new “High temperature material corrosion test loop (HTC)” is of absolute necessity and will therefore be fully supported by the T-TAC. The foreseen operational range of up to 550 °C at relevant flow velocities and full oxygen control to obtain corrosion data of T91 and SS316L steels is appropriate for the future operation of TEF-T. Are T91 and SS316L the only candidates for structural materials of TEF-T? If yes, the T-TAC has not noticed any explanation for this materials choice. Nevertheless, regarding

the test schedule of HTC loop until 2022, a close link to TEF-T which starts its operation in 2019, to allow design modifications of the corresponding target concepts A-C, if necessary, must be guaranteed.

- The proposed layout of the test sections and the oxygen control system resp. the oxygen control device of HTC loop is not really clear from the presentation, whereas the envisaged general test program seems to be very reasonable to meet the future design requirements of TEF-T.
- Complementary to the HTC loop, two additional facilities are foreseen, “The Test Stand for LBE Technology (1)” and the “Mock-up loop of TEF-T Target Station (2)”. Facility (1) is planned to focus on remote handling techniques, freeze valves and liquid metals related instrumentation. This is, except the freeze valves, absolutely meaningful and needed for the operation of TEF-T. The T-TAC is not convinced about the use of freeze valves in a large-scale facility like TEF-T, whereas the development and qualification of instrumentation and remote handling techniques are of high priority. The objectives set by the people of the Transmutation Section are well defined and are appropriate for the realization of TEF-T. Additionally, the built-up of the Mock-up loop to investigate the system behavior of TEF-T (heat removal, EM-pump etc.) is fully supported by T-TAC. Nevertheless, in the time schedule for both facilities up from 2018, the activities “Development of advanced technologies” are not yet clear and have to be more specified for the T-TAC to review the meaningfulness in the near future. Most of the necessary objectives within this activity are well addressed but some clarification is needed.

Recommendations:

2.2.1 Overthink the use of joints/flanges and valves in any of the existing/planned loops because of high risk of failures

2.2.2 Ensure a strong link between the new results coming from the HTC loop with necessary modifications of the target design/construction

2.2.3 Make more clear and benefit from existing corrosion loops concerning the design of the test section and the oxygen control device

2.2.4 Consider also the testing of the mechanical behavior of relevant materials under TEF-T conditions (e.g. fatigue due to beam trips)

2.2.5 A detailed test plan for materials investigations (Temperature, Oxygen Concentration, LBE speed) has to be delivered

2.2.6 The sampling of LBE from the HTC loop for chemical analysis (impurities) has to be foreseen

2.2.7 Deliver an integrated safety analysis for the operation of the loops and TEF-T

2.3 Applicability of LBE Instrumentation & Control (I&C)

2.3.1 I&C for Oxygen Control System

One of the key challenges for the use of heavy liquid metals, like lead or LBE, as coolant of prospective nuclear and transmutation reactors, is the compatibility of structural and cladding materials, mainly steel-based, with the coolant. One measure to minimize the materials corrosion is the controlled addition of oxygen to the LBE to promote the oxidation of steel elements, e.g. iron and chromium, for the formation of stable and protective oxide layers on the surface of highly loaded parts. The concentration must be high enough to oxidize iron, the main component of the steels, but should not exceed the value at which oxidation of lead can occur. Hence, the concentration range of oxygen must be kept between ca. 10^{-5} and 10^{-7} wt.-% to fulfill these conditions. During the last year’s researchers in several laboratories all over the world examined the suitability of austenitic and ferritic steels as structural and cladding materials in liquid LBE at temperatures relevant for nuclear transmutation systems.

Observations and Comments:

- The specific issues regarding oxygen chemistry and the influence of oxygen on the materials compatibility of steels in LBE are well addressed in the presentation made to T-TAC.
- The envisaged limits of the oxygen concentration in LBE is with $10^{-4} – 10^{-8}$ wt.-% a bit too wide for practical applications. With the higher value one would be too close to the solubility limit for typical temperatures ranging from 400 to 550 °C and with the lower value, beginning dissolution corrosion of iron-based materials have to be taken into account. Hence, better narrow it to about $10^{-5} – 10^{-7}$ wt.-% of oxygen which is also easier to establish in a technical system.
- The control of oxygen in LBE requires an adequate process of adding/removing of oxygen to and from the LBE and the precise measurement of the oxygen activity resp. the oxygen concentration in the liquid metal. In a first step international collaborations with SCK•CEN and KIT to test different type of oxygen sensors including JAEA sensors have started, too. In the desired temperature range, all sensors showed sufficient accuracy and reliability. The results are therefore encouraging to be integrated in an OCS for a future use in TEF-T and the T-TAC recommends continuing this activity with high priority.
- The calibration of oxygen sensors is a prerequisite for the application in an Oxygen Control System (OCS). In the presented schedule, the development of calibration process is foreseen in parallel to the beginning operation of TEF-T up from 2019. The T-TAC recommends intensifying the existing collaboration to finish this development by 2018 to be in line with the construction and operation schedule of TEF-T. The testing of oxygen sensors in flowing condition in JLBL-4 loop is of absolute necessity and is well addressed in the corresponding overall schedule.
- Additionally, the presented development of the “wet” oxygen control method is not consistent with the actual “state of the art” for oxygen control systems, published in the open literature. The adding of water vapor to the argon gas mixture to establish an equilibration oxygen partial pressure in the gas phase is related to a distinct scatter of oxygen concentration values in the LBE and the formation of large amounts of so-called “black dust (PbO)” in the gas phase of the oxygen transfer device including connecting gas pipes. System failures and blockages within the gas system cannot be excluded. In the meantime, an optimized process is already published which has proven its applicability in large LBE test loops for more than five years of successful operation.

Recommendations:

2.3.1 Intensify the testing of oxygen sensors under flowing conditions.
2.3.2 Modify/optimize your gas-liquid exchange method for oxygen control regarding new, optimized process without adding of water vapor.
2.3.3 The range for oxygen concentration testing has to be narrowed to about $10^{-5} – 10^{-7}$ wt-% of oxygen.
2.3.4 The proof of long-term functioning of oxygen sensors has to be clearly shown.
2.3.5 The calibration method for oxygen sensors has to be evaluated.
2.3.6 The PbO mass exchanger as an option for oxygen control systems can only be long-term, but is too complex and complicated for the use in TEF-T.
2.3.7 The testing of oxygen sensors under irradiation (in TEF-T) is encouraged.
2.3.8 Continue the international collaborations concerning the Oxygen Control System.

2.3.2 I&C for loop operation and maintenance

The performance requirements that are specific to the operating environment and the main monitoring parameters of the primary loop system have been presented. It has been stated that the measurement of temperature and the cover gas pressure are available techniques. The systems for the measurement of coolant pressure, level and flow rate are however R&D topics. The roadmap to develop these systems includes preliminary tests in 2014, long term experiments in 2015 in flow condition for every system and qualification in a radiation environment at MLF during the 2 first years (2016-2017) of the planned construction of TEF-T.

It is intended to monitor pressure and pressure loss in each component of the loop in order to detect clogging of the filters and of flow channel. Differential pressure-type flowmeter is considered as diversified system to the main flowmeter. Level gages installed on the 'surge' tank and the 'drain' tank will be used for the detection of possible small leak in the primary flow channel and drain valve. The indications of the flowmeter are directly related to the cooling performance of the beam window.

The comparison of signals delivered by a level gauge and by a pressure gauge that are both under development was presented. The signals have been logged during the same test in static condition at 300 °C. The analysis of the results showed a constant bias between the indications of the 2 instruments in nearly the full the range of the level measurement. This is an encouraging result.

The rationale for the selection of the ultrasonic (US) type flowmeter out of other candidate techniques like coriolis, pressure differential, electro-magnetic was given. The existing experience at MLF and JAEA for the selection of the US instrumentation has been taken in account. Experimental results of temperature resistance up to 500°C of selected US transducers as well as verification tests of the US flowmeter in the JLBL-4 loop experiments have analysed and have been concluded positively. It is intended in the next step to develop an US measurement system that is completely without contact with the LBE. In this case the US transducers are fixed at the outer surface.

Observations:

- The experience gained in other sectors like fast reactors systems cooled by Sodium and MLF in J-PARC has been taken into account to set-up the R&D activities for the qualification of the instruments.
- The proposed roadmap and methodology for the development of the intended sensor for pressure, level and flow seems sound.
- Results of first experiments and screening tests are encouraging and confirm the selected options.

Comments

- The presented instrumentation is focused on the continuous monitoring that is performed during operation and it is essentially based on checking the operating parameters (temperature, flow rates, pressure) and the measurement roughly reflecting the state of the structures and components (leaks). Some additional instrumentation might be considered like mechanical deformation, vibratory characteristics, … in order to monitor the parameters allowing early detection of drift or irregularities with regard to the operating range. It must allow the comparison of the real operating parameters with the project values considered for dimensioning and qualified by start-up tests.

Recommendations

2.3.9 In addition to confirming the status observed by continuous monitoring, the periodic inspection program must validate the hypothesis and project values concerning the damaged mechanisms considered during the design studies. It must therefore check that no unforeseen mechanism is at play, neither in the degradation process of the materials' mechanical properties, nor in corrosion-type mechanisms. The possible need of periodic inspection tools for example based on Non Destructive Techniques technics during shutdown and maintenance should be studied.

2.3.10 Make sure that the instrumentation is able to take all the necessary measurements according to the results of the safety studies (phenomenon or initiating events to detect, associated response time) and potential hazard (type and size of defects).

3. VALIDITY OF TEF-P CONCEPT

The concept of TEF-P has been presented with the mission of TEF-P. The mission includes 1.Nuclear data verification relating to ADS design, 2. Reactor physics of ADS, 3. Operation of ADS with zero –power, and 4. Physics of other reactors. As the concept, horizontally-split type core was chosen in which the fuel plates of FCA can be utilized with large amount of minor-actinides in kg-order. The concept seems satisfactory.

The commercial-grade ADS is planning to use the lead-bismuth eutectic as spallation target and coolant and mono-nitride (MA+Pu)N+ZrN as fuel, but the TEF-P will use oxide fuel. The difference between the fuels has some issues in the engineering stages but in the fundamental research stage the concept of using oxide fuel is reasonable. This is because, for nuclear data verification, the uncertainty evaluated for subcriticality, is mainly caused by uncertainties of nuclear data of Pb, Np and Am. Thus the TEF-P will be very useful to estimate the effect of these nuclear data to the core performance of TEF-P.

The experiment schedule of TEF-P has been presented, and the mile-stones are shown such as first critical, MA fuel supply to TEF-P. The main experiment issues for the nuclear data for ADS, reactor physics of ADS and operation of ADS are shown, which are very important for ADS. Therefore the approach is assessed as satisfactory. T-TAC wants to point out that mostly high level information was given to T-TAC at this stage concerning TEF-P and that a more in depth reviewing of TEF-P project needs to be done in the future.

Recommendations:

3.1 To achieve TEF-P project it is inevitable to prepare the fuel and minor actinide for FCA core. Please make sure the availability of Pu fuel and MA.

3.2 TEF-P project also will be very useful for MA transmutation plan using fast reactors. So it is recommended to promote the project cooperatively with the fast reactor MA transmutation project.

CONCLUSIONS

The Technical Advisory Committee for the Transmutation Experimental Facility project T-TAC met on July 10th and 11th, 2014 at the J-PARC centre, Tokai and toured on the 11th the Linear Accelerator Tunnel, the Material & Life Science Experimental facility as well as the site for the planned construction of TEF.

Given that the industrial ADS will most probably be going towards a window design target, T-TAC considers the TEF-T facility will contribute to main objective of demonstrating at engineering scale the feasibility of such a window target and its operability at demonstration time durations needed for the strategic decision to embark for ADS technology for industrial transmutation of High Level Waste. The objectives of the presented ADS program during the T-TAC meeting should not be the promotion of research activities such as Radio Isotope production, physics, generic HLM technology, … but remain focused on the development of nuclear transmutation technology for enhancing the safety of processing and disposal of radioactive waste as written in "Strategic Energy Plan". Multipurpose use of TEF-T certainly provides high flexibility, however, the narrow space implies several drawbacks with impact on potential mutual influence of neighbouring instruments/experiments regarding space, shielding, access, cross-talking background, etc. and on manufacturing cost of the target monolith.

T-TAC considers that the preparation of the works for the 'beam transport and injection' for TEF-T is very well advanced and that the presented planning to start the construction works in 2016 is credible. Indeed, an extensive know-how concerning beam transport exist at J-PARC. Moreover, there is limited civil work to carry out for TEF-T; the first meters of the gallery to transport the beam to TEF-T already exists in the 400 MeV accelerator tunnel and no dismantling works of existing installation for site preparation are needed for the construction of TEF-T as it could be observed by T-TAC during the tour on July 11th. The approach of the safety steps to isolate TEF-P from the accelerator beam is credible. A co-existence of TEF-T and the intended TEF-P to be realized in a next step is found to be possible by T-TAC.

In the meantime, activities for the realisation of target head, the LBE primary loop and the necessary Instrumentation and Control can progress further following the presented schedules. T-TAC formulated a list of recommendations for these topics. In the context of international participation, an attractive program can be mounted with the ADS project MYRRHA in Belgium that can have a complementary role in order to accelerate the realisation of the ADS transmutation roadmap of J-Parc.

High awareness of the TEF team for safety has been observed by the T-TAC members and needs to be a high priority in the next phase. The T-TAC is convinced that J-PARC is responding to the TEF project challenges in a professional manner and that given the proper resources, it can 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.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

1. ADS Development program

Recommendation #1.1

The ADS program should be planned based on the candidate concept of ADS with preferably some variety of design and certain ranges of design parameters so that the results of R&D can be applicable to the various future ADS design flexibly.

Recommendation #1.2

In addition to the recommendation of the International Advisory Committee 2014 of J-PARC (IAC 2014 Recommendation #13) to engage in the ADS program the personnel and expertise available at J-PARC (for ex-targetry) or at JAEA (Monju), T-TAC recommends to involve the Monju people in the ADS program in terms of design for the industrial ADS and in terms of realisation for the TEF-T. The experience gained by key members of the Monju team during the LFR design is an asset to consider during for reassignment.

2. Readiness of TEF-T construction

2.1 Feasibility of the Target Head Design

Recommendation #2.1.1

Clearly establish the range of design parameters (flow rates, wall and sample temperatures, flow velocities, beam current density, dpa and He production levels) needed to address all viable ADS candidate concepts.

Recommendation #2.1.2

Carefully evaluate the applicability of the CFD codes to predict flow and heat transfer conditions at the zero flow point arising from the coaxial flow arrangement, and confirm sufficient margin in the design such that there is high confidence in the predicted beam window temperature.

Recommendation #2.1.3

Irradiation scenario relating to the target performance should be considered and expected dpa values should be evaluated.

Recommendation #2.1.4

Assess the response of the secondary loop to off-normal events, e.g., loss of site power, loss of flow in the secondary, etc.

2.2 Feasibility of the basic design of LBE-primary loop

Recommendation #2.2.1

Overthink the use of joints/flanges and valves in any of the existing/planned loops because of high risk of failures.

Recommendation #2.2.2

Ensure a strong link between the new results coming from the HTC loop with necessary modifications of the target design/construction.

Recommendation #2.2.3

Make more clear and benefit from existing corrosion loops concerning the design of the test section and the oxygen control device.

Recommendation #2.2.4

Consider also the testing of the mechanical behavior of relevant materials under TEF-T conditions (e.g. fatigue due to beam trips)

Recommendation #2.2.5
A detailed test plan for materials investigations (Temperature, Oxygen Concentration, LBE speed) has to be delivered.
Recommendation #2.2.6
The sampling of LBE from the HTC loop for chemical analysis (impurities) has to be foreseen.
Recommendation #2.2.7
Deliver an integrated safety analysis for the operation of the loops and TEF-T.

2.3 Applicability of LBE Instrumentation & Control (I&C)

Recommendation #2.3.1
Intensify the testing of oxygen sensors under flowing conditions.
Recommendation #2.3.2
Modify/optimize your gas-liquid exchange method for oxygen control regarding new, optimized process without adding of water vapor.
Recommendation #2.3.3
The range for oxygen concentration testing has to be narrowed to about 10^{-5} – 10^{-7} wt-% of oxygen.
Recommendation #2.3.4
The proof of long-term functioning of oxygen sensors has to be clearly shown.
Recommendation #2.3.5
The calibration method for oxygen sensors has to be evaluated.
Recommendation #2.3.6
The PbO mass exchanger as an option for oxygen control systems can only be long-term, but is too complex and complicated for the use in TEF-T.
Recommendation #2.3.7
The testing of oxygen sensors under irradiation (in TEF-T) is encouraged.
Recommendation #2.3.8
Continue the international collaborations concerning the Oxygen Control System
Recommendation #2.3.9
In addition to confirming the status observed by continuous monitoring, the periodic inspection program must validate the hypothesis and project values concerning the damaged mechanisms considered during the design studies. It must therefore check that no unforeseen mechanism is at play, neither in the degradation process of the materials' mechanical properties, nor in corrosion-type mechanisms. The possible need of periodic inspection tools for example based on Non Destructive Techniques technics during shutdown and maintenance should be studied.
Recommendation #2.3.10
Make sure that the instrumentation is able to take all the necessary measurements according to the results of the safety studies (phenomenon or initiating events to detect, associated response time) and potential hazard (type and size of defects).

3. Validity of TEF-P Concept in technical point of view

Recommendation #3.1
Make sure the availability of Pu fuel and minor actinide for TEF-P.
Recommendation #3.2
Consider the cooperative research studies with fast reactor MA transmutation project.

Appendix I

T-TAC

Transmutation Experimental Facility Technical Advisory Committee Meeting

Agenda

10th, July

9:00	Welcome & Mission of T-TAC (Ikeda, Closed)
9:10	Closed Session for TAC Member
10:00	Break
10:20	ADS Development Program (Oigawa)
10:40-11:40	TEF-T Overview & Multipurpose use (Sasa)
11:40-12:00	PIE plan in JAEA (Okubo)
12:00	Lunch
13:30-14:00	Spallation Target Design (Kogawa)
14:00-14:30	LBE Loop Technologies (Saito)
14:30-14:50	LBE Measurement Devices (Obayashi)
14:50-15:10	Oxygen Concentration in LBE (Sugawara)
15:10	Break
15:30-16:00	Proton Beam Transport to TEF (Meigo)
16:00-16:30	Linac Beam Separation (Kinsho)
16:30	Closed Session for TAC Member
17:30	Adjourn
18:30	Dinner

11th, July

9:00	TEF-P Overview (Nishihara)
10:00	Break and Group Photo
10:15	Closed Session for TAC Member
12:00	Lunch
13:30	Summary and Recommendations
14:30	J-PARC Tour
16:30	Adjourn

Schedule for J-PARC Site Tour

11th, July

14:30	Depart IQBRC (Take luggage with you)
14:35	Security Check at JAEA Entrance (Prepare your passport)
14:40-15:10	① Linear Accelerator Tunnel (TEF-BT area)
15:15-15:50	② Material & Life Science Experimental Facility (Target Maintenance Cell etc.)
15:55	③ Hadron Experimental Facility (Through the Bus Window)
16:00-16:15	④ Site for Transmutation Experimental Facility
16:20	Leave JAEA to Terrace-Inn Katsuta

Appendix II

Charges to T-TAC 2014 from J-PARC

by **Yujiro Ikeda**

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

- The conceptual design for the ADS Target Test Facility (TEF-T) at J-PARC and adequacy with regards the co-existence of TEF-P
- Base-line parameters
- Feasibility of the LBE neutron production target system
  - Proton beam transport and injection
  - LBE target cooling scheme
  - Time-line (Resource and Schedule)
  - Operation and Maintenance scheme
- Safety aspects

Appendix III

T-TAC Committee members for 2014

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