JPARC Materials and Life Science Facility
Technical Advisory Committee
(N-TAC)

Report on the Fifth Meeting

Held at JAEA Tokai Site
Nov. 20 – 22, 2006

Executive Summary and Main Recommendations

As in the past, the JSNS Project staff continued to impress the Committee by the quality of the engineering and science that supports the Joint Project. The progress on the construction site is truly impressive and documents excellent craftsmanship.

While a new organisation for the operation of the J-PARC facility is now emerging with many new staff to be employed, the Committee was somehow under the impression that people currently assigned to the project from the participating organisation in some ways still have some difficulties in establishing friction free working relations. A spirit of unconditional cooperation is, however, of prime importance for the success of J-PARC under the difficult boundary conditions it has to cope with. The Project Management might consider paying extra attention to this issue and – if real- think of ways to promote integration within the team as the new organisation is put in place.

With respect to restoring the originally planned energy of the injection linac into the synchrotron there remains the difficulty of securing the required 85 Oku Yen. Given the excellent progress the JSNS team is making on all other fronts the Committee is pleased to see that this problem is one of the top priorities of the Project management. Full performance of JSNS will be an important factor in the planned internationalization of the J-PARC Project.

Given the fact that JSNS is well into its integration phase, discussions at the N-TAC 5 meeting focused mainly on commissioning and operational issues. The Committee was pleased to see that the majority of its technical recommendations made in the past have been incorporated in the project.

While there are several minor points the Committee recommends for consideration, in order to facilitate commissioning and operation of the facility, the most significant findings and comments are:

Target protection: The possibility of directing a focused beam onto the target remains a concern. We recommend considering to complement the planned interlocks on the relevant quadrupole power supplies by other relevant signals.

Installation of a VIMOS-type monitoring system and using the information from the laser diagnostic device on the target might be options worth examining.

Radioactive off-gas handling: The methods foreseen for detecting tritium and removing it from the cover gas should be examined. Adjust relative humidity is probably best accomplished by introducing water vapour or spray. Free tritium reacts rapidly and irreversibly with H_2O to form HTO, which, in a scintillator-water solution, it is easily and distinctly detected.

Fail safe position of mercury drain valves: There may be situations, e.g. a fire or leak in coincidence with an electric power failure, in which the mercury drain valves should not remain closed fail safe. A separate accumulator with compressed air and with manual actuation could provide the ability to open the drain valves in such situations.

Decontamination of mercury contaminated surfaces: The degree of adhesion of mercury to materials (316SS or epoxy resin) may be strongly affected by the surface conditions of the materials. The surface conditions of the materials should be controlled when decontamination experiments are carried out and surface conditions should be specified accordingly wherever a risk of mercury spills exists.

Commissioning with intense proton pulses: It could well be that during the commissioning of the accelerator systems it will be easier to produce very high pulse intensities but at low frequency. The target team should consider defining limits based on pulse intensity. This will protect the target from the potential damage of the $(\text{power density})^4$ dependence of cavitation erosion.

Mitigation of pressure pulse effects: The good progress made so far in understanding cavitation erosion justifies continued support of this work. It is of great importance that the effectiveness of gas injection in mitigating pressure pulse effects be demonstrated conclusively and quantitatively. Base on this a method for bubble generation at the required location must be developed with urgency.

Target vessel re-design: Efforts to reduce the amount of material that must be put to waste storage at each target vessel exchange should be intensified. In this context the flow configuration in the target might be worth re-examining in view of the need to generate a suitable distribution of gas bubbles.

Mercury pump: The committee welcomes the decision to abandon the gear pump after completion of the loop tests with water and commends the team for the successful development of a custom made EM-pump based on rotating magnets.

1. Introductory remarks

The N-TAC Committee, comprising the members

Dr. Günter S. BAUER (Chair)	ex Forschungszentrum Juelich GmbH, Germany
Dr. Timothy A. BROOME	ISIS, Rutherford Appleton Laboratory, UK
Dr. John M. CARPENTER	Argonne National Laboratory, USA
Mr. Hajo HEYCK	Paul Scherrer Institute, CH
Prof. Hiroaki KURISHITA	Tohoku University, Japan
Dr. Thomas J. MCMANAMY	SNS Project Oak Ridge, USA

was invited to hold its fifth meeting on November 20 to 22, 2006, at the Tokai site of JAEA, Ibaraki Prefecture.

As before, the Committee felt very well received and preparations by the Project Team were excellent. We wish to express our sincere gratitude to the Project Management and its supporting organizing team for a smooth and effective meeting and the confidence put in us as an Advisory Team.

The comprehensive response to the N-TAC4 recommendations is much appreciated.

Again as at similar times in the past, the Project exhibits impressive progress. The goal of first beam in May 2008 seems attainable. The JSNS Project team continues to deliver rapid progress and solutions to problems as they arise, and to work as an integrated unit. Their presentations to the Committee (in English!) were well prepared and generally very clear, revealing that the presenters fully command their subjects. Construction on all fronts is truly spectacular as evidenced by a most impressive visit to the site at the beginning of the meeting.

The fifth meeting of N-TAC was called at a point in time when the overall Project was well into its integration phase. Numerous items had already been put in place or were in advanced stages of manufacturing or factory testing. While safety, commissioning and maintenance issues were still important points in the discussions, operational and control aspects became more dominating, as appropriate for this stage of the project.

The design, fabrication and installation progress is excellent and appears to support the goal of first beam on target in May, 2008. The design team is to be commended for their work. There has obviously been great deal of attention paid to the details and good solutions have been found for all anticipated and unanticipated problems.

The general quality of workmanship on the site appears outstanding. The proper level of attention is being given to maintenance activities through the use of mock-ups and demonstrations. New ideas and solutions to problems are being implemented. The development of the laser diagnostic for monitoring the target shell response to pressure waves in order to obtain an indication for progressing cavitation damage of the target is a remarkable example.

The Committee again refrained from highlighting advices and recommendations in the report because the extensive response delivered by the Project Team showed, once again, that all comments are taken very seriously and are dealt with in an appropriate manner. As always, we offer our comments fully in the spirit of helpfulness.

A detailed report of the Committee's findings and comments was given at the closeout session of the meeting and the presentation material was handed over to the Project to allow immediate action without waiting for this report to be completed.

As before, an attempt has been made for the structure of the report to follow roughly the agenda for the presentations. In some cases, however, issues relating to certain components or sub-systems may appear in context with those components or sub-systems rather than under the headings they were presented.

2. Operations and Controls

All important control system safety aspects like password levels according to operational competence, electric power buffering and firewall protection against unwanted influence from the internet seem to have been addressed in the concept.

The development of the cryogenic systems has proceeded very well indeed. In particular the success in fabrication of the integrated AIC decoupler is most impressive.

The plan for obtaining operating approvals for 20 kW, 100 kW and higher appears reasonable. The details for the level of documentation required should be reviewed by experts who are familiar with what the Ministry of Education, Culture, Sports, Science and Technology (MEXT) expects to be presented.

Our general and specific suggestions, comments and questions are:

- There should be as much simulation of control functions as possible to save time for commissioning.

- Does the beam permit system allow low intensity beam under less restrictive conditions than normal operations? For example, very low intensity running for tuning the accelerator could be considered with the target and moderator system interlocks at different settings to normal operation. This would allow tuning when the target systems are not fully operational.

- The possibility of to directing small cross section proton beams on the target remains a concern. This condition is prevented by interlocks on the relevant quadrupole magnets currents. Consideration could be given to including other signals, for example from the laser diagnostic device on the target in the interlock system as a further protection. Also efforts to install a VIMOS-type beam monitoring system should be strengthened.

- X-Y plane harp measurement does not give information on true peak intensity, if the beam is tilted!

- Is there an interlock which ensures that the target is in the operational position before proton beam is allowed to the target station?

- The instruments may want to suspend their data taking if conditions in, for example, the moderators change. Does the control system and network have provision for this?

- The restricted (not always accessible) areas should include the neutrons scattering and muon instrument locations.

- Radiation surveys will be needed as power is increased at defined increments and it is likely that areas will be discovered which will have to be controlled until additional shielding is added.

- Maintenance activities on activated components may require some areas to be controlled during the work for example, the neutron beam choppers.

- Radiation sources will change as induced activity builds up in different areas, such as around the water pumps and heat exchangers and in mercury gas filters. The figures which indicate radiation only in operation present too simple a picture of the radiation environment.

- The samples to be used in the neutron scattering experiments will become activated. These will require management including controlled storage and audit to avoid dose to staff and visitors.

- There may be significant radiation levels on the roof of the building. If this is so the control of access will be required.

- Contamination is a source of radiation exposure. Consideration should be given to classification of areas based on levels of contamination as well as prompt or induced activity.

- The system for managing mercury target off gases is basically well conceived. However, we recommend that the detectors and procedures for sampling and radiation checking should be re-examined.

- Calibration of the devices to measure the radioactivity in the gas handling systems could require permission to release defined quantities of standard radioactive gases such a tritium of krypton. If this is required these calibration sources should be included in the 'radioactive isotope' requirements.

- The sampled gas should be well mixed before measurement in order for the results to be really representative.

- Recent operating experience at SNS shows that Xe and Kr were trapped on mercury filter (Au). More generally (observation at SINQ), noble gases seem not to behave as usually expected but have a tendency to concentrate in certain areas.

- The method of detecting tritium (not described in detail in the presentations) should be considered carefully, recognizing that the decay beta is of very low energy—a detector separate from the indicated β-γ monitor (liquid scintillator or flow chamber) might be considered.

- The chemistry of tritium removal should be examined. We question whether introducing H_2 and O_2 gases is an efficient way to adjust relative humidity (R.H.)—that might better be accomplished by introducing water vapour or spray. Free tritium (T) reacts rapidly and irreversibly with H_2O to form HTO,

  $T + H_2O \longrightarrow HTO + H$,

  and HTO seeks water, where, in scintillator-water solution, it is easily and distinctly detected.

- Adjusting relative humidity by injecting H_2 and/or O_2 seems inefficient. Spraying water might be more effective.

- While there is generally good awareness of the safety aspect of fail safe position of valves in the systems, special attention should be paid to situations where the mercury drain valves should not remain closed fail safe. This can happen for example in the case of fire or a leak in coincidence with an electric power failure. A separate accumulator with compressed air and with manual actuation could provide the ability to open the drain valves from fail safe closed position if necessary.

- Electric power supply failures can also have unexpected effects like blow down of systems with radioactive media. Because this can result in unwanted release of radioactivity, it is recommended to pay special attention to such situations and to check the system reactions by comprehensive tests.

Cryogenic Systems/Moderators

- It appears that there is an interlock to prevent beam to target unless the cryogenic systems are fully cold. Is this necessary?

- There is a requirement to keep the hydrogen concentration in the ventilation stack below the lower explosive limit. Consideration should be given to making the stack intrinsically 'hydrogen safe' with no ignition sources. This could remove the condition to maintain a low hydrogen concentration which could be problematic in accident conditions.

3. Safety Design

Our comments to the licensing aspects as presented are included in section 2.

Mercury vapour behaviour

The experimental work was done well and produced useful information. The mercury spill evaluated was a 100 cm^2 area which produced a gas density of approximately 1.5×10^{-7} g/m^3. If a spill did occur, it could easily be larger then this area and could also be at a time where the system was open during a target change. In this case the vapour concentration might be significantly higher. At SNS, concentrations in the cell exhaust were up to 90 micro $\mu g/m^3$. These levels, however did drop to about 2 $\mu g/m^3$ after the piping was closed.

- The ease of decontamination of mercury, i.e. the degree of adhesion of mercury to materials (316SS or epoxy resin) may be strongly affected by the conditions of surfaces of the materials. The surface conditions of the materials should be specified when decontamination experiments are required. Otherwise, one would obtain different results.

The efficiency of charcoal filters of >99.96% inevitably decreases with time. Pre-evaluation of life time of the filter is needed to know how often the filter should be exchanged. A limit should be established for how much mercury can be allowed to accumulate in any one of the filters (risk of release during a fire, e.g.)

Further work is recommended, for example to measure the evaporation rate after decontamination of the surfaces. Also the degree to which the condition of the surface affects the success of decontamination procedures is important to be understood in detail.

4. Component Maintenance

To the extent possible at the present stage (many of the components are still under manufacturing or factory testing) the demonstration of the effectiveness of the various remote handling concepts and their realization is first class. Improvements accomplished on individual systems, such as the moderator pipe cutting device and others are as expected. If this scrutiny continues there is good reason to be confident that the systems will perform as required in operation.

The need for full demonstration of the key remote handling activities before activation remains.

An important point that can only be accounted for to a limited extent in pre-operational testing is radiation exposure of personnel. It is important to include measures to keep this exposure to a minimum in the actual tests because necessary shielding may affect the actual accessibility.

It is good practice to establish a schedule for anticipated maintenance procedures during operation of the facility, taking into account prognosed service life periods and time requirements for service or replacement of the various components. This, in turn, gives valuable feedback on the required quality design and control and allows overall optimization of efforts, including requirements to the availability of qualified staff and equipment. This aspect must, in turn, be an important input parameter to the plan.

In order to obtain the predicted service life of the first target the team should establish rigorous guide lines relative to allowable proton peak intensities.

5. System Commissioning

- The general principles of commissioning are observed quite well.

- The schedule for commissioning and testing seems to be very tight and requires good coordination and planning.

It could well be that during the commissioning of the accelerator systems it will be easier to produce very high pulse intensities but at low frequency. The target team should consider defining limits based on pulse intensity. This will protect the target from the potential damage of the $(\text{power density})^4$ dependence of cavitation erosion.

It is essential for future operation and maintenance that comprehensive documentation of the systems is produced. This must describe the 'as built' configurations and, ideally, should include some description of the reason for the design choices. Comprehensive photographs will prove to be very useful but they will need careful and precise cataloguing.

6. R&D for High Power Target / Materials Issues

Cavitation phenomenology

The JAEA-university group investigating pressure wave effects in rapidly pulsed liquid mercury continues to produce revealing new data and new insights, and are significant participants in the multi-institution collaboration on high power liquid metal target development. The group is well integrated in the broader high-power target development effort and interacts there with great impact.

The MIMTM instrument continues to provide new data, being applied in applications beyond its original purposes, especially with the installed flow loop. The observation that flow alone reduces cavitation damage is a welcome new revelation.

The group has made considerable progress in quantitatively understanding the behaviour of cavitation bubbles in mercury, their growth and subsequent collapse as affected by the magnitude and duration of negative pressure and of dissolved rare gas, and the dynamics of rare gas bubbles.

We feel that understanding how to provide longer target vessel service lifetime will come in time to support full power operation of the new facilities. The parts of the puzzle are coming together but the picture is still not clear. We encourage continued high-level support of this world-class effort.

Practical issues of mitigation of PW-effects

The technology to make controlled gas bubbles in mercury requires development of an appropriate gas nozzle. For this development, work with powder metallurgical methods using glass fibers has been started and seems very promising. The Committee continues to support this effort because glass fibers with any desired diameter (e.g., 10~100 μm) and lengths are commercially available. By using the developed gas-nozzle, it should be possible to generate controlled micro-bubbles and to demonstrate how the micro-bubbles mitigate the pressure waves in the MIMTM apparatus and in more realistic tests.

It is crucial that the degradation of fatigue strength of 316SS is more conspicuous in mercury than in air. SEM observations of fatigue-fracture surfaces for 316SS (air) and 316SS (Hg) tested with 1 Hz and 600MPa showed a distinct difference. It is important to clarify the cause of the difference and the following studies are recommended. First, prepare transmission electron microscopy (TEM) specimens from a fatigue-tested specimen (away from the fracture surface). FIB (Focused Ion Beam) technique is very convenient to prepare TEM specimens containing the targeted region such as a grain boundary. Then, perform TEM observation and EDX analysis for the specimen to measure the Hg concentration at grain boundaries or grain interiors.

Impurities (including gaseous impurities) in the mercury target might affect the pressure wave issues. Therefore, the chemical compositions of impurities in the mercury targets should be determined and their role should be investigated.

Development of a retro-reflecting corner cube mirror

A brazing treatment for Ni and 316SS decreased the reflectance of the mirror, and the decrease increased from 2~3 % for 600C-brazing to 38% for 1000C-brazing. The cause of the reflectance decrease may be a slight distortion of the mirror due to residual stresses after brazing or a change of the surface state due to heating. Their possibility should be examined.

Mercury pump

The Committee commends the Project Team for their decision to switch from a gear pump to an EM-pump after initial loop tests with water have been completed.

The progress reported on the development of a “Japan made” rotating magnet induction pump is truly impressive. The Team fully understands the issues involved and have demonstrated their ability to make realistic performance predictions. It is comforting to see that the pump now ordered for the commissioning phase (J.P-400) designed to be used up to 400 kW of beam power can in principle also be used at 1 MW. This gives confidence that the final J.P-1M to be developed on the basis of the experience that will accrue from the operation of J.P-400 will have enough reserve for save and reliable long term operation.

Modified Target Concept

The efforts to develop a new target design that would produce less waste by allowing to retain a larger part of the target vessel upon exchange of the front part prone to damage are highly supported by the Committee. While this may seem to be a more long term issue, it is in fact quite urgent because the transition will be much easier while the target maintenance area is still accessible without excessive protective gear. This is why the Committee was slightly disappointed by the apparently low level of effort that had been put to this topic in the past year. While the basic options presented have some promise, the full range of possible designs may not have been studied exhaustively. In this context it might be worth while also to reconsider the basic concept of the cross flow configuration, in particular in the light of gas bubble injection into the mercury volume.

In order to progress on this front more rapidly we recommend to convene a group of international experts for a brain storming workshop around the middle of 2007.

END OF THE REPORT

Waldshut, Feb. 17, 2007

Günter Bauer

on behalf of the Committee