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

Report on the Third Meeting

Held at JAERI Tokai Site
Oct. 26 – 28, 2004

Executive Summary and Main Recommendations

The JSNS Project staff has demonstrated beyond doubt that the engineering and science of the Joint Project is of the highest quality. The progress in the construction programme, the detailed design of the target systems and the related R&D work are most impressive. The target station team of the Joint Project seem to have full control over their part of the project and are fully dedicated to success.

The Team have recently introduced some design changes (partly prompted by the N-TAC in their 2nd meeting in 2003), which are clearly an improvement in overall safety and performance of the system. In some instances consequences of such changes still need to be considered throughout the system. Some detailed comments will be given in the main body of the report.

The JSNS Project is in a critical period. The design of the target station is nearing completion in all areas, many important design decisions have now been made and procurement is well underway. This leaves little room for technical changes, but the Committee still has a couple of recommendations, the most important ones of which are:

- Consider replacing the gear pump in the Hg-loop by an EM pump of the type recently developed at the Institute of Physics of the University of Latvia.
- Rather than providing two Hg-tanks on the target trolley considering to use the main drain tank also to collect spilled material from the catch pans.
- Aggressively continue the successful research on the pitting issue in collaboration with the international community.
- Work with the accelerator and beam transport team to develop a method to produce the required proton intensity distribution at the beam window at every moment, not only in the time average.
- Seriously try to find ways of adjusting the alignment of the beam line magnets from the top after their final placement and addition of shielding.
- Discuss with the licensing authorities the need for a secondary containment around the off-gas system and for shielding between the decay tanks.
- Rework the schedule for testing and commissioning, allowing contingency for typical start-up problems and integrating the test plans into a common resource loaded schedule.

1. Introductory remarks

The N-TAC Committee, comprising the members

Dr. Günter S. BAUER (Chair)	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 third meeting on October 26 to 28, 2004, at the Tokai site of JAERI, 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 presentations on the technical status given were excellently prepared and were complemented by an informative visit to the construction site, which demonstrated most impressively the rapid progress the overall Project is making. Team members continue to mature in their work and in their self-confidence, while they work ever more together with team spirit.

The third meeting of N-TAC was called at a point in time, when the Project was already well into the construction phase. Numerous orders had already been placed in an attempt to keep up with the extremely tight project schedule. This put the main emphasis in the present meeting on safety, commissioning and maintenance issues. As a result the Committee feels that there is little scope left for recommendations of revolutionary significance. We therefore chose to give our general findings primarily in the form of comments and observations and leave it to the Project to draw the right conclusions and decide on possible actions. We offer our comments fully in the spirit of helpfulness.
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We are, as before, pleased to note that the comments and recommendations of the first and second N-TAC meeting have been studied very thoroughly by the Project Team and, where deemed appropriate, they have been adopted and new designs presented. The design team is to be congratulated for developing a mature design in a relatively short time from the start of the project and for staying abreast with the overall progress by appropriately prioritising their decisions or leaving enough flexibility for future adoptions where feasible.

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. While we have been informed that the Project has already reacted to some of our comments, we still keep them in the present report for the sake of completeness.

2. The Spallation Target System

2.1. General comments

Two important changes have been applied to the spallation target design in the last year:

(1) the shape of the front window was changed from flat to half-cylindrical and
(2) in compliance with the advice given by N-TAC a containment wall was introduced about 60 cm from the target front window in the interspace between the liquid metal container and the outer, water cooled containment shroud.

The change in shape of the target window was introduced to reduce thermal stresses caused by the local heating in the area where the proton beam hits the target. This is a welcome improvement and should have little influence on the thermal hydraulics of the mercury flow in the target. Nevertheless the details of the flow distribution with the new geometry should be examined.

The introduction of a containment wall in the target shell has the important consequence that a mercury spill caused by a breach of the inner shell (e.g. due to pitting erosion) is not an accident but an operational incident for which suitable precautions have been taken to make it of no radiological consequences.
There are, however two important aspects that need to be considered:
(a) Detection of a mercury leak into the enclosed interspace must be fast and reliable to shut off the proton beam and
(b) Overheating of the mercury in the interspace must be avoided to secure proper cooling of the outer shroud.
Item (a) requires that a detection system be developed that works reliably, has sufficient life time and whose functionality can be tested. The Team proposes two systems: a radiation monitored Helium gas loop and a pair of resistive wire detectors. *Both are, in principle suitable, but it must be ensured that the helium flow is established throughout the interspace and that a breach of the resistive wire leads anywhere will be detected immediately.* Detection of excess radioactivity in the He-gas is an unambiguous method and the functionality of the detectors can be checked regularly. It does however take a certain time (about 30 sec) to transport the He gas to the detection system. This is why the following consideration is important.
Item (b) may require a further adjustment of the geometry to avoid accumulation of spilled mercury in regions where it can be hit by the beam and lead to excessive local heat loads on the water cooled shroud (burnout phenomenon). *The distance between the outer shroud and the target container nose should, therefore, be reviewed*. *Furthermore, D_2O flow and temperature rise in the shroud cooling loop should be monitored and used as a further signal to trip the beam if set limits are exceeded.*

The Committee was also impressed by the progress that has been made in understanding the pitting (cavitation erosion) phenomenon by experiments with the MIMTM apparatus and by theoretical work (see below). It seems now possible to predict the life expectancy of a wall subject to pitting damage as a function of its thickness and stress load, at least under conditions as they prevail in MIMTM. Establishing the relevance of these findings to the situation of a real target in a proton beam, however, remains an open problem and requires aggressive R&D work. The same is true for the development and validation of a mitigation scheme.

This remaining uncertainty is the main reason, why the introduction of the containment wall was such an important improvement, because it allows to run a target to failure of the inner wall (which is the one affected by pitting) without causing any significant problems.

2.2. Leak detectors in the mercury target interspace

As mentioned above, the detection of a leak via radioactivity in the He-gas of the interspace will require at least 30 seconds. It is, therefore, a good method to signal small leaks with high reliability. *It is probably a good idea to search specifically for a particular signature of a specific Isotope.* ^{127}*Xe, which is produced in the Hg with rather high activity, might be such an isotope if it has a gamma-line which is sufficiently separated from others to make it detectable in a low background situation*. In the case of a major breach in the target container, however, the interspace may fill up quickly and the He-flow may even be interrupted. For this situation resistive wire detectors are foreseen, which will be short-circuited when in contact with mercury.

It is important that the functionality of these wires can be tested, most desirably permanently. This can be achieved by designing them as current loops whose current is continuously monitored. A short-circuit by Hg will reduce the loop resistance (increase the current), whereas a breach of the leads anywhere will make it infinite (stop the current).

2.3. Mercury Pump

Currently a gear pump is foreseen to drive the mercury flow in the target. The advantages quoted for his type of pump are its high efficiency and the fact that it does not block the mercury flow completely when it jams. However there are problems with the leak-tightness which the Project Team proposes to circumvent by a controlled leakage capture system. *In the Committee's view this is a problematic solution, in particular since escape of a certain amount of (radioactive) Hg-vapour cannot be reliably avoided.* We pointed out to the Team that a novel type of pump developed at the Institute of Physics of the University of Latvia (IPUL) is now being used successfully at various locations (ENEA, PSI, ORNL). This type of pump works on a completely enclosed mercury loop by inductive forces generated by a rotating magnet drum outside the loop. A laboratory type version of this pump (not suitable for use in high radiation fields or for remote handling) procured by the ESS project has now become redundant at FZ-Jülich. The pump has the following ratings:

Flow rate:	170 kg/s (13 L/s)
Pressure head:	5 bar
Absolute pressure rating:	10 bar (PN 10)
Nominal Hg operating temperature:	25^0C
Maximal Hg operating temperature:	200^0C

While these specifications do not meet exactly those of the pump needed for the JSNS mercury loop, it might be useful for testing purposes.

We recommend that the Project should seriously consider the possibility of using this type of pump rather than the gear pump.

2.4. Monitoring of the Hg-flow and level

Monitoring of the mercury flow in the target is crucial to the safe operation. The Project team are aware of the difficulties of obtaining a reliable signal from the inductive flow meter and intend to use the temperature difference in the forward and return flow as an additional indicator. *Since this quantity depends on the proton beam power as well as on the flow rate, it is recommended to use the pressure drop across the target module as a beam power independent signal.*

While direct detection methods are foreseen to monitor the integrity of the target container (see above), the method proposed to detect a leak anywhere in the loop is the monitoring of the mercury level in the surge tank by capacitive level sensors. In this context it is important to take into account the possibility of the mercury surface in the surge tank not being smooth and quiet, which will be particularly true if He-gas is injected as a means to mitigate the effect of power pulses. *The level monitoring system should also allow for the variation of the mercury level as a function of temperature due to the large thermal expansion coefficient of the mercury.* This means that a large measuring range is required and possibly the set points may have to allow for the temperature of the mercury, if early leak detection is to be ensured.

2.5. Draining of spilled mercury

Currently two shielded tanks are foreseen on the target trolley: the normal drain tank which accepts the whole mercury inventory during target shell exchange or maintenance periods and a second tank which is intended to accept spilled mercury from the two catch pans. The argument for the second tank is that mercury that was collected in the catch pans might be "dirty" and should not be used again in the target loop. The Committee members have difficulties concurring with this for the following reasons:

(a) no reason can be seen why the mercury collected in the catch pans should be "dirty" since the catch pans reside in the target maintenance area ("hot cell") which is completely closed most of the time and has a well filtered ventilation system. Furthermore, cleanliness in the hot cell is an important prerequisite to avoid spreading of contamination.

(b) If some pollution of the mercury occurs the material will float on the mercury surface or, in rare cases sink to the bottom, but is very unlikely to remain in suspension over extended periods of time. Since the mercury loop will always be filled from the volume of the drain tank, sparing the top and bottom layers, there is practically no risk of filling "dirt" from the drain tank back into the loop.

(c) If a separate collection tank is used, it may get filled up in the course of time, in particular if a major leak occurs. In this case it will run out of capacity and will not be able to accept more mercury. Emptying radioactive mercury from this tank would be an extremely complicated and undesirable procedure, as would be replenishment of lost mercury in the loop.

(d) The total amount of radioactive mercury which has to be disposed of would be unnecessarily increased.

For these reasons we recommend considering to use the main drain tank also to collect spilled material from the catch pans, possibly increasing its capacity somewhat.

2.6. Safety and Target Protection Interlocks

2.6.1. General

The Project team is in the process of defining the safety and control system as part of a project wide safety concept which is monitored by several independent committees, including an “Expert Committee on Neutron Target”. A preliminary version of the safety analysis report has been drafted and continues to be refined. The approach as presented is fully endorsed by N-TAC. As an input to the imminent detailed planning work we would like to offer a few thoughts, with more relevant comments to be found under the various system headings.

Separating the functions of a personnel protection system (PPS), a target protection system (TPS) and machine (accelerator) protection system (MPS) is an effective solution to react at the proper level and avoid unnecessary stops of the ion source.

Warning signals should provide the operating personnel with the necessary time for adequate corrective actions to prevent unintended beam trips, initiated by the interlock systems.

Experience shows that interface problems between target protection system, personnel protection system and machine protection system can be avoided by using the same product technology in each (hardware and software). This reduces the efforts in implementation, trouble shooting and unnecessary beam down time and makes the task easier for operating and maintenance personnel alike.

It is also recommended to use only one prime contractor for configuration, implementation and commissioning of the systems. Having only one responsible contractor avoids the issue of assigning blame for malfunctions to different suppliers, who always tend to negate their responsibility.
Using standard hardware and software where ever possible reduces the risk of becoming dependant on one manufacturer or supplier and makes changes easier if the original supplier pulls out of the market.

Passive safety as provided by shielding and the spatial arrangement and proper design of components should be given priority over surveillance instrumentation, where ever possible.

2.6.2. Target Protection System

The monitoring for loss of the heat removal should include also the survey of the mercury flow in addition to the temperatures.

The loss of mercury flow should be monitored directly by the monitoring of the flow instead of AC frequency or current of the gear pump. Monitoring the pressure difference at inlet and outlet of the target and/or pump could be a more adequate method.

The leak detector concept by using resistance wires should take radiation effects into account (Ionization, deposition of conducting materials on insulators through sputtering, etc).

For the target- as well as the machine protection system a two out of three selection logic might be considered to increase reliability in case of random malfunctions in single signal channels. This also allows to interchange or test signal channels during beam operation (this principle might be considered also for other signal channels which are critical with regard to availability.
Online monitoring of the inter space He for Xe127 could be considered, if this isotope has a sufficiently unique gamma signature.

Surge tank level monitoring should also take into account radiation effects. Level bistables on the basis of electrical contact by mercury have shown to produce reliable signals.

Adequate D_2O coolant flow and outlet temperature in the target safety hull should be monitored also by the target protection system.

2.7. R&D on pitting (cavitation erosion)

Pitting erosion damage as a consequence of pulsed power input into liquid metal spallation targets is presently the prime concern in the life time estimates for the target container. This effect was first demonstrated by the JAERI research team under M. Futakawa, and has triggered an international collaboration between JSNS in Japan, SNS in the US and ESS in Europe. Unfortunately, with the termination of the ESS project in 2003 and the very limited R&D-funds available at SNS, progress in demonstrating a mitigation scheme (thought to consist in injection of the right amount and size of non-condensable gas bubbles in the target) was very slow. In this situation it is particularly important that the work continued at JAERI with reasonable support.

During the last year the progress made by the JAERI-team in understanding and measuring the mechanism of the damage and it dependency on operating parameters of the simulation device, MIMTM, was outstanding. Some of the insights seem to be entirely new! A large body of experimental evidence has been produced which together with computational simulations, helps to establish and understand relations between the pulse power density, the surface hardness and the damage to the test specimens. In particular the development of the laser observation technique to measure the time-dependent response of the container walls to the pulse impact proved helpful in developing and refining the damage potential concept, which can be used to estimate the service life of a target container. The observed response consists of a "low frequency" distortion of the container which can be directly related to the time during which bubbles exist in the liquid and a high frequency response that sets in after the bubble collapse. Although it may well be possible that this high frequency component represents the eigenresponse of the container which depends on the amount of "low frequency" deformation, the analysis that derives the intensity of the impact (damage potential) from the amplitude and duration of these oscillations is probably valid and useful. One must be careful, however, because the results obtained with the MIMTM apparatus in terms of life time predictions may not be directly applicable to a real target. Nevertheless, the method developed is extremely useful and The Committee wish to emphasise that this research is of highest quality and fully deserves continued and increased support. This is particularly true for the in-beam experiments under preparation at Oak Ridge in collaboration with JAERI, which are scheduled to be carried out in June 2005. However, even if these experiments confirm the applicability of the optical observation technique also for this situation, important open questions that remain to be investigated are:

(a) the quantitative relations between the simulation experiments on MIMTM and a real target situation (influence of target geometry, semi-confinement, fluid flow etc.);

(b) the effect of pulse repetition rate on the pressure build-up ("survival" of cavitation bubbles in the volume as opposed to the ones collapsing near the surface)

(c) the effect of non-condensable gas in the right quantity at the position of the beam impact

It was found by 3-point bending tests that the effect of surface roughness due to pitting formation on measured fatigue limits is more significant in Kolsterized and 316LN-20%CW than in 316LN, whereas the threshold against pitting formation is higher in Kolsterized and 316LN20%CW than in 316LN.

It is thus expected that the development and use of 316LN with a hardened, but not tightly bonded layer may give better solution to pitting issues.

While some of these questions can only be answered by further in-beam experiments, continuation of the work with MIMTM is extremely important, in particular the planned injection of gas bubbles and, if possible, use of the technique on a loop with flowing mercury. **Once again, this research is of high scientific standard and of paramount importance to the successful long term operation of pulsed spallation sources with liquid metal targets**.

We understand that the team leader has made highly useful working connections to others in the general field; these are much desired to hasten and deepen the understandings coming about. *It may be desirable for the Project to convene an experts' review of this truly outstanding work*.

Projections resulting from the work to date lead to the conclusion that it is essential to find means to mitigate the pressure pulse as well as to understand the pitting, in order to operate JSNS at full power. ***This calls for continued heavy concentration on these issues.***

3. Proton beam line and muon facility

3.1. Proton beam footprint and intensity distribution

Ensuring a flat intensity distribution over the specified footprint on the mercury target (and proton beam window) seems to be still an unresolved issue. The Project has been considering to use rastering of a narrower beam over the surface of the desired footprint to generate the right time average intensity distribution. While this would help to ease the problem of radiation damage in the window material, it would have two negative effects:

(a) The stress gradient at the edges of the narrower beam (with higher peak intensity) would increase, bearing the risk of enhanced fatigue.
(b) Since the pitting erosion damage is believed to increase with the 4^{th} power of power density in the target (as given by the peak beam intensity), the life time of the target would be drastically reduced, because rastering is not possible during individual power pulses of a few microseconds duration.

It is, therefore, imperative that a method be found to produce the right intensity distribution at every moment, not only in the time average.

- For the proton beam define both the peak time averaged proton current density and the peak current density in a pulse.
- Ask for profiles both with 120 MeV linac and 400 MeV linac.

3.2. Proton beam monitoring

In order to observe the beam intensity distribution for optimisation of the beam optics and for surveillance during operation a system of resistive wires is proposed whose spatial distribution of the secondary electron emission would be analysed. In order to reduce heat generation in the wires the use of SiC fibres instead of W-wires was considered. This might be a good idea if SiC has enough resistance to radiation damage. *We recommend investigating this question.*

In this context the Committee notes that a novel method (“VIMOS”) of optically observing the light emitted from a W-wire mesh has been developed and successfully tested at PSI. The method has the advantage of not depending on the integrity of individual W-wires as long as the mesh as a whole remains in the beam. It allows to determine the beam intensity distribution on line with good precision and it was found during the test period that erroneous magnet settings in the beam line could be diagnosed quickly and with high sensitivity.

3.3. Beam line magnets

The alignment procedure for the beam line magnets foresees positioning on a base plate with a precision-aligned seat. Subsequently the magnets will be lifted out again and an insertion guide system will be installed. After the end of the installation process the heavy top shielding will be put in place. It is our understanding that the seat has to carry the full weight of the magnet and its shield plug and there will be no way of correcting the magnet alignment later, although a precision of better than 0.5 mm has been specified. We are concerned that, if any settling of the floor occurs, realignment of the magnets will be an extremely tedious and time consuming procedure or may even be impossible if the magnet is activated.

Although kinematic mounts, as they are in use elsewhere, may be more costly, the team should seriously try to find ways of adjusting the alignment of the magnets ***from the top*** *after their final placement and addition of shielding.*

Also, suspending the magnets from above rather than making them support the full weight of the shielding plug seems to be a more desirable alternative.
The Committee is also concerned that it is intended not to repair any magnets but to discard all components in the case of a defect. To our knowledge repairs of magnets (mostly their cooling water or electrical connections) is carried out routinely in the ATEC area (hot cell) at PSI. Minor defects on magnets seem not to be uncommon. In case of the replacement of a magnet by a new one, the alignment procedure mentioned above will be particularly problematic.

3.4. Muon facility

3.4.1. General

The Committee note, with pleasure, the progress on the muon facility design.

As with the proton beam magnets the Committee is concerned that the current design for magnet supports will make realignment of the muon beam lines very difficult and time consuming. Magnet adjustment will likely be needed due to non-uniform settlement of the MLF building as mass is added for shielding.

Wide angle nuclear elastic scattering makes a significant contribution to the heat deposited in the scraper systems. The team should check that the calculations include good models for this effect as the standard models in some transport codes are quite limited.

3.4.2. Muon Target

Two target designs were presented. A stationary target comprising a carbon disk brazed into a surrounding copper cooling ring and a rotating carbon target. The work to date has been focussed on the engineering (i.e. mainly cooling) requirements.

The muon target foreseen for initial operation is the edge cooled graphite block which will allow muon extraction from its front and back surface only. This is also true for the rotating target concept intended for installation at a later time. Although the Committee members are not experts in muon targets and their use, we observe that targets used elsewhere (in particular the rotating target at PSI) allow muon extraction also from the side faces (which are much larger in area than the front and back faces). It appears to us that the J-PARC team may be giving away the chance for a real high intensity muon beam by not allowing this option. Of course, it would mean that the target chamber and muon extraction system would have to be designed accordingly from the very beginning.

The Committee recommends that the efficiency of the proposed designs for muon extraction be examined in detail to ensure that the target designs are properly optimised for this most important aspect of their performance.

Close contact with PSI on the rotating target design is very desirable to take full advantage of many years operating experience and new ideas for improving the design. There is also considerable experience at TRIUMF with stationary carbon targets and the Committee recommends that the project team contact the TRIUMF staff to see if they have data of great value to the J-PARC muon target designers.

4. Moderators and Experimental Facilities

4.1. Poison and Decoupler Plates

The vigorous development program on cladding of poison and decoupler plates is yielding good guidance toward production of required materials. Continuing work of this kind will define methods for producing the needed products. In spite of the fact that calculations show that no significant temperature problems arise because of non-bonded areas, we recommend persevering to find ways to produce continuously bonded, defect-free materials.
Good bonding was achieved for large-sized specimens of AIC-A5083 HIPed at 530C/100MPa/10 min and for those of AIC-A6061 HIPed at 530C/100MPa/60 min by performing the following three modifications. (1) encapsulation of AIC- and Al-alloys with mild steel, (2) use of a ternary AIC-alloy (68%Ag-2.5%In-29.5%Cd) instead of two binary alloys, (3) surface cleaning before HIP. For AIC-A6061, however, T6 heat treatment after HIPing at 530C/100MPa/60min caused debonding over some area starting from one edge of the large-sized specimens (ultrasonic inspection). They concluded that AIC-A5083 HIPed at 530C/100MPa/10min can be used as a material for the AIC decoupler.

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1. AIC-A5083 case

Although the period for R & D is limited to another 5 months until the end of this fiscal year, bonding tests on large-sized specimens of AIC-A5083 HIPed at 530C and 100MPa for more than 10 min, say ~30min should be conducted. The reason for this is as follows.

One of the three large-sized specimens of AIC-A5083 HIPed at 530C/100MPa/10min with the three modifications showed a low tensile strength although any significant defects were not detected by ultrasonic inspection. This indicates that this HIPing condition (530C/100MPa/10min) may not be optimum. In view of the possible inhomogeniety in the temperature distribution over the large-sized specimens during HIP, the HIPing time of 10 min seems too short. In addition, it is hasty to conclude that the optimum HIPing condition for good bonding between AIC and A5083 is 530C/100MPa/10min, not 530C/100MPa/60min by the following reasons: (1) test results obtained for the small-sized specimens of AIC-A5083 with the three modifications showed that the bonding strength measured by tensile tests tended to increase with increasing hard intermetallic layer thickness, though fracture always occurred at the intermetallic hardened layer. This suggests that there exist very weak portions that are more susceptible to crack initiation or propagation than the initermetallic layer itself and can be strengthened or eliminated by increasing the intermetallic layer thickness (or diffusion layer thickness). (2) the occurrence of a little shrinkage cavity observed for AIC-A5083 specimens HIPed at 530C/100MPa/60min with the above three modifications may be attributable to other causes, such as poor temperature control during HIPing, which may cause heating over the eutectic temperature.

2. AIC-A6061 case

The observed debonding for the large-sized specimens of AIC-A6061 after T6 heat treatment may be attributable to the occurrence of thermal stresses due to temperature gradient on the specimens during water quenching from 515C.

Therefore, efforts should be made to minimize the temperature gradient on the specimens during quenching by modification of the quenching procedure, because the embrittlement by neutron irradiation at room temperature is known to be less in AIC-A6061 than in AIC-A5058.

Note: It will be fruitful to consider using bare Cd plates (with appropriate support) for poison plates in LH_2, giving appropriate consideration to the finite burnup lifetime of Cd in these applications.

4.2. Hydrogen Flow System

The team has done much good work and given needed attention to details of the coupled moderator and flow system design details. Designers are providing correctly for thermal contraction of the cold parts and for the methods and order of fabrication and testing. The designers have a cold prototype, which will prove to be a big advantage. X-ray tests developed for in-situ examination of positions of components in the prototype will provide needed confidence in the design.

Designers are carrying out good work on pressure control in the hydrogen loop. *A convincing case needs to be developed supporting the need for a bellows system: Maybe workers should look into the thermodynamics of the He-H_2 system as a part of this case.*

Have others reviewed the listing of off-normal events in the hydrogen system? That is, is the list reasonably complete? Maybe the Project could use the current list of events as a starting point from which to address those who will evaluate the final safety analysis: they may have more ideas and suggestions as to interactive events that need treatment and that may call for design response.

4.3. Neutronics

The presenter defined a perfectly acceptable definition of acceptance criteria for neutronic performance of the target/moderator system, and outlined a reasonable set of testing goals and methods for measuring the quantities defined. However, some of the goals are quite tight and constraining as acceptance criteria: (> 0.7 x intensity estimates?). Moreover, some goals need further refinement (total intensity vs. spectral intensity, etc.) as to what is needed for "commissioning." Some goals may be beyond what is necessary for commissioning, especially the pulse width measurements, which will require fairly high proton beam power (> 10 kW?), most especially the pulse width at 1/100 max. *The Project should carefully consider whether these data are really needed at commissioning time. Details of the arrangements for commissioning measurements now need to be worked out and a plan developed to test the procedures ahead of time.*

Calculated time-average spectra seem to considerably overstate the low-energy (long-wavelength) intensity from the moderators. *The Project should look into whether this is true, and eventually display its most accurate performance estimates*.

4.4. The Testing Facility

The NOBORU installation will be useful for a great variety of tests, techniques demonstrations, and technical component developments, beyond monitoring of source characteristics, and should be equipped for those uses. *Details of the needed data acquisition system, detector arrangement, and auxiliary equipment should be defined in the next period.* ***Work to provide a low-background environment***, in order that the installation be broadly useful. For some of its applications, an image plate reader should be available for use with this instrument. NOBORU is an excellent name for a facility with these purposes.

4.5. Neutron Beam Lines

For some instruments, aluminium is suitable for neutron beam windows, although it introduces sharp structure (Bragg edges) in the spectral intensity that can be troublesome in data analysis. Some instrument designers might prefer windows of null matrix alloy (~50/50 wt.% Zr/Ti) (no coherent scattering). A new material has appeared which might be useful in shielding and collimation applications—Ferro-boron, FeB, which bonds with various metallic solders to form a hydrogen-free composite. Consult Tim Pike, NIST

5. Helium Vessel and Shutters

Exceptionally good progress has been made on the Helium Vessel and Shutter systems. The design and manufacturing of the helium vessel has been completed and the vessel delivered to the site. The vessel insert remote handling system was fabricated and the insertion operation demonstrated. This also verified the helium vessel flange design.

Manufacturing for the interstitial blocks has started. The shutter insert design is progressing and the shutter control system scheme has been defined.

The design for the helium vessel and helium vessel inserts appears to meet all major requirements. Previous N-TAC comments have been considered and the design solution to allow replacement of the insert attachment bolts looks practical. The Committee does, however have a few comments which relate to operations and maintenance (see below).

Installation of the Helium vessel will obviously be a very important step and will set the geometry for the proton beam line, all neutron beam lines and the target port. Some comments related to installation of the Helium vessel are given below. These have probably already been considered in the design but some of them have been issues during the SNS installation:

- Tolerances on position, angle and elevation must be defined.
- Methods for making fine adjustments to achieve tolerances must be planned.
- Survey equipment and methods must be capable of measuring to the accuracy required.
- Survey data should be taken after installation for all ports and outside references established for future use on the neutron beam lines.
- There should be reference points established for measuring elevation which will remain visible in the future to monitor the amount of settlement.
- Is there a possibility that the gold plated E-Seal could be exposed to mercury vapour? This would not be good.

6. System Commissioning

6.1. System start-up

The design team has done a very good job for this stage of the project at developing the set of subsystem and integrated system tests required for commissioning.

Test plans were presented for most major systems. Preliminary schedules have been developed and the critical path through cryogenic systems and remote handling testing identified. Test planning for the cryogenic and remote handling systems is well developed for this stage of the design.

The tests should be ranked according to which are essential before beam operation, which are highly desired and which could potentially be done after first beam operation. Hard choices may be needed in the future if schedule or financial pressures become extreme.

Input to the required testing is needed from the group who will be responsible for Operations. They will likely want to demonstrate the procedures to be used for normal operation and responses to off normal events and train the system operators to qualify them for operation.

The schedule durations in general appear to be based on first estimates with the assumption of no or minimal problems.

Schedule contingency for typical start-up problem needs to be included either in the estimated durations of each test or as a separate overall duration.

The test plans need to be integrated into a common resource loaded schedule.

All systems required for operations should be included in the planning. This includes the off-gas treatment systems, water loops and the building ventilation systems

The tests should be performed according to written plans with documentation of the results. The plans should include the data to be taken and what results are need to be acceptable.

6.2. Target testing

The 3.5 day duration for mercury circulation tests appears quite short. Allowance should be made for unexpected difficulties. There will likely be some period for fixing initial problem and then time will be needed to demonstrate all operating modes and train the operators. The SNS Target Test Facility ran a full scale mercury loop for testing. Based on that experience, SNS is planning on a 20 working day test period with mercury. This is in addition to a similar time for testing the loop with water prior to loading mercury. The water tests may also be used to develop the pump curve, if the Project decides to stay with the gear pump.

The target test schedule should be integrated with the schedules for the water loops and remote handling.

Prior to loading mercury, leak detection and hot cell ventilation systems should have been demonstrated to be functional and this should be included in the schedule

Testing should include proper operation of the off-gas treatment systems. Some verification may be need prior to loading mercury.

Integrated water loop tests should be defined for initial filling and demonstration of the pumping system prior to the safety hull and shield block testing. Given the typical complexity of these systems these tests could take several weeks.

Consider testing the water loops on the carriage prior to loading mercury. Water leaks would then be easier to clean up in case some mercury leakage is found during initial testing with mercury.

6.3. Cryogenic System Commissioning:

The test planning is well developed, however it might be worth considering not to split the testing with remote handling demonstrations in the middle. It seems more straight forward to do the remote handling testing first and then all the cryogenic testing.

7. Operations and Maintenance

It is vital that the requirements for efficient maintenance are incorporated into the design of equipment at an early stage. This requirement is obvious for equipment which has to be handled remotely. However, the principle applies also to maintenance of equipment in radiation areas as, by careful design and layout, radiation dose to maintenance staff can be minimised.

The JSNS team have done impressive work in most areas particularly in the detailed implementation of the remote handling concepts presented at previous meetings. The Project Team should be commended for starting planning of the commissioning phase at this relatively early stage of the project. This allows a more qualified planning of the subsystems, accounting for their needs for testing and maintenance. *In detailing this planning, input should also be sought from the future operations group who will finally have to be involved in the testing.* This may also help to avoid overly optimistic estimates for the durations of the individual steps and to sequence them in the most efficient way of execution. *It will be useful to include all tests that need to be carried out into one resource loaded plan*.

Execution of the tests should be according to written plans with documentation of the results. The plans should specify the data to be taken and the acceptance criteria that need to be met.

The Committee also has some detailed comments about the systems and designs presented which are given in the following sections.

7.1. Remote Handling

Analysis of the dose rate in Hot Cell (from mercury remaining in circuit after draining or small spills) indicates that limited entry to cell MAY be possible. However considerable contamination and thus dose must be anticipated, in particular in view of the cutting operations proposed to be carried out in the cell.

The Committee recommends no change in the policy of designing systems assuming NO ENTRY is possible.

With respect to the remote handling activities in the target maintenance area (hot cell) in the operations phase the method of decontaminating the handling casks which are brought into the hot cell and then into the high bay should be evaluated and a procedure should be developed which excludes spreading of contamination during this process. The concern is for potential mercury contamination. The amount of mercury needed for an area to be declared contaminated is extremely small.

Lowering heavy loads from casks may require development of rough and fine alignment guides near the installed position to ensure proper location. Demonstrations with prototypes may be helpful in developing the procedures for these operations.

Planning of maintenance operations must allow time for problems for example if a leak test fails and a new seal has to be fitted. It is most important to keep to the advertised schedule for operation of the facility for users. This is put at risk if insufficient time is allocated to remote handling tasks. As experience is gained the time taken to carry out remote handling tasks will become easier to estimate accurately.

The Committee recommends a conservative approach in making the initial estimates of the time required for remote handling tasks.

Too much time pressure on remote handling operators can easily lead to mistakes and consequent delay.

The designs presented covered the replacement of major components well but replacement of smaller items, such a instrumentation (pressure sensors etc.) also present a remote handling challenge which must be considered carefully.

Consideration should be given to providing templates (mock-ups) for the components which have to be replaced on a regular basis to ensure that the replacement will fit.

Replacement of the mercury pump must be checked very carefully, particularly if the gear pump (which leaks) is retained.

Some remote handling demonstration may be possible by using the RH equipment for initial installation.

Finally, it will be important to demonstrate maintenance for the remote handling equipment itself, which should be included in the planning. This maintenance will likely require decontamination and the equipment should be designed to allow the decontamination process such as a water spray.

7.2. Off Gas Processing

Since the production of radioactive gases in the mercury target exceeds the permissible emission limits by almost two orders of magnitude, storage of the gas in decay tanks is foreseen to allow the radioactivity to decay by roughly a factor of 1000 before releasing the gases to the atmosphere (with Tritium removed and converted to water). This is, in principle the correct way to go and the system proposed will in all likelihood fulfil the function in normal operation. With respect to the practical design presented, three things might be worth considering:

(a) The system has four decay tanks, two of which are foreseen to be used in each gas discharge cycle. These four tanks are surrounded by a common steel shielding. It is, however, likely that these tanks will have to be considered as pressure tanks with pressure relief equipment that must be tested regularly. If this is the case, the possibility must exist of temporarily evacuating any one of the tanks and accessing the pressure relief equipment. It was not obvious that this had been taken into account in the design. *The Committee recommends considering installing shielding for each tank separately*.

(b) No secondary containment seems to have been foreseen for the gas handling system. While the steel shielding might be designed and built in such a way to perform this function for the decay tanks, this still leaves the rest of the gas handling system vulnerable to internal or external events that might lead to an unacceptably high release of radioactivity to the atmosphere. *The Committee feels that a secondary containment around the off-gas system should be considered.*

(c) The Committee is also concerned about the consequences of a fire in the off-gas processing area (i.e. high release of active gas). This potential problem needs examination.

The Project Team should discuss the concept with the licensing authorities at an early stage to make sure that an operating license can be obtained.

The lifetime of the Molecular Sieve and Copper Oxide bed is not known so replacement of these potentially highly radioactive components must be considered.

The tritium absorption in the off-gas treatment is most important. However, it is not clear how the efficiency of the absorption will be measured. It is important that there is confidence in the efficiency of the system and some method of measuring the effect of the absorption beds would be desirable.

Bearing in mind both the lifetime and efficiency of the Molecular Sieve and Copper Oxide bed consideration should be given to installing two sets to give good operating margin.

7.3. Shutters

The procedure of aligning a shutter insert as presented seems quite complicated and indirect, measurement of the inclination of the top surface of the shutter by a laser being the final criterion whether the angular adjustment of the insert in the vertical plane is correct. It was our understanding that, if this is found not to be the case, the whole shutter must be removed again, the insert must be realigned according to the measured angular deviation and the whole system re-installed. It was not clear, how horizontal alignment is achieved and it seems that the alignment in the height is by the vertical position of the shutter when open, as controlled by the mechanical shutter lifting system. The Committee is not convinced that this procedure would yield the precision required when neutron-optical components will be used in the shutter inserts.

We recommend to reconsider this procedure in its entirety and consider foreseeing in situ alignment opportunities for the inserts. The techniques developed for SNS and ESS (for the latter cf. the ESS-update report 2004) might serve as a guidance.

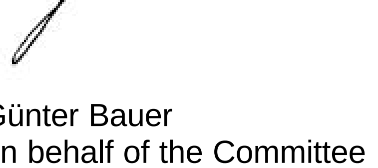
It should also be borne in mind that the shutter inserts will be fairly radioactive and possibly contaminated after extended use. It is therefore important to develop a method for their exchange which ensures adequate shielding at all times, even if a problem occurs with the exchange mechanism at the most awkward moment.
The same is true for the shutters themselves which, when moved from their operating position to the shielding cask will travel for some distance unshielded (while passing through the region of the neighbouring drive mechanisms). It is important that a scheme be devised to recover from a fault in the lifting gear with the shutters half way out.

The Committee recommends that this aspect of the shutter alignment, removal and replacement procedure needs further examination. This comment also applies to replacement of the Helium Vessel Window Inserts.

A prototype shutter should be purchased soon to check that the alignment procedure and lifting system are reliable.

END OF THE REPORT

Grenoble, Jan. 13, 2005



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on behalf of the Committee