Report of the Third Spallation Neutron Source Accelerator Advisory Committee Meeting

SNS Accelerator Advisory Committee

March 11, 2010

Contents

1 Executive Summary

This was the third meeting of the SNS Accelerator Advisory Committee. All but two of the Committee members were in attendance. During the two day meeting, the Committee heard reports on the progress made since last year's meeting, the plan to ramp-up the beam power to the design level, and plans for future upgrades to 3 MW. This executive summary provides a brief overview of the report. Any recommendations noted in the executive summary are also repeated in the body of the report.

1.1 Operations and ramp-up plans

FY2009 operations met or exceeded commitments. During FY2009, 2165 MW-hours were delivered on the neutron target, with 3553 hours of neutron production, and 4500 hours operations (total), at 81% availability. This was a significant improvement over FY08 (72% availability).

FY2010 operations have been at power levels up to 1 MW, with 85% availability. This is a significant improvement over FY09. The FY10 commitment is 3250 MW-hours of neutron production, with 85% availability.

The FY10 operating strategy puts the emphasis on availability, rather than beam power. The plan is to maintain high availability while operating with as high a power as possible, hopefully > 1 MW. Modulator performance is a key to achieving this. For example, a recent reduction to ~ 700 kW was necessary, due to duty factor limitations from continuing modulator issues.

The main issues for availability in the past year have been:

- Modulators, which remain an issue of major concern.
- RF systems-ion source and MEBT-solutions have been identified.
- Controls (issues with MPS-solution implemented).
- Foil failures (spring/summer) appears resolved, but deserves continued attention.

SNS is systematically cataloging failures in all systems, with the priority on hitting the biggest offenders. However, there is not yet a larger strategy that analyzes downtime and provides a structure for the associated AIPs; and there is not yet a systematic analysis of incidents that could induce significant downtime, or a major reduction of performance over an extended period.

The final performance goal remains 1.4 MW power, and 5300 MW-hours/year @ 90% availability. The plan is to achieve this goal by October 2011. This is delayed one year from last year, and two years from two years ago. Beam parameters remain the same as last year. Resolving the modulator problems are the key to achieving the goal, together with plasma processing for a linac energy increase. Losses and residual activation at 1.4 MW remain somewhat uncertain.

Recommendations in this area include:

- Establish a fall-back set of specific parameters (lower power, higher availability) in case there are issues meeting the plan for operations at 1 MW in FY2010
- Continue pursuit of an "operational vulnerability analysis" suggested last year, and development of a bottoms-up, systemwide availability model.
- Retain focus on resolution of modulator issues.
- Complete the planned spare high beta cryomodule (CM). The spare cryomodule should meet the requirements of the Power Upgrade Project (PUP). Consider utilization of this spare to enhance operating energy margin via continuous swapping of spares with lower performing CM's.
- Continue to pursue beam loss experimentation and simulation to support extrapolations to 1.4 MW operations.

1.2 95% availability planning

A top-down plan was presented for reaching 90% and then 95% availability. It was stressed that 95% is a goal not a commitment. The plan is based on recent operational experience at SNS. Major causes of downtime have been identified. A Configuration Control Board has been established and has started to function.

The plan is a work in progress. It is expected that a bottoms-up plan will be fleshed out by the next AAC meeting. The Committee strongly supports the approach that was outlined and encourages its rapid implementation. The Committee notes that 95% availability will not be reached unless the modulator problems are resolved by an aggressive, funded project.

1.3 Ion Source and LEBT

Significant progress has been achieved with the original ion source and LEBT. 38 mA is routinely delivered to the MEBT, compatible with 1.4 MW power for SNS. The downtime has decreased by factor of 4 from 2007. The major offender is the 2-MHz amplifier, for which a solution has been identified.

A deepened understanding of cesium management has been developed, so that only one cesiation is needed for four weeks.

The LEBT sparking is expected to be down to one per day.

Development of an alternate source, and further development of the LEBT, is still necessary, in view of increased availability requirements and the current upgrade. The Committee recommends that the LEBT chopper rise/fall time be brought back to < 40 ns.

1.4 RFQ, Front End and normal-conducting linac

The principal RFQ issue (a resonance frequency shift) looks mitigated by protecting the RFQ from over-pressurizing. The Committee nevertheless encourages rapid procurement of a spare RFQ. Other efforts, including H_2-flow reduction, were effective for improving reliability.

Further efforts under investigation are endorsed by the Committee:

- A smaller aperture at the entrance of RFQ.
- A gate valve between the LEBT and the RFQ.
- Minimization of the gas flow from the ion source to the RFQ.

The MEBT stripline chopper has been implemented and shows increased efficiency.

On DTL6, frequency control and the input window have been improved.

1.5 Linac beam dynamics

The SNS linac has successfully reduced the beam loss down to a level of $< 10^{-3}$. This beam loss level is sufficiently low for the presently required performance.

Further effort to theoretically understand the presently achieved low beam loss is a good idea, since the effort is required anyway for upgrading the machine performance to the several-MW level in the (near) future. The effort is exemplified by finding a weak 60-degree resonance in the lattice. However, the presently available computer simulation codes like XAL, PARMILA and IMPACT look insufficient for predicting beam loss below the 10^{-3} level. (IMPACT may be OK, but needs impractically long computation times).

The Committee recommends the study of observed off-normal loss events in the SNS machine to provide feedback to operations. This should include developments and improvements of the simulation codes, together with their benchmarking on the real machine.

1.6 SC Linac cryomodules and cryogenics

The SCL has supported neutron production at 1 MW and 930 MeV, with 80 out of 81 cavities in operation. Beam loss results in frequent cavity trips, which are typically benign, but in two cases cavities (5a and 6c) lost performance after beam loss.

SNS has made good progress in understanding field emission limitation in the High Beta cavities. However, the mitigation strategies are still unclear.

The RFTF has been considerably upgraded, and the infrastructure for plasma cleaning R&D is established. Major improvements of the PUP cryomodule were worked out.

The Committee makes the following recommendations:

- For the immediate term: Continue RF processing of cavities 5a and 6c to try to recover the original performance. The result will be decisive for further actions.
- For the near term: Assemble and exchange the spare module (after replacing a poor performing cavity so that module meets the PUP spec); Finalize and implement in situ plasma cleaning technology.
- For the medium term: Any new cryomodules (spares or for PUP) should use newly fabricated SRF cavities built and processed using J. Mammosser's recipe.

1.7 HEBT/Ring/RTBT (including foil development)

In 2009, a notable accomplishment was the achievement of the design peak intensity of 1.55×10^{14} ppp with tolerable losses in the accumulation ring.

The HEBT momentum scrapers proved very useful in past operations, and a new HEBT momentum dump has been designed. Installation is under way.

The e-p instability shows up well below the design intensity but can be controlled (just barely) at the design intensity with full RF voltage. Active damping (transverse damping) has been shown to have some beneficial effect on e-p and, if further developed, could provide a highly desirable additional margin of safety.

The value of TiN coatings for stainless steel vacuum chambers has been questioned in the light of data obtained in the past few years. A systematic study to resolve this issue can be expensive. SNS has already made the investment in the hardware for TiN coating and will prudently continue to coat new chambers that are installed in the ring.

The main reliability issue was a rash of foil failures after May 3, 2009. Several changes to the foil system were made which were motivated by several plausible hypotheses, and resulted in a foil arrangement that lasted for the most recent 3 month run period.

It was not clear which changes were most responsible for the success. Arcing from charging of the foil seems most likely root cause of foil failures. Charging has at least two sources:

1. secondary emission from protons passing through the foil, and
2. reflection of convoy electrons from the region of the electron catcher.

New observations of hot spots and edge glow are rather puzzling and not well understood, although some plausible hypotheses have been put forward. The edge glow that persists for 1-2 seconds after beam is shut off is very mysterious. Lack of a clear understanding of these poses unknown risk factors to reaching reliable operation at the design intensity.

The Committee applauds the vigorous effort to understand and correct the foil system failures. Development of reliable, long-life foils and foil system is a highly important goal for SNS. While nano-crystalline diamond foils have demonstrated many desirable properties, improved conductivity to significantly reduce the foil charging is highly desirable. Development of more conductive foils via boron doping is underway, and thin metallic coatings are being considered.

Development of HBC-like foils is also an option under consideration. The HBC foil developed at KEK has excellent lifetime in proton beams such as the LANL PSR and is expected to have good conductivity. It should be tested at SNS.

The Committee strongly encourages a focus on development of higher conductivity foils with long life times. The electron beam test stand is an essential tool for evaluation of foil developments.

1.8 Ring beam dynamics

Orbit Response Matrix (ORM) methods have been used successfully to improve the ring lattice model. A Model Independent Analysis (MIA) shows significant beta function beating in both planes.

The benchmarking program for ORBIT revealed problems with the painting waveforms, which have now been corrected. There are still some disagreements between measurements and simulations of transverse beam profiles at high intensity in the vertical plane for the painted beam. These are presently under study.

Measured losses at A13b are in reasonable agreement with simulations.

Good agreement between simulations and measurements were obtained for the kicker-impedance-driven instability. Simulations of the e-p instability for bunched beams is a work in progress.

It is the Committee's assessment that the progress on understanding and modeling of the ring optics and beam dynamics is progressing at a reasonable pace for the needs of the 1.4 MW goal.

1.9 Target Systems

1.9.1 Target lifetime

Given the current limitations and uncertainties in target service life, the SNS has decided not to count downtime needed for target replacement against the availability contingent. Operational pauses to repair targets are referred to as "planned unscheduled shut-downs." Since these are likely to take the better part of two weeks each, this situation should prevail for as short a time as possible. Once SNS arrives at a scheme where three to four targets are needed per year (10 dpa-limit), the operating schedule should be adjusted to accommodate the target changes in the planned shutdowns.

In the quest to come to grips with the pitting erosion problem, the collaboration with J-SNS has proven highly effective. This collaboration should be continued by all means.

Limited examination of Target 1 suggests that (shear) flow is an important parameter controlling pitting damage rate, causing maximum damage at the point of flow stagnation in the center of the proton beam window. It is highly desirable to validate this conclusion by examining other regions of the shell(s). The Committee recommends trying the following measures on the next few targets:

1. shift the stagnation point as far as possible from the window center by using different size orifices in the two inlet flow channels (a near term option for the next target)
2. try to mimic a cross flow configuration by introducing a guide baffle in one of the inlet channels to split

the flow (It might be possible to insert a tube carrying the baffle plate in one of the targets currently on order for manufacturing before the front window is welded on.)

3. In the medium time scale a target applying the gas wall idea developed during the R&D work may provide additional - and possibly ultimate - protection (requires target re-design and some additions on the target trolley).

In the long run, raising the dpa-limit should be a goal, based on PIE results of used targets. PIE of spent targets must, therefore, be given high priority.

1.9.2 Other target systems

Leak detection system Dependable detection of a leak of mercury into the interspace is important for saving the outer shell. The Committee supports the efforts of adding more diversity to this system.

Target imaging system This has been a highly successful development adding important capability to analyse and control the beam on target. The performance is satisfactory at the present current level, but more development will certainly help for the future. The Committee supports this effort unanimously.

Development of a rotating target This option for the Second Target Station (STS) holds promise for a significant extension of the target life time (up to 10 years). Ongoing work has been very successful so far, but more studies are needed to prepare a qualified decision, since this would introduce a new technology with its associated side effects on handling and waste disposal.

Cold Moderator SNS has luckily avoided two potential down times because the following incidents occurred during shut down periods:

1. Power outage on the CMS compressor controls. A $> 3-6$ sec outage can cause 3+ days of downtime. SNS should try to identify similarly critical systems and hook them up to uninterrupted emergency power supplies.
2. Degradation of the moderator refrigerator capacity due to contamination of the heat exchanger and adsorber was discovered and fixed during a shutdown. Regular regeneration during planned shut downs should be considered.

Interesting ideas have been presented for novel moderator concepts. These should be pursued with an appropriate effort in the medium term. The proposed Moderator laboratory would be an important asset in this effort.

Component Replacement / Remote Handling Remotely handled replacement of two major components - the target and the proton beam window plug - was accomplished successfully, although some lessons can be learned:

- Make sure all procedures are described precisely and in detail, including numerical values, e.g., for the torques to be applied or dimensions to be checked. Make sure that compliance with these procedures is closely monitored throughout the process.
- As a backup, provide tooling that may be needed for fault recovery (but don't view them as a substitute for careful work).

Efficient remote handling techniques become increasingly important as the beam power continues to go up. In particular, the imminent core vessel insert replacement on BL 16 will be a challenge, which must be thought through in all details.

An impending problem is disposal of radioactive or contaminated waste. It is important to make sure that pileup and disposal of stored components does not jeopardize source operation.

1.10 High Voltage Converter Modulators (HVCM)

The Committee acknowledges the following significant accomplishments in this area:

- Formation of the HVCM Development Group.
- Completion of a dedicated HVCM test stand for development.
- Improvement of HVCM availability by IGBT timing adjustments.
- Replacement of 4kV capacitors with new pretested self-healing capacitors.
- Development of a new IGBT driver circuit.
- Development of new control specifications.
- Development project for the energy storage capacitor bank fast disconnect switch.
- Replacement of SCR supply connectors.

The Committee notes that the HVCM is the major contributor to the SNS Accelerator down time, so it needs more work to meet availability goal. The 4kV capacitor failures are not completely understood, so it is not clear if the failure problem is solved by their replacement. The warm section HVCM resonance capacitors were all replaced, although the cause of their failures is not totally understood.

The IGBT failures are not understood, so their availability is uncertain. IGBT over voltages are generated by diode "snap off" during IGBT pulse termination. These may be the cause of IGBT failures. The cause of the droop compensation failures is also not understood.

The Committee makes the following recommendations for immediate action:

- Implement snubbers or equivalent devices across the IGBT's to reduce the overvoltage due to diode "snap off".
- Procure, test, and replace all of the resonance capacitors for warm section modulators, and monitor all resonance capacitors.
- Implement the new IGBT driver circuit to improve the monitoring and protect the IGBT's from "shoot thru" pulsing.
- Implement the energy storage capacitor bank fast disconnect switch to improve failure diagnostics and prevent explosive faults under IGBT/capacitor failure.
- Proceed with procurement of the new control driver to provide improved monitoring and control.

For the longer term,

- Continue evaluating the IGBT failure problems.
- Develop a new modulator topology using series connected output rectifiers to reduce voltage stress on high voltage components.
- Reduce ground loops and develop damping for the energy storage capacitor bank.
- Develop automatic methods to insure minimum power loss in IGBT's.
- Study automatic core saturation and output voltage droop compensation techniques to reduce the RF requirements and adjustment requirements.

1.11 RF systems

If the availability is to be improved to maximize the scientific output of the facility, both the downtime and the event rate (for example, trip rate) also should be minimized. (Of course, the latter also contributes to minimization of the down time.)

The trip rate (and the downtime) of the high-power RF and pulsed components can be improved by increasing the maximum peak power and duty factor ratings, say by 20 or 30%, to achieve an availability of $> 99\%$.

Of course, a sufficient number of spares and a coordinated replacement scenario decreases the downtime. The presently proposed efforts will be effective for this purpose.

1.12 Control Systems

Generally, there has been very solid performance in this area. No major problems were experienced. The actual availability of control systems nearly matches the 2010 goal.

It was found that many MPS nodes did not trip beam in the required 20 ms. Delays of 3 - 194 ms were measured. This MPS delay problem was aggressively attacked and has been repaired.

LLRF load problems will be resolved with a better processor (MVME5500), which will become standard after the winter outage.

1.13 Beam instrumentation

The existing beam instrumentation is capable of supporting machine tuning and production runs.

Improvements to the laser "wire" scanner system (nine stations, served by one laser, using mirrors) included reduced vibrations in the mirror mount and reduced cross talk between planes.

The HEBT beam scraper was implemented, allowing measurement of halo down to the 10^{-5} level.

The ring profile monitor, which uses an electron beam, was improved. It still needs a higher energy (100 keV) e-beam.

A transverse feedback damping system was installed, with an analog processor and an 800 W amplifier with 300 MHz bandwidth.

The main goal for FY10 is to bring the beam shape monitor and the MEBT emittance devices to user-friendly status.

1.14 Accelerator engineering

The engineering group has now gotten into a rhythm of building projects while the accelerator is operating and installing during the downtime. The work is aimed at repair of those items that are causing downtime. All of the work appears to be well designed, well executed and planned.

Equipment that was not well engineered initially is being rerworked, e.g, replacing bolted vacuum chambers in high radiation areas. The priorities are well adapted to improving availability and continuing the performance ramp-up.

The Committee suggests using dry nitrogen to cool the injection dump (not air), to avoid ozone and nitric acid production.

1.15 Power and current upgrade projects

The Power Upgrade Project (PUP) goal is an energy increase to 1.3 GeV, with a consequent beam power increase to 1.8 MW. The scope includes 9 new cryomodules with associated rf power (36 klystrons, 4 modulators). In the ring, the project includes upgrades to chicane magnets and the injection/extraction kickers.

The PUP Project Plan has a TPC in the range of $90M-$96M. CD-1 was approved in January, 2009. CD-2 is expected in January, 2011, with a construction period from 2012 to 2015.

The Current Upgrade (CU) is a collection of AIP projects whose goal is to raise the SNS power level to 3 MW (1.3 GeV energy, 42 mA average current). The cost is estimated at ∼$60M over 5 years. A careful analysis will be required to determine how to provide the current capability in the existing linac and in the accumulation ring. A second target station (STS) is required to fully utilize the 3 MW of beam power.

The Committee noted the following issues:

- the need for a consistent configuration between PUP and CU-AIP (and STS).
- CU-AIP Funding availability.

The Committee's recommendations in this area are:

- Produce an integrated (PUP, CU-AIP and STS) plan in support of the PUP CD-2 review in January, 2011.
- Use new cavities in the PUP cryomodules, not SNS spares.

2 Introduction

2.1 Committee Membership and Charge

This was the third meeting of the SNS Accelerator Advisory Committee. The Committee membership is given in Sec. 21. At this meeting, all members of the Committee were in attendance except Alex Chao and Roland Garoby.

The Charter for the Committee is presented in Sec. 20. The specific charge for this meeting was:

1. Assess the performance of the SNS accelerator complex to date.
2. Assess and provide advice on the plans for improving the beam availability, and continuing the ramp-up in performance of the SNS accelerator complex to the baseline design level (1.4 MW, > 90% availability, 5000 hours operation/year). Is the approach on the most critical systems (modulators, foils, SCL, target) appropriately directed?
3. Evaluate the risks to the plan and the mitigating actions aimed at addressing those risks.
4. Assess the progress and approach for the Power Upgrade Project.
5. Assess the progress and plans for neutron source development.

Following the agenda outlined in Sec. 22, the Committee heard two days of presentations assessing the current status of the SNS accelerator systems, plans for the ramp-up to the baseline level, and plans for further upgrades.

2.2 General remarks

The Committee thanks the SNS staff in both the RAD and NFDD for the excellent quality exhibited in the presentations, and generally for the warm hospitality provided during the review.

The Committee congratulates the staff on the progress it has made since the last review:

- beam power increase from ~ 0.6 to > 1 MW,
- beam availability increase from 72% (FY08) to ~85% (FY10 to date),

while at the same time providing useful neutron beams to SNS users engaged in pioneering experiments. Improving accelerator performance while maintaining good reliability is a challenging task, and the staff is to be commended for its successful efforts to maintain a good balance between these sometimes competing objectives.

The Committee appreciates the attention which the SNS management has paid to last year's AAC comments and recommendations. Most of the Committee's comments and recommendations from last year were addressed, and a number of the recommendations were implemented.

Availability was a major focus of this year's review and is highlighted in the responses from the AAC presented in the following sections of this report.

3 Accelerator Overview

3.1 Findings

Operations in FY2009 exceeded the commitment goals established at the beginning of the year. Most significant were 2165 MW-hours of beam on the neutron target and 81% availability. Performance in FY2010 to date has also been very good: there have been several weeks of operations above 1 MW on the neutron target, and availability has averaged 85%. All 23 cryomodules are now installed, and 80 of 81 cavities are operational. Over the last year an additional modulator has been installed to provide operating margin. These improvements have enabled operations at an energy of 930 MeV. In addition a spare cryomodule is currently under construction. This performance bodes well for the FY2010 commitment goals of 3250 MW-hours of neutron production accompanied by 85% availability.

The operating strategy going forward places priority on availability rather than beam power. The goal for FY2010 is consistent operations at 1 MW. Modulator performance is the key to achieving the FY2010 goals. Ongoing issues with the modulators are currently limiting beam power to about 700 kW because of the difficulties in running at duty factors required for 1 MW. In addition to limiting beam power the modulators remain the primary downtime contributor. A number of improvements have been implemented, including an IGBT gate drive upgrade and replacement of all capacitors. However, it is still too early to assess the impact of these improvements.

There is now an improved understanding of losses through the linac. This is based on improved diagnostics and an absolute calibration of the BLMs. Beam loss through the entire linac is measured to be about 1×10^{-5}. Most importantly residual activation is not rising with integrated accelerated charge, and is not limiting operations. There are still a few mysteries that are under study, most notably why decreased focusing lowers losses and residual horizontal-vertical coupling observed in the linac.

3.2 Comments

The current approach to reliability improvement is to systematically catalog failures and performance shortfalls, and then deal with the biggest offenders first. Significant improvements have been made over the last year in dealing with issues in the Machine Protection System (MPS), foil failures, the MEBT rebuncher, and ion source reliability. The outstanding issue is the modulators as described above.

However, it remains unclear that there is a larger strategy that analyzes downtime and provides a structure for the associated AIPs. In addition we retain a concern that incidents that could induce significant downtime, or a major reduction in performance, over an extended period have not been considered in a systematic manner. The Committee made both these comments last year, and they have been accepted by the SNS team. We continue to encourage their planning to address these issues over the next year, as we feel they are key to achievement of longer term availability goals.

3.3 Recommendations

- Continue to pursue the operational vulnerability analysis suggested last year: Identify possible failures or incidents that could compromise operations for a significant period. Prepare a strategy based on assessment of probabilities and impacts.
- Retain focus on resolution of the modulator issues.
- Pursue analysis and modification, as required, of the machine protection system.

4 Ramp up Plan Overview

4.1 Findings and Comments

The goal of the ramp up plan is to achieve 1.4 MW operations, with 90% availability and 5300 MW-hours of operations per year. The current goal is to achieve this performance by October 2011. The Committee notes that the target date for this goal is delayed one year from last year, and two years from two years ago. Nonetheless, significant progress has been made as noted above, and the basic operational strategy to meet the power goal remains unchanged: 960 MeV operations with 38 mA beam current, a 0.95 msec pulse length and a 68% chopping fraction. Key improvements to achieving the power and availability goals are the modulators and in-situ cavity processing to increase the gradient. The Committee notes that while the understanding of losses in the linac has improved significantly over the last year, a reliable extrapolation of losses and residual activation into this realm needs to be developed.

As noted above, the overall strategy is based on addressing reliability issues first and power issues second. The Committee agrees with this approach, while noting (again) the central role in resolving modulator issues to support the overall strategy. There are multiple AIPs in place to support the ramp up plan, however as noted above it is unclear the AIPs have been organized in the context of a coherent strategy for achieving $> 90\%$ availability.

4.2 Recommendations

- Complete the planned spare high beta cryomodule as soon as possible. Consider utilization of this spare to enhance operating energy margin via continuous swapping of spares with lower performing CM's.
- Continue to purse beam loss experimentation and simulation to support extrapolations to 1.4 MW operations.

5 95% availability planning

5.1 Findings

A top-down plan was presented for reaching 90% and then 95% availability, but it was stressed that 95% is a goal not a commitment. The plan is based on recent operational experience at SNS, rather than being derived from industrial experience of the components (a reasonable decision). The major causes of downtime have been identified and a Pareto Chart is used to rank order the major causes of lost time.

A Configuration Control Board has been established and has started to function. Examples were given of instances where the Board had been involved in decisions. This is a good step forward, even though the Configuration Control Board has not yet been fully chartered.

5.2 Comments

The plan is a work in progress. It is expected that a bottoms-up plan will be fleshed out by the next Review. The Committee strongly supports the approach that was outlined and encourages its rapid implementation.

However, 95% availability will not be reached unless the modulator problems are resolved by an aggressive, funded project. At present, the expected availability of the machine from all causes except the modulators is on track to meet 90% availability in FY10. Because the primary cause of RF downtime has been identified and corrected, this may even exceed 90%. However, the modulators are such a major cause of downtime that overall, even 85% availability will require considerable effort and vigilance.

In general, a Configuration Control Board functions in a way that limits the changes that occur in the machine. The first question that is asked is whether the change will cause any harm. This is indeed the correct attitude in general. However, in the case of the modulators, this may lead to a focus on studying the problems and tend to delay actually addressing them.

It was stated that the capacitor failures followed the well-known Weibel curve, but with a considerably reduced lifetime compared to industry experience for these capacitors operating in a standard configuration. The modulators are configured in a non-standard configuration without the standard industry protections (snubbers). The impact of this non-standard configuration can be estimated by comparing the capacitor lifetime in this configuration to the industry standard. The best estimate of the lifetime of other components would be to reduce the industrial data by the same factor as the capacitors.

In this scenario, the Change Control Board should re-evaluate the criteria for making a configuration change. Given that the non-standard configuration has already had a measurable negative impact on component lifetime, the question to be asked is: "is it prudent to maintain the present configuration" rather than "is it prudent to make a change to the configuration," which is usually the correct question.

5.3 Recommendations

- Develop a bottoms-up plan for reaching 95% availability.
- Re-evaluate the criteria required by the Change Control Board for modifying the modulators to convert them to an industry-standard configuration.

6 Ion Source and LEBT

6.1 Findings

The Ion Source Group has made significant progress with bringing the original ion source, equipped with an internal rf antenna, up to full specifications and beyond for beam production. Beam currents of 38 mA are routinely delivered to the MEBT, compatible with 1.4-MW average proton-beam power on the spallation target. Compared to the performance in FY 2007, the total downtime has decreased by a factor of four, which is a very remarkable result. One four-week run yielded 42 mA. Only one failure of an internal antenna occurred over a 3-month running period.

The understanding of the cesium management has been deepened, with the result of reducing the cesiation times from 30 to 20 minutes and requiring only one cesiation for an entire run of up to four weeks.

Many components in Ion Source and LEBT have been replaced by better engineered parts, and this has resulted in gradually increased availability, most recently achieving 98.8%.

The 2-MHz rf amplifier is the most critical subsystem, and a plan to overcome the related problems has been presented. It consists of procuring two 60-kW solid-state amplifiers that can be stacked to supply the antenna, and an isolation transformer that will allow operating the amplifiers a ground potential, thus reducing the danger of sparking induced damage considerably.

The performance data for Run 10-1 show a major drop in power-efficiency of the 2-MHz amplifier: The beam current decreased from 42 mA at 45 kW to 26 mA at 72 kW. The rms antenna current signal dropped from 2.1 [V] to 1.8 [V] over a two-month period when two ion sources were alternatively utilized in six installations. Refined procedures for LEBT conditioning in combination with installing pre-dried sources has resulted in a significant reduction of the sparking rates, now about 1 spark per week on Lens-2 at full duty factor. Overall, 1 spark per day is the current performance expectation for the LEBT.

The development source with external rf antenna was utilized for beam production in eight two-week installments. The average beam current was 35 mA, and 5 failures (3 different types) occurred and resulted in a total availability of 96.6%. As a consequence, this ion source was not utilized anymore for production-beam generation. The antenna problems had been resolved by improving the insulation, but problems with igniting the plasma gun persisted. Moreover, the power efficiency of this source system faded significantly over 4 of the eight 2-week installations.

A prototype LEBT with two magnetic solenoids is currently being assembled. A far-reaching goal that was already presented in the previous review aims at increasing the beam availability by building a long magnetic LEBT with two ion-source lines and a switching magnet. Beam testing of the switching magnet would occur once the feasibility of the two-solenoid LEBT has been demonstrated. In parallel, the Ion source Group intends to develop an improved electrostatic LEBT with chopper electrodes operated from ground potential.

The long-range ion source development plans are aimed at producing 59 mA at the end of the MEBT. In view of this goal, a variety of ion-source types are going to be investigated, including two different helicons, a magnetron and a reverse magnetron. The last one has been proven elsewhere in a production environment and delivered 50 mA of H^- beam in 1-ms pulses at 10 Hz repetition rate, with an emittance quoted as "larger than 0.2π mm mrad."

6.2 Comments

The mitigation plan for the 2-MHz rf amplifier problems is endorsed by the Committee.

During a tour of the facilities after the review, spent internal antennas were displayed that showed coatings of carbon. Most probably these layers stem from disintegrated O-rings, for example, the ones sealing the filter-magnet tubes inside the discharge chamber that can be exposed to rf power or excessive plasma heat load. The resulting impurities may well have contributed to the noted fading of power efficiency in Run 10-1.

To provide a more suitable environment for the LEBT-chopper electronics, protective series resistors had previously been installed that slowed down the chopping waveforms from about 30 ns rise/fall time to 75 ns. It is plausible that with the now achieved, significantly reduced LEBT sparking rate, the protective resistors can be further downscaled to achieve 40 ns ramping times. This would be especially valuable in view of the declared intention to exclusively utilize the LEBT chopper to provide mini-gaps in the beam.

The noted power-efficiency fading of the external-antenna source was characterized during the review as a poisoning effect, but it remained unclear whether this is caused by material sputtered off the main aluminum-nitride insulator confining the main discharge or stems from the plasma gun. For the latter case, it would be helpful to run the plasma gun in a short-pulsed mode; the duty factor (presently d. c.) could be reduced by as much as a factor of 10^5 and on the other hand a power supply with a much higher voltage than 3 kV, operated in current-limited mode, would eliminate the noted ignition problems.

The plans for LEBT development include the two major LEBT types, magnetic and electrostatic, and the development efforts will be very valuable to narrow down the design choices to accommodate future requirements for increased beam currents. For the magnetic LEBT types, simulations need to include the effects caused by loss of space-charge compensation due to the high electrical fields of chopper and RFQ.

Of the alternative source types that are planned to be investigated, the helicon types require comparatively small SNS funds, but they are rather far from producing high-intensity beam currents at this time. The reverse magnetron represents the most promising approach that utilizes a different discharge technology than rf power.

6.3 Recommendations

- Investigate whether O-rings in the discharge chamber can be exposed to excessive power loads and, if so, devise and implement a mitigation strategy.
- Investigate ways of restoring the LEBT-chopper ramping times of 40 ns and, if found feasible, implement this change.
- Continue the development of the external-antenna rf ion source, employing a short-pulsed plasma gun.
- Pursue a collaboration with the National Science Academy in Sumy, Ukraine, to develop and test a cesiated reverse magnetron at their facility.

7 RFQ, Front End and normal-conducting linac

7.1 Findings

The SNS RFQ has two issues. One is its sudden detuning, which happened twice. The other is that the RFQ becomes unstable with high-duty operation.

It is believed that the detuning happened due to an over-pressurizing of the cooling water, or a steep temperature change. In order to prevent the over-pressurization from happening again, the pumps were replaced by those with a low design pressure, and a bypass valve was set to an output pressure of 110 psi. A temperature alarm was also added in order to observe any steep temperature changes.

The second issue is that the RFQ becomes unstable with the high-duty operation. One hypothesis is that the discharge between vanes starts by adsorbing the hydrogen from the ion source. The warm-linac group is trying every possible remedy for this issue, including a new gate-valve installation between the

LEBT and the RFQ, and an aperture reduction at the RFQ entrance. This is the right approach in the case that the cause for a problem cannot be definitely identified. The similar, but perhaps slightly different, phenomena at the J-PARC RFQ have seriously damaged J-PARC performance. There, the problem has been practically solved in the same manner.

The work on a spare RFQ, with basically the same physical design as that of the present one, but with a mechanically stronger structure, is in progress.

Some improvements in the MEBT are in progress. A new chopper will be equipped with solid copper strip lines instead of the meander line structure, ultimately reducing the extraction losses by increasing the deflection angle by 15%. Also, the horizontal scrapers to be installed will reduce downstream losses. These will contribute to the beam power ramp up.

DTL improvements include new gate valves, and DTL6 temperature control (DTL input windows are described in Section 14.3). The new gate valves are equipped with RF shields, being hidden from electrons by the longer stroke.

The DTL resonance control system is marginal for high duty operation, which is necessary for the power ramp up. The upgrade of the system is perhaps necessary as proposed by the warm-linac group. The proposed action includes cooling system modifications, a more efficient heat exchanger, a more powerful pump, DTL6 tank slug tuner modifications (machining DTL6 slug tuners, with each tuner length to be increased), and a tank temperature increase.

7.2 Comments

Regarding the RFQ, it can be said that the warm-linac group is doing what it should do and it can do. The Committee also agrees that the completion of the spare RFQ needs two years.

Regarding the DTL resonance control system improvements, to develop the most efficient strategy for this work, prioritization of the improvements should be done, since not all of them may be necessary. If the proposed actions are done by step by step, the goal may be reached before everything is done.

In summary, the Committee founds no show stopper in the warm linac for 95% availability and the beam power ramp-up, if the upgrades proposed by the group are completed.

8 Linac beam dynamics

8.1 Findings and Comments

The SNS linac (and J-PARC linac also) have successfully reduced beam loss below the level of 10^{-3}. This beam loss level is just sufficient for the presently required performance. Both the linacs fully take into account the new knowledge acquired by almost twenty or thirty years' world-wide efforts of the high-intensity proton accelerator community. Also, this reveals that both the linacs have sufficient field quality.

However, further efforts to theoretically understand beam loss are definitely required for upgrading machine performance. From that view point, the Committee was very much impressed at the accomplishments regarding the 60° resonance. The SCL phase advance was decreased to around 50° from the baseline value of 60° in March, 2009. As a result, SCL beam loss, as well as residual radioactivity, has been reduced by around 50%. However, beam simulations with IMPACT indicated no big emittance difference between the base line phase advance and the reduced one. Beam simulations with ORBIT have been done with neither RF acceleration nor space charge. The simulation result shows that the weak sixth-order resonance will give rise to a maximum beam emittance increase at a phase advance of 60°, if the duodecapole component is sufficiently large, and the linac is sufficiently long. In order to empirically confirm the simulation result, beam loss was measured by varying the phase advance. Here, all the SCL cavities were turned off, that is, the

186-MeV beams were transported through the linac, while all the correctors were set to zero. The empirical result also showed a beam-loss peak at the phase advance of 60°. The PARMILA simulation with a beam current of 38 mA similarly shows the biggest beam loss, if a 30-unit duodecapole term is included. Beam loss measurement was then conducted with RF acceleration turned on. The effect of the 60° resonance was observed here also. Quantitatively speaking, however, beam loss reduction by reducing the phase advance from 60° is much less than the model prediction. The Committee agrees with the presenter's comment that other factors should be taken into account to obtain agreement between the measurement result and model prediction.

Following the Committee's recommendation, the beam-dynamics and beam-diagnostics groups have been making efforts to understand the longitudinal emittance growth in terms of model simulations. Among the four Bunch Shape Monitors (BSMs) the measured values of one of them could not be fit by any model. This monitor may have some problem. For this reason, the values measured with the other three BSMs were fit with either model XAL or PARMILA. The normalized longitudinal emittances varied from 0.4 to 0.8 mm-mrad in contrast to the design value of 0.3 mm-mrad As the presenter mentioned, further efforts are required to confirm the measured data and to improve the model in order to understand the discrepancy.

Some efforts have been made in the transverse beam matching, resulting in little progress. Theoretically speaking, no model is very useful. For example, the on-line envelope model is not reliable beyond several periods of the linac lattice. Empirically speaking, the data is not reliable, due to ion source transients, and so forth. Progress in the experiments can be foreseen, since it is just a matter of more effort. Then, empirical benchmarking will be possible. On the other hand, the presently available computer simulation codes, like XAL, PARMILA and IMPACT, look insufficient for predicting beam loss below the 10^{-3} level. (IMPACT should be accurate enough, but needs impractically long computation times.) Efforts to theoretically understand beam behavior at this level are strongly encouraged by the committee. Otherwise, accelerator technology progress at high beam power levels will be limited. Here, collaboration with the European HIPPI community and J-PARC linac team is recommended.

8.2 Recommendations

The Committee recommends the study of observed off-normal loss events in the SNS machine to provide feedback to operations. This should include developments and improvements of the simulation codes, together with their benchmarking on the real machine.

9 Superconducting linac cryomodules and cryogenics

9.1 Findings

There has been considerable progress in SRF technology at SNS during the last year:

- The SCL supported neutron production at 1 MW and 930 MeV with 80 out of 81 cavities.
- There is increased understanding and there are new ideas for mitigation of field emission (FE) limitation in high Beta cavities.
- There are new facilities and components.
- The RFTF is considerably upgraded.
- The infrastructure for plasma cleaning R&D is established.
- Major improvements to the PUP cryomodule were worked out.

But events of beam loss in the superconducting linac were observed:

- Vacuum bursts tripped cavities.

- In one event, cavities 5a and 6c lost performance.

9.2 Comments

The Committee applauds the SRF crew for the successful operation of the superconducting linac at and above the 1 MW beam power level. So far the SC linac has been operated in a very reliable manner. The recent down time of 20 hours was mainly due to recovery from beam loss induced quenches. Meanwhile the response time of the MPS has been improved.

The very systematic investigation of FE limitations in high Beta cavities uncovered the reason for reduced cavity performance: low RRR Niobium was used in the end group parts. This material has low thermal conductivity and experiences an unusually rough surface after BCP treatment. It might be worthwhile to try electro-polishing as a repair action, but the remaining bad cooling capability makes this effort very questionable.

Beam loss in the SC linac was caused by errant beam and a too long time delay time of the MPS. The latter problem has been mitigated. Nevertheless beam loss in the SC linac might still happen in the future. Therefore the result of conditioning cavities 5a and 6c will be very decisive for future actions.

The upgraded RFTF, the infrastructure for plasma cleaning R&D, the modifications of the module design and the effort to meet the high pressure vessel code clearly indicate the establishment of a centre of excellence of SRF technology at SNS. This will assure leading knowledge, a pre-requisite for state of the art design, fabrication and processing of new modules for the energy upgrade.

9.3 Recommendations

Immediate term activities:

- Continue RF processing of cavities 5a and 6c to try to recover the original performance.
- It is recommended to carefully examine the hardware and software of the MPS to provide fail safe operation, even under extraordinary operating conditions.

Near term activities:

- Assemble and exchange spare module (after replacing a poor performing cavity, so that the module meets the PUP spec)
- Finalize and implement "in situ" plasma cleaning technology

Medium term activities:

- Any new cryomodules (spares or for the PUP) should use newly fabricated SRF cavities built and processed using J. Mammosser's recipe.

10 HEBT/Ring/RTBT (including foil development)

10.1 Findings

Except for a rash of stripper foil system failures after May 3, 2009, these systems were reliable and were generally available for the 2009 run periods.

A notable achievement in 2009 was running at the design peak intensity of 1.55×10^{14} ppp in the ring with manageable losses during a beam studies run at 1 Hz. In addition, a new higher-power, air-cooled (to avoid radiolysis which plagued the previous water-cooled system) HEBT momentum dump has been designed and installation is underway, which will enable renewed use of HEBT momentum scrapers that proved very useful for reducing beam losses in past operations.

The sequence of foil failures necessitated running for several weeks at reduced beam power (400 kW instead of 800 kW) while the foil problem was studied and a number of potential remedies investigated. Vacuum breakdown (arcing) caused by charge buildup on the stripper foil appears to be the most likely root cause of the majority of foil system failures. Charging of the foil has at least two sources: a) secondary emission from beam passing through the foil and b) reflection of convoy electrons (500 keV electrons stripped from the H^- beam) from the region of the electron catcher.

Several changes to the foil system were made for the last run period including the use of Ti as bracket material and an improved foil mounting for better electrical contact. The new SNS diamond foil lasted for the entire Sept. to Dec. run period and saw a charge to target of 4820 Coulombs compared to the previous record of 978 Coulombs. It is not clear which of the several changes were most responsible for the longer life.

New observations of hot spots and edge glow on the foil along with foil flutter are rather puzzling and not well understood, although some plausible hypotheses have been advanced. The edge glow that persists for 1-2 second after the beam is shut off is very mysterious. The lack of a clear understanding of these observations poses unknown risk factors to reaching reliable operation at the design intensity.

Development of reliable, long-life foils and foil handling system is an active program that has been underway for several years at SNS. The corrugated nano-crystalline diamond foils developed at SNS were highly successful until the problems at higher power were experienced in May, 2009. In light of recent experience, the development of more conductive, long life time foils to significantly reduce foil charging is highly desirable.

Development of more conductive diamond foils via boron doping is underway, and thin metallic coatings are being considered. Development of HBC (hybrid boron carbon)-like foils is an option also under consideration. The 30 keV electron test stand, now in place at SNS, is a valuable tool for evaluating foil lifetimes and maximum operating temperatures and is expected to be used extensively in the present foil development program.

The e-p instability shows up well below the design intensity but has been controlled (just barely) at the design intensity using the full ring RF voltage. Active damping (transverse feedback) has been shown to have some beneficial effect on the e-p instability and, if further developed, could provide a highly desirable margin of safety.

The value of TiN coating for stainless steel vacuum chambers has been questioned in the light of data obtained in the past few years. A systematic study to resolve this issue can be expensive. SNS has already made the investment in the hardware for TiN coating and will prudently continue to coat new chambers that are installed in the ring.

10.2 Comments and Recommendations

The Committee applauds the vigorous effort to understand and correct the foil system failures. We endorse an aggressive follow up program to develop better foils and improve the foil handling system. The capability to measure the electrical signal from the foils will be a valuable diagnostic.

The Committee strongly encourages a focus on the development of higher conductivity foils with long lifetimes.

The HBC foil developed at KEK has excellent lifetime in high intensity proton beams such as the LANL PSR and is expected to have good conductivity. We suggest that an HBC foil also be tested at SNS.

11 Ring beam dynamics

11.1 Findings

Orbit Response Matrix (ORM) methods are used routinely to improve the ring lattice model and obtain better agreement between measured and predicted values for tunes and the average beta function. However, beta function measurements using Model Independent Analysis (MIA) shows significant beta function beating in both planes.

The benchmarking program for ORBIT revealed problems with the painting waveforms, which have now been corrected, but there are still some disagreements between measurements and simulations of transverse beam profiles at high intensity in the vertical plane for the painted beam case. These are presently under study.

The measured losses at A13b are in reasonable agreement with simulations.

Good agreement between simulations and measurements were obtained for the kicker-impedance-driven instability.

The e-p instability observed at SNS for bunched beams is controlled, for present operations, by sufficient ring RF voltage and control of the longitudinal profile to avoid a long trailing edge. However, the instability is not well understood nor adequately characterized to reliably assess its risk to the power upgrade goals. The source(s) of the electron clouds that drive the instability is still a key unknown. Another problem is a lack of systematic and reproducible experimental data characterizing the instability and the factors influencing it.

11.2 Comments and Recommendations

It is the Committee's assessment that the overall progress on understanding and modeling of the ring optics and beam dynamics is progressing at a reasonable pace to meet the 1.4 MW goals.

We encourage a systematic and sustainable program to better understand the e-p instability and the factors that affect it.

12 Target systems

12.1 Findings and Comments

12.1.1 Overall Evolution and Target Systems Availability

SNS has, for the first time in history, run a spallation target in pulsed mode at a power level of 1 MW for an extended period of time, which is a great achievement and the result of zealous endeavors of the whole team. This deserves unrestrained applause! The success was made possible by carefully developing all subsystems to a point where they were able to cope with the extreme loads at this power level. This included solving problems with the mercury pump sealings, bringing a cryogenic heat exchanger up to specified performance, correcting a manufacturing fault in a cryogenic moderator, developing a totally non-invasive beam profile monitoring system, etc.

Since SNS is now in user mode, emphasis is being put on availability of the facility, which means that reliable functioning of all parts during scheduled operation periods is of high priority. While this will, in the long run, also have to be true for the mercury target system, SNS must be given credit for the novelty of this concept and the total lack of operating experience with such a target elsewhere. The SNS management has, therefore, created the concept of “planned unscheduled shutdowns” in case a target would have to be replaced during a scheduled running period. These would not count against the availability goal of 85% (now), and respectively 95% (long term).

The Committee concurs with this concept but also strongly supports the management’s position that this situation should prevail for as short a time as possible. SNS therefore wants to arrive at a situation where they can safely count on covering a full year’s operation with four targets at most and if necessary keep the beam power at a level which is consistent with this goal. This would enable them to schedule beam time in such a way that target exchanges will happen during scheduled shutdowns. Again, the Committee favors this plan, over the concept of running targets to failure at the highest beam power available.

This position is also a consequence of the findings from the inspection of the first target (see Section 12.1.2), because it turned out that the most vulnerable part is not the outer wall of the target vessel, whose failure would cause a detectable leak into the interspace to the water cooled shroud, but rather the inner wall, whose failure is much less consequential but also more difficult - if not impossible - to detect. This means a shift towards the situation where radiation damage, which affects the target shroud in a similar way as the target container, becomes life time limiting[1].Even then, however, there is still a big likelihood for the target vessel to fail before the shroud due to its much more severe mechanical load situation. Thus the interspace leak detection system remains of great importance. It would be particularly desirable to have a system which can detect a crack or very small leak even before mercury enters the volume in larger quantities (see Section 12.1.3).

12.1.2 Target Development

The first target module was removed during the shutdown in July, 2009, after having received a beam load corresponding to a peak damage rate in excess of 7.5 dpa (displacements per atom), which is 50% more than the original limit set by some materials experts. While dpa damage is considered the life time limiting factor at low-to-moderate pulse intensities, cavitation erosion becomes a bigger concern as the pulse power increases. The first SNS target went exactly through this transition during its service life and hence it was of major interest to see to what extent and where in the target such damage had occurred. In particular circumstantial evidence was believed to exist that

- the damage was particularly high in a narrow channel (such as the space between the inner and outer wall of the target shell), and
- shear flow along the wall would reduce the degree of damage.

Examination of samples cut out by core drilling from the four walls of the first target seem to reveal that

- flow has indeed a strongly mitigating effect on the damage - to an extent that no severe damage at all was found on the outer target wall, and
- the inner target wall was severely damaged in the center of the beam entrance area where the mercury flow has a stagnation region near the wall - to an extent where small holes had developed all the way through the wall.

In other words, the positive effect of flow seems to have been confirmed and seems to be strong enough to counteract the enhanced damage in narrow channels which had been observed in experiments with stagnant mercury. This may be considered good news and - together with results from the ongoing R&D efforts - may open up a route to stepwise improvement of the target life over the next few years (see Section 12.2).

An interesting observation was the absence of obvious rapid crack propagation in the cavitation affected zone. Based on earlier off-beam tests the damage was thought to be combined with fatigue whose crack propagation initiates at the bottom of the pits. However, several isolated holes caused by mercury cavitation were recognized in the specimen taken from the inner wall of the beam window. Using the

[1]This is the situation which all efforts to mitigate cavitation damage aim at.

recorded beam history and the evaluated dependence of damage on pulse power, the JAEA-JSNS team analyzed inversely the relationship between each power level and related erosion depth, assuming that the hole penetrated through the 3 mm thick wall just before the first target was replaced.

According to this analysis some erosion occurred even below 200 kW and the erosion was accelerated above 400 kW. This allowed an estimate of the time until the pit holes would penetrate the thickness of 3 mm at 1.4 MW, assuming the beam profile was the same as in the past at lower power. The estimated time to the penetration is two weeks for 1.4 MW at 60 Hz or four weeks at 1 MW.

In order to judge how this would affect the end of life of the target, it would be important to evaluate the influence of an inner wall failure on the operation. However, such estimates are very speculative, since the flow pattern may be affected more or less due to the eroded holes or tears in the inner wall, depending on the sizes of eroded areas. Assuming pessimistically that cavitation erosion on the outer wall sets in immediately after the inner wall has been perforated, one might anticipate a service life of the target of four weeks at 1.4 MW (eight weeks at 1 MW) until leakage occurs into the interspace to the outer shroud, where it can be detected.

There is concern that fragments from the eroded parts of the inner wall might get trapped in the heat exchanger pipes, valves, etc. of the mercury loop. It is, therefore, wise to limit the beam power to a value which is consistent with four target changes per year. This beam power level, however, remains to de determined.

Good progress was also made in the efforts to find a long term solution to the cavitation problem by gas injection into the mercury. These efforts are carried out in close and fruitful collaboration with the JAEA-JSNS team who are pursuing a similar target concept. The two potentially useful techniques have been identified: injection of small bubbles into the mercury or establishing a protective gas layer along those walls which are particularly vulnerable to corrosive attack.

In-beam experiments carried out at Los Alamos with the protective layer have not yet been analyzed in full detail but first inspection seems to show very little or no damage on a surface which was covered with a drilled texture to enhance gas coverage. Given the finding that erosion damage was mainly concentrated in the center of the beam window, this technique may be a good choice if it can be developed to function in a realistic window geometry and mercury flow conditions. In parallel, good progress was also made in developing the small bubble injection technique and bubble diagnostics. Nevertheless it will be several years before a target with active cavitation mitigation will be available. For this reason it is highly desirable to experiment with flow manipulation in the near term (see Section 12.2).

12.1.3 Other Target System Improvement Plans.

Leak detection system Dependable detection of a leak of mercury into the interspace between the target container and the water cooled shroud is important for saving the outer shell. Currently there are two diverse systems in place:

- two continuity probes which are checked periodically for continuity throughout operation, and
- a heated thermocouple junction, calibrated for Hg and H_2O leakage into the system.

The SNS team has analyzed the situation of undetected leakage of mercury into the interspace and found that the helium in the interspace would be compressed enough to allow the mercury to rise above the beam level. In order to avoid this situation the Team is proposing to add burst discs to the helium space which are set in such a way that they would yield at a pressure low enough to be reached before the mercury rises to the beam level. Yielding of the burst discs would then provide an additional trigger for beam interrupt.

While the Committee supports the efforts to add more diversity to the leak detection system, it seems important to analyze carefully the risks (e.g., of contamination) associated with the proposed system and also the likelihood of malfunctioning or false alarms. Another option might be to create a continuous stream of helium through the interspace and analyze the gas for certain typical volatile isotopes produced in the mercury. The advantage of this system would be that it triggers before a large leak develops, as soon as the first perforation of the target container occurs.

Target (beam) imaging system The SNS team has developed a system which allows to analyze the beam distribution directly on the target window by viewing a fluorescent screen via a system of optical mirrors and fiber cables. This has been a highly successful development adding important capability to analyze and control the beam on target. The performance is satisfactory at the present current level, but more development, as proposed, will certainly help enhance its accountability and dependability in the future. The Committee supports this effort unanimously, since precise control over the beam profile will grow in importance as the beam power goes up. In this context it will be important to understand exactly the effect of radiation damage on the optically observed image up to 10 dpa on the target vessel in order to have a dependable measure of the beam distribution which extends over areas of varying radiation damage (locally as well as temporally) as irradiation goes on.

Development of a rotating target SNS has embarked on the development of a rotating target as a possible alternative for a future second target station (STS). The main advantages of this system are

- it does not use liquid mercury and hence is not prone to cavitation damage,
- in case of a leak there would only water be entering the target vault which is much less of a hazard to aluminum structures than mercury, and
- the radiation damage is equally distributed over the whole target circumference, extending the target service life by more than an order of magnitude.

For STS this option holds a promise for a target life time of 10 years or more. All wear parts are in a region where they are accessible for hands on maintenance and repair. Ongoing work has been very successful so far, and has resulted in a thorough thermo-mechanical analysis and an impressive demonstration test stand for the wheel and its drive and water feed system. More studies are needed to prepare a qualified decision, since this would introduce a new technology with its associated side effects on handling and waste disposal. Unfortunately the prospect for a second target station has been moved in the more distant future by DOE during the period of this review, but it would certainly be wise to devote enough resources to the development of the technology to make sure that it can be documented comprehensively.

12.1.4 Component Replacement / Remote Handling / Waste

Remote handling plays a major role in the operation and maintenance of the SNS target systems due to the high and wide spread activation levels caused by the energetic neutrons generated in the spallation process. All of the systems that need to be replaced or maintained in high radiation zones have, therefore, been designed with a view on remote handling.

In the mean time two major components directly exposed to the proton beam have been replaced remotely, by and large demonstrating the validity of the SNS remote handling concept: the first target shell and the first proton beam window. Both operations went essentially according to plan but nevertheless there were important lessons learned. In particular when pulling a vacuum on the mercury process loop (originally not part of the target exchange procedure) a leak was discovered which took the better part of three weeks to localize because it was in the non-accessible part of the loop with the target in operating position. In the end, after improvising tools and procedures for the leak detection, the problem could be fixed by re-torquing a Hiltap fitting, which took a couple of minutes. As a consequence the team now considers regular use of many of the tools and procedures in future target replacements and plans to develop similar procedures for the water, vacuum, and helium loops. While this may help to identify problems prior to inserting the target cart, it will clearly add to the complexity and duration of the target replacement process.

The Committee concurs with the idea of having emergency procedures at hand but would like to caution the operations team against counting on using them. Instead, the team should make sure that all standard replacement procedures are described precisely and in sufficient detail, including numerical values, e.g. for the torques to be applied or dimensions to be checked. Adherence to these rules during the replacement process should be closely monitored to avoid having to take corrective actions afterwards.

High levels of contamination were observed during the target replacement by direct smears of servo-manipulator grips and also of the in-cell 7.5 ton crane hook and block. By the nature of these operations, these components were in direct contact with mercury-contaminated tools and components. Their contamination is to be expected and was anticipated.

No Transfer Bay entries have been performed following the nose drilling operation to ascertain contamination levels. While the liquid mercury released during drilling was trapped in the hole cutters and the assembly enclosure, mercury vapor can propagate widely and condense on surfaces. This potential for contamination must be closely watched in particular in the Transfer Bay.

Measures to trap mercury vapor on absorbers with the help of a portable ventilation system during operations such as hole drilling might be worth considering. Although the target service area is designed for completely remote operation, high contamination levels constitute a big nuisance because they complicate severely any transfer of tools or parts into and out of the Bay and pose a risk for contamination to be set free outside the Bay.

While detailed planning and - where possible - mockup practice of remote handling operations is particularly important for systems containing radioactive fluids, efficient remote handling techniques become increasingly important also in other areas as the beam power continues to go up, in particular with respect to availability. The imminent core vessel insert replacement on BL 16 will be a challenge which must be thought through in all details. Extensive practice on the MUTS (Mock Up Test Stand) as exercised by the team is of great importance and should be done in all details.

Finally, it came to the Committee's attention that a problem that seems to be creeping up is disposal of radioactive or contaminated waste. It is important to make sure that pileup of stored radioactive components does not jeopardize source operation.

12.1.5 Cold Moderator Operation and Development

With the successful completion of a corrective action to a manufacturing fault in one of the cryogenic moderators just prior to the 2009 meeting of the Committee, SNS is now able to run its cryogenic moderator system at full design power level. However, SNS has luckily avoided two potential down times because the respective incidents occurred during shut down periods:

- a power outage on the CMS compressor controls which, while lasting only a few seconds, may cause a down time of several days and
- degradation of the moderator refrigerator capacity due to contamination of the heat exchanger and adsorber, which was discovered and fixed during a shutdown.

Experiences of this kind are not unusual in the early phases of facility operation and contribute to the knowledge base of the operating crew. It is important, however, that such incidents receive proper attention and that operating procedures be updated to prevent similar things from affecting the source availability in the future.

Novel moderator concepts Interesting ideas have been presented which may hold a promise to make pulsed source moderators more effective by directing a larger fraction of the neutrons produced into the beam tubes. These concepts are based on the use of interleaved systems of solid and liquid materials with the goal of creating a preferred direction for the leakage of the cold moderators from the system. According to some estimates gains up to a factor of three are achievable in theory. While this would be a great achievement if realized in practice, there is still a large amount of study work required to demonstrate that such systems can be operated and are still effective under the high load conditions prevailing in SNS. Nevertheless it is worth while pursuing these ideas with an appropriate effort in the medium term by identifying critical issues and showing that they can be overcome. SNS has proposed a new Moderator Laboratory for a variety of development and testing tasks such as testing and qualifying sensors and actuators. This laboratory would certainly be an important asset also in the effort of pursuing novel ideas.

12.2 Recommendations

The Committee considers it highly important to arrive at a situation, where unscheduled planned shutdowns will not affect the de facto availability of SNS. We therefore have the following recommendations:

1. Run the present target (Target 2) and the two following ones (Target 3 and 4) at the highest possible beam power until they fail. If, at the beginning of a scheduled maintenance shutdown any one of them has reached a dpa level (of the order of 10) which raises doubts that it will survive another scheduled operating period, exchange it during the shutdown. If necessary, announce an extension of the shutdown to the users before they arrive.

2. For the next target (Target 3), try to establish a flow configuration (by tailoring the inlet flow orifices) which moves the stagnation region as far as possible from the window center in order to reduce the cavitation damage at this position and verify the importance of shear flow for damage mitigation.

3. Try to interfere with the manufacturing process of one of the targets presently on order by introducing a flow baffle which directs part of the flow from one inlet channel all the way across the beam entrance window to establish shear flow on the whole entrance window. Use this as early as possible (Target 4?) to obtain conclusive evidence if a cross flow configuration is less prone to cavitation erosion than the present dual inlet flow.

4. Based on the experience with Targets 2, 3 and 4, adjust the operations schedule to accommodate sufficiently long shutdown periods before the projected end of service life of each of the following targets. In the mean time, in order to minimize the number of unscheduled planned shutdowns, adjust the current operating schedule for bi-monthly target exchanges and perform an estimate of the tolerable beam power.

5. In parallel, continue to explore the potential of gas injection, in particular the gas wall concept, for its potential to mitigate cavitation damage in a realistic target configuration (curved window). At the same time continue the highly efficient collaboration with JSNS on the gas bubble injection technique.

6. Give high priority to PIE (post irradiation examination) of spent targets - including further work on Target 1 - in order to verify the validity of the conclusions drawn from the first examination of Target 1. In addition examine the tensile and/or fatigue properties of specimens from high dpa regions not strongly affected by cavitation in order to explore the dpa limits the targets can be taken to in the long run. This should allow the development of a long term mitigation scheme which can be incorporated in the design of future targets and establish an irradiation dose which the targets can safely be taken to.

7. In the effort to add more diversity to the leak detection system for the target interspace, try to go for a system which has the capability of early warning (e.g. by analyzing the isotope content of the helium) rather than - or in addition to - a "post mortem" system which is activated by a rising mercury level in the interspace.

8. Continue improving the optical target inspection system with particular emphasis on long term reliability under the effect of irradiation. Ideally image processing software should be developed which corrects for the spatial and temporal change in emissivity of the fluorescent screen as it degrades under irradiation.

9. Carry out an analysis to search for systems which are particularly vulnerable to short power losses and would create long down times as a consequence of such losses. Hook these systems up to an uninterrupted emergency power supply.
10. Carry out preventive maintenance during scheduled shutdown periods on systems which are known to degrade with time, such as the cryogenic heat exchanger and its adsorber.
11. Re-examine all procedures on mercury-containing parts or systems with a view to minimizing spills and controlling contamination spread in the Service Bay.

13 High Voltage Converter Modulators

13.1 Findings

The Committee recognizes the accomplishments in the improvements of the HVCM system reliability. The accomplishments include the formation of a development group, not responsible for the day-to-day operation and maintenance of the HVCM, which allows for the investigation of improvements to the HVCM. This group has developed a new IGBT driver circuit and a new control specification and system. The group also determined that an adjustment to the HVCM turn off procedure appeared to improve the reliability of the HVCM. The completion of a dedicated HVCM test stand with full rated load allows for extensive testing of the 4kV capacitors, the new driver, and control system. The replacement of the 4kV capacitors with pre-tested self-healing capacitors may result in improved availability. The HVCM modulator however is still the major contributor to the down time of the SNS Accelerator. To meet the 90% or 95% availability requirements, significant improvements must be made to the HVCM.

13.2 Recommendations

The Committee recommends for immediate action the following items to help insure an improved availability:

1. Implement "snubber" networks on all of the HVCM IGBT's. Measurements made by the development group demonstrated that the "snap off" of the IGBT diodes during turn off results in fast over voltages on the HVCM switching IGBT's. By changing the turn-off timing of the IGBT's, there was a significant reduction in the over voltages and an apparent improvement in availability. The turn-off the IGBT's due to random fault conditions is not controllable, which may result in "snap off" over voltage problems. The classic way of reducing diode "snap off" over voltage is the use of a "snubber" network. The original HVCM simplified schematic indicates that there were such snubbers, but they were never implemented.
2. Implement the new IGBT driver. The present IGBT driver circuit has no protection for over current, over voltage, or auxiliary supply under voltage, which subjects the IGBT to possible failures under unusual conditions. In addition, there is no provision for preventing the two inline IGBT's from turning on at the same time, the so-called "shoot thru" condition. The "shoot thru" fault then results in a catastrophic explosion failure. The new IGBT drive circuits (SLAC design with improved monitoring by the development group) should be implemented as soon as practical. The new IGBT drive will not only protect the IGBT's but will provide valuable information about the performance of the IGBT's.
3. Measurements should be made on new capacitors, in the test stand, to verify that the losses are or are not the ongoing capacitor problems. The high voltage resonance capacitors in oil are beginning to fail. It is not clear that the problem is internal overheating, and that a lower loss capacitor will solve this problem. The failures could be coronal failures due to the high dV/dT inherent in the present design.
4. The capacitor bank fast disconnect switch should be implemented to eliminate the fires and/or explosions resulting from equipment failure. The result of an IGBT failure will result in a "shoot thru" or short circuit of the 100kJ energy storage capacitor. Under this circumstance, due to the very low

impedance between the IGBT and the energy storage capacitor, it is unlikely that the non-failed IGBT can interrupt the resulting dI/dT of > 10 kA/μs. The IGBT can successfully interrupt the currents of spark down test with a $dI/dT < 3$ kA/μs To insure that the IGBTs can clear such a fault an impedance of ~ 1 μH should be installed between the two series IGBTs. In addition to prevent the explosive behavior resulting from the "shoot thru" faults the "energy storage capacitor bank fast disconnect switch" should be implemented. To insure that the fast disconnect switch will clear the fault, a resistor of ~ 0.2 Ω shunted with ~ 1 μH should be installed in series with each fast disconnect switch. This would limit the fault current rise to < 5 kA yet have low loss and not affect of the normal pulse current which has a much slower rise time.

5. The present control and monitoring system should be replaced as quickly as practical. The present system is very inflexible and hard to control and is a real limitation on the ability to diagnose the failure problems of the modulator. It also has no ability to control the core magnetic flux, which should be implemented with the new control system.

The Committee also recommends that a long-term development be implemented consisting of a minimum of the following:

1. Undertake a systematic review of the IGBT failures. The IGBT failures are not at present understood. The IGBT failures under phase control operation are even more perplexing. There are lots of possibilities, such as over temperature from increased switching losses due to resonance frequency changes, diode "snap off" over voltage, power loss from the diodes causing an over temperature failure, or "shoot thru" due to improper IGBT triggering. To improve the availability, the cause and remedies for the IGBT failures need much more study.

2. The rectifier topology of the HVCM uses an unusual configuration consisting of a wye connected secondary winding of the transformer with the center point connected by capacitors to the output. This type of connection, not only requires very high output voltage swings on the resonance capacitor, but also allows the possibility of generation of the so-called "zero sequence" third harmonic currents, which flow from the transformers and can affect the transformers magnifying current. The center tape wye connection is a difficult configuration to control properly. The more conventional topology of series stacking lower voltage full wave bridge rectifiers would reduce the voltage stress on the resonant capacitors and decouple the three individual drivers for much more flexibility in operation.

3. Develop an automatic method of controlling the IGBT's power loss and the transformer core saturation so that small changes in individual components, such as capacitance value changes or connection impedances, do not move the modulator into an unsafe operation condition. Convert the modulator from an open loop control circuit to a closed loop control modulator

14 RF systems

14.1 Introduction

The RF systems group is in charge of many pieces of equipment: ion Source RF, RFQ, MEBT rebuncher system, warm linac RF, superconducting linac (SCL) RF, ring RF, low level RF and RF test stand. The status of all this equipment was reported. On the basis of operational experience, reliability issues were discussed, together with klystron spare inventories. Finally, the strategy for operation at 95% beam availability was proposed. In the following, the Committee will make somewhat general comments and recommendations for the availability issues. Then, it will present its findings for each component together with its comments and recommendations.

14.2 General Comments and Recommendations for Availability Issues

The SNS is focusing its efforts on the improvement in beam availability. The availability is to be improved to maximize the scientific output of the facility. Then, not only the downtime, but also the event rate (or trip rate) should be minimized in order to maximize the quality of the experiments, in general. It is also noted that the latter contributes to minimization of the down time itself.

As already mentioned in the last AAC report, the major contributor to the trip rate and down time is in general the high-power RF and pulsed components. From this viewpoint, the Committee feels that the down time budget is too low for these two systems.

The trip rate (and the downtime) of high-power RF and pulsed components can only be improved by increasing the maximum possible peak power and the duty factor, say by 20 or 30% at least, if you are trying to obtain an availability more than 99%. It is thus highly recommended to develop and improve the power/duty capabilities of all the high-power RF and pulse components. As a matter of course, a sufficient number of spares and a good replacement scenario decreases the downtime. The presently proposed efforts will be effective for this purpose.

14.3 The present status of each component system.

The RF group is in charge of the 2-MHz RF system driving the ion source. In order to maximize the reliability of this RF system, a solid-state amplifier to be operated at ground by use of an isolation transformer is under preparation. The transformer will be combined with a matching network to cope with the various plasma conditions of the ion source as an RF load. The first Tomco amplifier with a power of 60 kW was set up for a site-acceptance test, while the second unit is on order. The transformer was prototyped. In this way, the new ultimate system is progressing well.

The MEBT rebuncher system will also make use of the Tomco solid-state amplifiers for improving its reliability and availability. At present, the system without the solid-state amplifier is in operation at a design power level of 20 kW and the down time was reduced to nearly zero by enabling the reset of the trip-off amplifiers from the control room. Nevertheless, in order to further reduce its trip-off rate, the group plans to install solid-state amplifiers. Cavity 4 is already powered by a solid-state amplifier, which will be installed in the other three cavities in the near future. One spare amplifier will be remotely switched to power any cavity. The existing system will remain in place and can be connected if necessary. The Committee believes that the RF group is making effort in the right direction to maximize the availability by very careful planning.

The RFQ has two issues. One is a shift in frequency and field flatness, which occurred twice, seemingly to be the result of a vane shifting due to a water pressure surge during maintenance. This issue is discussed in Section 7. The other issue is with loss of resonance control at high duty after several hours of operation. Every possible remedy for this issue has been tried, by limiting the gas flow from the ion source, improving water cooling, regulating pulse width and chiller temperature, adding pressure relief valves and changing chiller pumps.

The only issue found in the normal-conducting linac is a vacuum leak on the DTL-6 RF window. It was traced to a braze joint in the vacuum-side waveguide section. The window was not only replaced during the maintenance period, but also two spare windows have been RF-conditioned in order to prepare for the case that other windows begin to leak similarly. In addition, three spare windows were ordered with a welded joint rather than brazed, and three more spares will be built in-house. It can be said that due care is being taken for avoiding risk of shut down by the window problem.

The klystron lifetime is important for judging whether the number of spare klystrons is sufficient. However, the perveance data so far recorded is not sufficient for estimating the lifetime. For this reason, more detailed data taking has started, including waveform data. The Committee encourages this kind of effort to contribute to spares management.

The SCL RF Power limitation has been resolved, since the klystrons for SCL are now in operation at design cathode voltage of 75 kV. On the other hand, nine Thales klystrons for SCL had to be replaced, while two are planned to be replaced during next maintenance period. Three klystrons showed instability issues. In this relation it is noted that all klystrons have more or less high gain. The RF group did not present the reason for these frequent replacements in more detail. It is recommended to solve the issues by finding the reason why so many klystrons had to be replaced. Otherwise, the number of klystrons which should be replaced in future may possibly increase. As the RF group mentioned briefly, the problem may be associated with too high gain, which tends to give rise to the instability. Electron beam analysis is usually necessary to find the remedy for this kind of problem. A close collaboration with the vendor is then required. The RF group discussed the issues of the SCL cavities and couplers. These are detailed in Section 9.

For the Ring RF system, several QEI amplifiers and several Lambda ALE anode supplies have failed. The former cannot be repaired any more, since their replacement components are no longer available. The Tomco solid-state amplifiers will replace the QEI amplifiers from now on. The Committee agrees with the expectation of the RF group that this will improve the availability also. The latter will be repaired in-house from now on, since the in-house capability is under development with the support of the vendor.

14.4 Beam availability issues

When one analyzes the machine performance on the basis of downtime statistics of each component system, it is very important to categorize the down-time events correctly from the viewpoint of improving the availability. The downtime budget and the improvement-effort budget will be formed on the basis of this kind of analysis. As already noticed by the RF group, most of the trip events arising from the discharge in the Superconducting Cavities (SCC) including the high-power input couplers were classified into the Low-Level RF (LLRF) events, simply because the events were detected by the LLRF system (it is interesting that this classification had also been done at J-PARC for the same reason, which has recently been corrected). Although the RF group is correctly classifying these events, the classification by the operational group like LLRF SCL is still misleading. As physical phenomena, these events are not at Low Level (LL), but at High Power (HP). The classification of this kind of down events should be defined in terms of the same non-misleading terminology, for example, "SCC discharge", to create the same understanding of the phenomena between different groups. It is also recommended that similar kinds of misleading classifications should be eliminated by carefully reviewing the other events.

The RF downtime seems to show no improvement from FY08 to FY09. However, most of the RF downtime at present arises from the MEBT rebunchers. (The down times of the other components were significantly decreased.) The seemingly long downtime of the rebunchers arose from intentionally changing the reset procedure for protecting the circuits. The rebuncher downtime was drastically decreased by recharging the filter capacitors in a current regulated mode (and by enabling quick reset). In near future, a solid state amplifier will replace the present system, further reducing the down time.

Although most of the LLRF down times are actually arising from SCC discharges, there still remain some issues in the LLRF system. The present Input/Output Controllers (IOCs) are heavily loaded, resulting in some problems. The improved IOCs will replace the present ones, while the data throughput will be improved to lower the IOC loading. The new system will be implemented and tested in the near future. Also, various efforts are being undertaken to improve the temperature stabilization of the LLRF. All these efforts will improve the LLRF control, resulting in better reproducibility and more stable operation. These are very important for upgrading the beam intensity and minimizing beam loss.

The RF test stand is a very important facility for improving RF performance, since the R&D for the high-power RF components including klystrons, RF windows, and SCC, can be efficiently and experimentally done only with this facility. HVCM improvement can also be done here using high-power long-term tests. Therefore, the Committee is pleased to hear that the facility will be ready soon.

Three types of klystrons, two types of tetrode and one type of triode (this will be replaced by a series of high-power RF transistors) are made use of in the SNS accelerator complex. Special care has been taken to store seemingly sufficient number of spares for each type of vacuum tube. However, the klystrons for SCL look to have some instability issues, implying a slight risk for shortage of spares. As previously mentioned, a study to solve this problem should start as soon as possible in order to minimize this risk.

14.5 Towards the 95-percent availability

The RF group presented a full-fledged list of proposals for operation with a beam availability more than 95 percent. However, the down-time budget of 0.76 percent allocated to the RF system looks too small, taking into consideration the experience of the other machines as mentioned at the beginning of this section. Twice this value is perhaps a reasonable measure. Here, not only the SNS statistics but also the statistics of other machines world-wide should be investigated to form a feasible strategy. The reason for this too small budget arises from a too large budget allocated to the HVCM down time, which is based upon the present SNS statistics. It should be noted that the present performance of the HVCM is very abnormal. In other words, the availability of 95 percent will be far from realization without solving the problem of abnormal HVCM performance.

Finally, the Committee recommends that the priority of all the proposals for availability improvements should be properly established. This will also contribute to steady progress toward the final availability goal.

15 Control systems

15.1 Findings

The Controls Group experienced no major problems and successfully addressed a number of issues. At 98.75%, the combined availability of Controls, Machine Protection (MPS) and Personnel Protection (PPS) Systems in Q1 of FY 2010 is slightly better than the assigned budget to achieve 85% SNS availability.

The IOC-PLC communication problems mentioned in the previous review were solved by implementing a series of hardware repairs, and installing upgraded processors and software/firmware upgrades. Interactions with the PLC vendor proved very helpful for the identification of individual issues and mitigation measures. No further failures occurred since the last summer outage.

Many MPS nodes exhibited large delay times up to 194 μs compared to a nominal value of 20 μs, and this problem was addressed and resolved.

A solution for an overload problem with the Low-Level RF (LLRF) processors was found: A much more powerful processor was identified and will be implemented as standard after the winter outage.

The radiation monitors exhibited some failures due to electrometer and/or high-voltage board instabilities and occasional, momentary fail signals, and these problems were resolved by redesigning the former hardware components, adding a 30-second delay on the “hard” PPS shutdown implementation and utilizing the MPS instead for an immediate shutdown.

Noise induced trips caused by the klystrons were eliminated by damping this noise at the origin and bridging a ground break in the RTBT sector.

As announced in the previous review, new archiver and alarm handler utilities are deployed on a new Oracle cluster entirely separate from the ORNL Enterprise Network.

15.2 Comments

The Controls Group is to be commended for a solid performance, systematically addressing all issues and resolving them.

16 Beam instrumentation systems

16.1 Findings

The existing beam instrumentation suite is fully capable of supporting machine tuning activities and production runs. The downtime caused by beam diagnostics systems is low; the assigned downtime budget is less than 10 hours in FY 2010, commensurate with past year's performance of 12 hours lost that were mainly due to a resolved problem with the Beam Loss Monitor software.

The Laser "wire" scanner system was implemented; one laser can be utilized at 9 different locations along the SCL, directing its light by mirrors. A problem with excessive mirror vibrations was resolved by redesigning the mirror mounts, and this resulted in about ten times better signal stability and up to 60% reduction of noise on the measured beam profiles. Future plans include increasing the feedback band width and inserting compensation magnets for the ion beam at every measurement station.

A HEBT beam scraper system was implemented to measure halo down to the 10^{-5} level. In a related effort on the wire scanners, the cross talk between horizontal and vertical wires was reduced by eliminating the 45° wire entirely and the intersection of the remaining two wires.

The ring profile monitor that uses an electron beam was equipped with magnetic shielding, greatly improving the signal stability. The system performance is still limited by the maximum beam energy of 60 kV, and a collaboration with Budker Institute has been initiated, aiming at developing a 100-keV beam.

A feedback damping system was installed, operating with an analog processor and an 800-W amplifier with 300-MHz bandwidth. Suppression of the e-p instability has been demonstrated in proof-of-principle fashion, and the Group now plans to change to a digital controller.

A high-power mode-locked laser with 2.2 MW peak power in each of 12 micro pulses of 55 ps duration has been installed in a dedicated room and will support the next series of laser-stripping experiments

The main goal for FY 10 is to bring the Beam Shape Monitor and MEBT emittance devices into user-friendly status to speed up the measurement times.

16.2 Comments

The Instrumentation Group is to be commended for achieving significant progress with a number of diagnostic devices and achieving excellent availability in their area of responsibility.

17 Accelerator Engineering

17.1 Findings

The engineering group has now got into a rhythm of building projects while the accelerator is operating and installing during the downtime. The work is aimed towards repair of those items that are causing downtime.

Recent projects include:

- Accelerator cooling system upgrades
- Momentum dump cooling loop

Projects currently in progress:

- New magnetic LEBT

- Momentum Dump
- MEBT scraper
- MEBT Chopper
- Primary & Secondary Strippers
- RID Aperture Increase
- Ring Beam Dampers
- HARP Assembly
- Spare Cryomodule
- Laser wire station corrector magnet

17.2 Comments

All of the work appeared to be well designed, executed and planned, and the quantity of work is impressive. Much of the work involves reworking equipment that was not well engineered initially (not done at SNS). One example is replacing the bolted flanges in high radiation areas with quick disconnect flanges - an excellent ALARA project. There is no evidence that corners are being cut in the rework or any of the other projects, so we can look forward to this kind of work tapering off to the benefit of an increase in those projects that enhance the accelerator performance. There seem to be few risks, and the priorities are well adapted to improving availability and continuing the performance ramp-up.

17.3 Recommendation

The project to redesign the Injection Dump is based on air cooling. The use of dry nitrogen to cool the dump rather than air is recommended to avoid ozone and nitric acid production.

18 Power and current Upgrade Projects

18.1 Findings and Comments

The Power Upgrade Plan (PUP) and the set of Current Upgrade Accelerator Improvement Projects (CU-AIP) represent a coordinated push to increase both the beam energy and beam power capabilities of SNS. The PUP is a formal project, subject to the standard DOE requirements, aimed at increasing the beam energy to 1.3 GeV. Achievement of this energy will naturally raise the beam power to 1.8 MW. The CU-AIP is a set of AIPs designed to raise the beam current to a level corresponding to 3.0 MW at the 1.3 GeV beam energy supported by the PUP.

The PUP strategy is based on adding 9 cryomodules to the linac, along with their accompanying power sources (36 klystrons and 4 modulators). Such an upgrade was foreseen during the original SNS construction and hence space for these components exists in the linac tunnel and gallery. In addition upgrades to the accumulator ring to support the higher injection energy are required. The PUP received CD-1 from DOE in January, 2009 with a cost range of $90-96M. The CD-2 milestone is in January, 2011 with construction anticipated over the period 2012-2015. $2.5 M of funding is available in FY2010.

The CU-AIP goal is to provide 3 MW of beam power following the PUP. The goal is to provide 42 mA average current (59 mA peak). The plan is not fully fleshed out, and the preliminary estimate of the cost is $63M. Careful analysis is required to assess the ability of the existing linac and ring to support the required current. It is proposed to execute the CU-AIP over the same time period as the PUP (2011-2015). The Committee notes that utilization of the 3 MW provided by the combination of the PUP and CU-AIP would require construction of a second target station, currently scheduled for later (beyond 2015).

The primary issue the Committee sees is the need to identify a consistent configuration between the PUP, the CU-AIP, and the second target station. Funding of the CU-AIP, because it needs to come out of SNS operating funds, is also an issue.

18.2 Recommendation

Produce an integrated PUP , CU-AIP, Second Target Station plan in support of the PUP CD-2.

19 Conclusion

The SNS team continues to make good progress towards the achievement of design performance, while simultaneously providing useful neutron beams to users.

The Committee looks forward to next year's visit to a > 1 MW facility operating with 88% availability, and to hearing a bottoms-up plan for 95% availability.

20 SNS Accelerator Advisory Committee Charter

- <u>Committee Charge and Responsibilities</u>

  The Accelerator Advisory Committee (AAC) will report to the Oak Ridge National Laboratory (ORNL) Associate Laboratory Director (ALD) for Neutron Sciences and will advise the Research Accelerator Division (RAD) and Neutron Facilities Development Division (NFDD) Directors on the operations and performance of the Spallation Neutron Source accelerator complex, which includes the target systems and the site conventional systems. The Committee will assess and provide advice on accelerator performance, performance limitations, proposed improvements to overcome those limitations, operation of the facility, the on-going program of accelerator science and technology development, and plans for future upgrades to the accelerator complex.

- <u>Committee Membership</u>

  The Chair and Members of the Committee will be appointed by the ALD for Neutron Sciences in consultation with the RAD and NFDD Directors. Members will be appointed to three-year terms with possible renewal by mutual consent.

- <u>Operations</u>

  The AAC will meet regularly, approximately once per year, but may be called upon at other times, via email or teleconference to address specific issues.

  A specific charge for each meeting will be developed by the RAD and NFDD Directors, and transmitted to the Committee in advance. The Chair, in consultation with the RAD and NFDD Directors, will set the meeting agenda.

  A verbal report will be presented at the end of each meeting followed by a written report to the ALD for Neutron Sciences submitted within 4 weeks. The AAC will also be asked to provide an oral briefing to the Neutron Sciences Advisory Board which meets yearly.

21 Committee Membership

- Günter Bauer
  Forchungszentrum Jülich (ret.)
  Wolfsackerweg 8,
  D-79761 WALDSHUT
  Germany
  Email: guenter@bauer-wt.de

- Richard Cassell
  Stangenes Industries, Inc.
  1052 East Meadow Circle
  Palo Alto, CA 94303
  Email: rlcassel@pacbell.net

- Alexander W. Chao
  Stanford Linear Accelerator Center
  2575 Sand Hill Road
  Menlo Park, CA 94025
  Email: achao@slac.stanford.edu

- Gerry Dugan, Chair
  Newman Laboratory
  Cornell University
  Ithaca, NY 14853
  Email: gfd1@cornell.edu

- Masatoshi Futakawa
  Japan Proton Accelerator Research Complex (J-PARC)
  Tokai-mura, Ibaraki-ken, 319-1195
  Japan
  Email: futakawa.masatoshi@jaea.go.jp

- Roland Garoby
  CERN
  European Organization for Nuclear Research
  CERN CH-1211 Geneve 23
  Switzerland
  Email: Roland.Garoby@cern.ch

- Stephen D. Holmes
  Fermi National Accelerator Laboratory
  105 (WH 2E)
  P.O. Box 500
  Batavia, IL 60510
  Email: holmes@fnal.gov

- Andrew Hutton
  Thomas Jefferson National Accelerator Facility
  12000 Jefferson Avenue
  Newport News, VA 23606
  Email: andrew@jlab.org

- Roderich Keller
  Group Leader, AOT-ABS
  Los Alamos National Laboratory
  P.O. Box 1663- MS H817

Los Alamos, NM 87545
Email: roderich@lanl.gov

- Robert J. Macek
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545
Email: macek@lanl.gov

- Dieter Proch
MHF-SL
DESY-Deutsches Elektronen-Synchrotron
Notkestr. 85
22603 Hamburg
Germany
Email: dieter.proch@desy.de

- Yoshishige Yamazaki
Japan Proton Accelerator Research Complex (J-PARC)
Tokai-mura, Ibaraki-ken, 319-1195
Japan
Email: yoshishige.yamazaki@j-parc.jp

THIRD SNS AAC MEETING AGENDA

Tuesday February 2, 2010
Room C-156

Length	Time Start	Time Stop	Talk	Speaker	Content
0:30	8:00	8:30	Executive Session		
0:30	8:30	9:00	SNS Overview	I. Anderson	Overview of SNS
0:40	9:00	9:40	Accelerator Systems Overview and Plans	S. Henderson	RAD, Accelerator System, Ramp Up Plan, Challenges and Progress
0:30	9:40	10:10	Neutron Facilities Development Overview and Plans	J. Haines	NFDD, Target Systems, Target Systems Challenges and Plans
0:20	10:10	10:30	Discussion		
0:20	10:30	10:50	Break		
0:20	10:50	11:10	SNS Operations Performance and Downtime	J. Kozak	Performance plots, downtime results
0:40	11:10	11:50	Accelerator Physics Overview	J. Galambos	Ramp Up progress and challenges, beamloss overview, key AP topics
0:20	11:50	12:10	Discussion		
0:50	12:10	13:00	Lunch		
0:35	13:00	13:35	Ion Source and LEBT Performance and Plans	M. Stockli	IS and LEBT Performance, limitations, challenges
0:25	13:35	14:00	Front-End and NC Linac Overview	A. Shishlo	Front-end performance, chopper systems, emittance, NC linac performance, losses, challenges, gate valve problem
0:10	14:00	14:10	Discussion		
0:35	14:10	14:45	Superconducting Linac Operations and Performance	S-H. Kim	SC Cavity and Cryomodule performance, testing program, understanding of limitations
0:15	14:45	15:00	Discussion		
0:20	15:00	15:20	Break		
0:35	15:20	15:55	HEBT/Ring/RTBT Overview	M. Plum	Overview, challenges, Idmp situation, RTBT situation, RTBT/Target interface, foils, etc.
0:35	15:55	16:30	Target Systems Performance and Plans	T. McManamy	Target Systems overview
0:30	16:30	17:00	Discussion		
1:30	17:00	18:30	Executive Session		

Wednesday February 3, 2010
Room C-156 Accelerator Breakout

Length	Time Start	Time Stop	Talk	Speaker	Content
0:30	8:30	9:00	Superconducting RF Activities and Plans	J. Mammosser	Spare CM Activities, Facilities progress
0:30	9:00	9:30	Linac Modulator Operations and Performance	V. Peplov	Modulator downtime, failure modes and performance
0:40	9:30	10:10	Linac Modulator Upgrades	D. Anderson	Modulator development and upgrade plans
0:20	10:10	10:30	Discussion		
0:20	10:30	10:50	Break		
0:20	10:50	11:10	RF System Performance	T. Hardek	RF System performance and issues
0:25	11:10	11:35	Linac Beam Dynamics Progress	Y. Zhang	Linac performance, matching, acceptance, SCL algorithms, output beam quality
0:20	11:35	11:55	Ring Beam Dynamics Progress	J. Holmes	Lattice, tunes, collective effects, high intensity, collimation, etc.
0:15	11:55	12:10	Discussion		
0:50	12:10	13:00	Lunch		

Room C-152 Target Breakout

Length	Time Start	Time Stop	Talk	Speaker	Content
0:20	8:30	8:50	Target Imaging System	T. McManamy	Progress on target imaging
0:30	8:50	9:20	Neutron Source Development	P. Ferguson	Cryo moderator, advanced materials, next gen IRP
0:35	9:20	9:55	Target Development	B. Riemer	R&D progress and plans, PIE
0:35	9:55	10:30	Discussion		
0:20	10:30	10:50	Break		
0:30	10:50	11:20	Target Engineering	P. Rosenblad	Limits on present target,planning for next target, leak detection system + other diagnostics
0:30	11:20	11:50	Remote Handling	M. Dayton	Experience with target/PBW changeout, PIE preparations, CVI procedures, waste handling
0:20	11:50	12:10	Discussion		

Room C-156 Full Committee

Length	Time Start	Time Stop	Talk	Speaker	Content
0:20	13:00	13:20	Foil Development Program	R. Shaw	Foil development progress, lifetime testing, plans
0:30	13:20	13:50	Controls System Performance and Plans	K. White	Controls systems overview, machine protection, performance issues, challenges and plans
0:25	13:50	14:15	Beam Instrumentation Performance and Plans	A. Aleksandrov	BI systems overview, new systems under development
0:20	14:15	14:35	Discussion		
0:20	14:35	14:55	Break		
0:35	14:55	15:30	Accelerator Engineering Progress	G. Murdoch	Momentum dump, foil, injection region, harp, etc.
0:25	15:30	15:55	95% Availability Plan	G. Dodson	Plans for reaching 95% availabiity downtime budget
0:25	15:55	16:20	Beam Power Upgrade Project	B. Thibadeau/Galambos	Status of PUP/CUAIPs
0:40	16:20	17:00	Discussion		
1:30	17:00	18:30	Executive Session		

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Length	Time Start	Time Stop	Talk
3:00	8:00	11:00	Executive Session
1:00	11:00	12:00	Closeout