COMMISSIONING STRATEGIES, OPERATIONS AND PERFORMANCE, BEAM LOSS MANAGEMENT, ACTIVATION, MACHINE PROTECTION

J. Galambos, SNS*, Oak Ridge TN, USA, T. Koseki, KEK, Tsukuba Japan, M. Seidel, PSI, Villigen Switzerland

Abstract

The working group D covered commissioning aspects of new high power machines, operational aspects of existing high power machines, and comparison of modeling and measurements of residual activation buildup. During discussions in this working group different institutes shared experiences, which are summarized here.

INTRODUCTION

This summary discusses overall conclusions from the material presented and discussions held at the workshop. The organization of this summary is broken into the commissioning experience discussion, a summary on the residual activation modeling and the operational experience discussion.

In particular, the material presented here regarding the operational experience is gathered from the presenters at the session and summarized as a collection. Much of this material was gathered before, during and to some extent after the session. This material is aimed at providing a reference base for new machines regarding expectations on activation levels, typical worker doses and machine availability.

COMMISSIONG DISCUSSION

In this workshop, there were three talks regarding the commissioning status of the J-PARC. Two of the three talks were presented in the working group D. Each talk discussed the details of the linac and the MR respectively. The other talk was presented in the opening plenary session. It gave an overview of the entire facility and details of the RCS. Beam commissioning of J-PARC has started from the linac in November 2006. The linac has been operated to provide a stable beam for the downstream facilities for nearly one year. The short-term beam stability and availability are sufficient for the present stage. Now the linac is in the transition phase from commissioning to operation. The RCS has completed initial tuning of the basic parameters. The peak beam intensity achieved so far is $1.1x10^{13}$ ppp in the single shot mode. It corresponds to 0.13 MW output for the nominal repetition of 25 Hz. The RCS recently started injection painting studies and is transitioning from the commissioning phase to the next challenging phase aiming at the higher current operation. Beam commissioning of the MR has started in May 2008. It took four days to achieve the first order commissioning goals, i. e. beam transportation from the RCS, injection, circulation with rf capture and extraction to the beam dump. Beam tuning including COD and chromaticity corrections have been done successfully at the injection energy of 3 GeV. Beam acceleration up to 30 GeV and extraction to an experimental facility is scheduled for December 2008. For the new ISIS Target Station commissioning, beam transport down the ~140 m proton beam line from the ISIS synchrotron to the new Second Target Station in December 2007 took only 1¼ hours, and most of that time was because some of the magnets had accidentally been set incorrectly.

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy

SNS beam commissioning tools and experience were discussed in the working group. XAL, a Java based high level programming for physics application, has been being developed since the beginning of the SNS commissioning and playing an important role in the commissioning and operation. From a point of view of experience of the XAL development, they concluded that an early staged commissioning approach is useful, with an iterative approach for commissioning tools, using physicists to write applications. On the other hand, what they did wrong are most applications and some of tools are SNS specific, lack of documentation, did not implement service daemons to reduce EPICS traffic, used commercial plotting package in the open source software.

Different commissioning schedules were discussed in this session. For SNS, 24 hour continuous operation was adopted in the commissioning run. For NuMI, 12 hour shifts (12 hour operation and 12 hour break) was scheduled instead of 24 hour operation because of the desired real time participation of all system experts. This leads to more efficient beam commissioning in NuMI. J-PARC also adopted a 12 hours shift for the same reason as NuMI, namely because of a lack of staff to commit full coverage of all experts.

RESIDUAL ACTIVATION MODELING

Two talks in the working group discussed the simulation of particle losses, the predicted activation of accelerator components and targets, and also the monitoring of the actually observed residual radiation. As a result of these efforts it is now possible to predict the radiation fields at a specific time after the accelerator has been switched off within a reasonable precision. This in turn allows dose predictions for maintenance work. The measured radiation fields can be compared with the prediction to improve the understanding on the loss mechanisms in the accelerators. On the basis of measurements and simulations extrapolations can be made for operation at higher currents. Furthermore the legal regulations for disposal of activated material often require specification of the nuclide inventory of the material, and this information is most easily obtained from the numerical simulations.

In the talk from PSI examples were shown on the prediction of the isotope composition of material with a known irradiation history. These results were compared with actual measurements of the isotope content. The achieved degree of agreement is typically within a factor three.

Another example from SNS compares prediction and measurement of residual dose rates at different times after the stop of accelerator operation. Although the loss distribution along the accelerator is not well known, the agreement is reasonably good. The simulation codes which are used for the described applications are developed and tested in collaboration between the laboratories.

OPERATION, PERFORMANCE, BEAM LOSS MANAGEMENT, AND ACTIVATION

The main discussion areas of operational experience for high power proton machines were: 1) typical build up levels for residual activation after full power runs , 2) typical radiation worker dose levels, 3) balance between operation, maintenance and beam study activities, and 4) beam availability. We note that any comparison of these quantities between different institutions is an inherently uncertain business due to differences in accounting rules, etc. None-the-less we attempt to summarize the community experience here, but caution that absolute comparisons are not the intent here.

Table 1. Facilities contributing to the High Power Operational Experience Comparison

	Accelerator	Power (MW)
PSI	Cyclotron chain, (CW)	1.2
SNS	Linac/accumulator Ring, (pulsed)	0.5
NUMI (FNAL MI, Booster)	Linac / RCS chain, (pulsed)	0.34
ISIS	Linac / RCS, (pulsed)	~ 0.18
BNL Booster/AGS	Linac / RCS chain, (pulsed)	~ 0.06
LANSCE	Linac / accumulator ring (pulsed)	~ 0.1 (linac ran 1 MW)

The values compared here are for five high power hadron facilities, as described in Table 1. We note that the Brookhaven National Laboratory data are historical, and the facility no longer runs high power operation.

Residual Activation Comparison

The first residual activation comparison is for regions of controlled beam loss. This refers to areas where the beam loss is expected in the design, for example beam collimation or a foil stripping at ring injection. Figure 1 shows characteristic levels at facilities. In general these are data taken at 30 cm, 24 hrs after beam is turned off. For ISIS data is at the collimation region after a few days, for PSI at extraction, for LANSCE at the PSR Ring injection 4 hours after shutdown, for the FNAL Booster, for a 1 hour cool-down at extraction and collimation, FNAL Main Injector (MI) on contact at extraction and beam abort, BNL is after 10 hrs cool-down and was not a limiting factor, and SNS is at the Ring Injection.

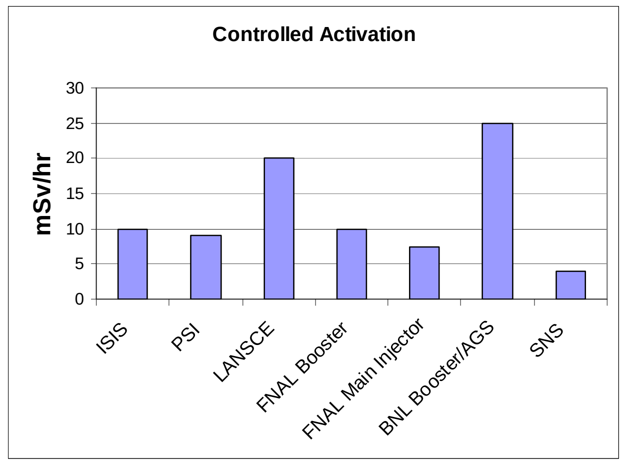

Figure 1. Comparison of residual activation levels at regions of controlled beam loss. See text for comments.

Figure 2 shows residual activation for uncontrolled beam loss, or regions that were not designed with beam loss considerations. It should be noted that most regions in these facilities are nearly loss free, but shown here are exceptions that are accepted in normal operations. For PSI the area is extraction; for LANSCE areas in the Ring are shown (linac is lower); for FNAL the booster numbers are for 1 hour cool-down and the Main Injector numbers are for a 3-4 hour cool-down; and for BNL the data are for a 10 hour cool-down.

Worker Dose

A common theme in the discussions was that specific residual activation levels are not critical, but rather the worker dose levels are the more critical issue. We compare here annual individual and collective (facility) worker dose experiences for these facilities. Generally facilities place a safety factor on the guidelines for the institution rule, and the institution guidelines often have additional safety factors applied to the legal limits impose by the governing oversight body. Together the allowable worker dose guideline for a facility is typically 3-4 times lower than the legal limit. Figure 3 shows some comparisons. The BNL numbers are typical for the period spanning 2000-2002; FNAL has an individual worker limit of 3 mSv/quarter, and 15 mSv/year. And the actual shown is representative of work in the booster.; for SNS, the numbers are for 2008 through September.

.

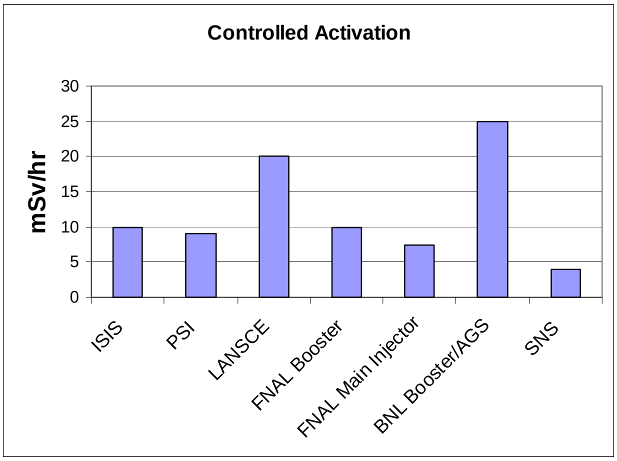

Figure 2. Comparison of residual activation levels for regions not specifically designed for loss. See text for comments

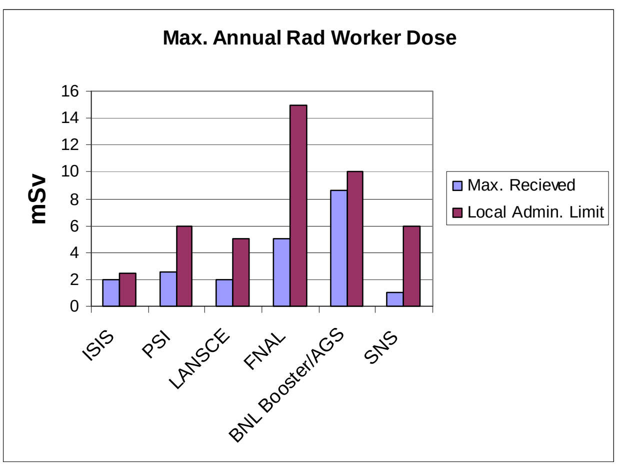

Figure 3. Maximum annual individual radiation worker dose and facility guidelines. See text for comments.

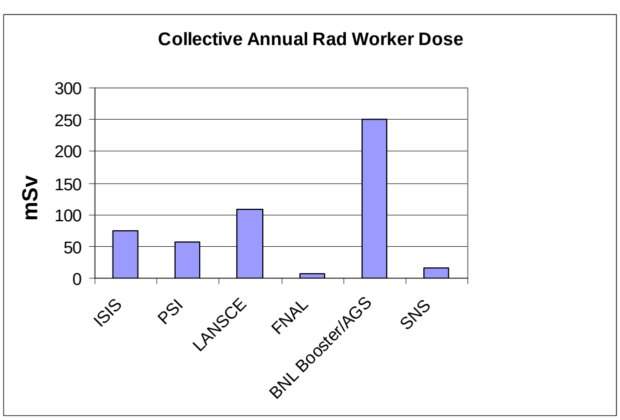

Figure 4. Collective dose rates for radiation worker force. See text for comments.

The collective radiation worker force dose rate for a year is shown in Figure 4. There is some variability in the definition of who is included here. For ISIS the total is for about 300 people, for PSI the numbers are for the 2008 shutdown and are for 188 people, for LANSCE the numbers are for 2007 and 119 people. For BNL the numbers represent an average for the years 2000-2002. For FNAL, the numbers are for a collimation installation task for the Main Injector in 2007. For SNS, the numbers are for the year 2008 through September.

Beam Availability

The high power accelerators are drivers for facilities that expect beam on for extended periods of time (weeks or more). Beam availability is especially important for the facilities that provide services to many users, each of which uses beam for only a short period of time (days). We define availability as the time beam is provided on the primary Target / scheduled beam time. Figure 4 shows some typical availability for the high power facilities in recent years. The NUMI availability at FNAL is dominated by Target Hall issues, and the primary accelerator beam was available for ~ 90% of the time. We note that the NUMI target hall system is more complicated than that of the other cases. The ISIS availability is an average over the last 10 years, with more recent years somewhat lower as a different accounting scheme is used. PSI and Lujan data are for 2007, and the SNS data is for 2008 through September.

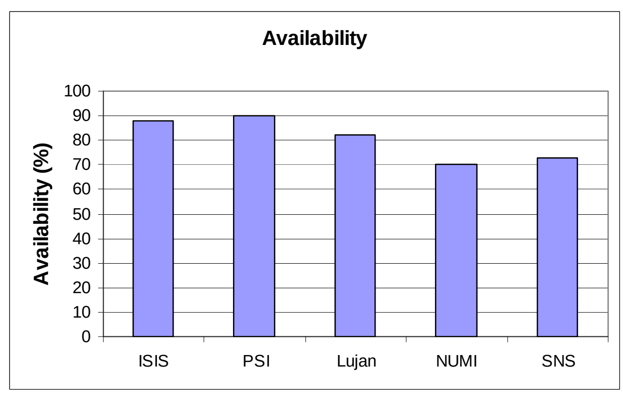

Figure 5. Beam on target availability for recent years. See the text for comments

Related to beam availability is the beam trip frequency. Trip frequency as a function of trip duration is shown in Figure 6. We note that the SNS is not a mature facility, which may explain its higher frequency of long durations. The overall shape of the curve is similar for the facilities that reported statistics.

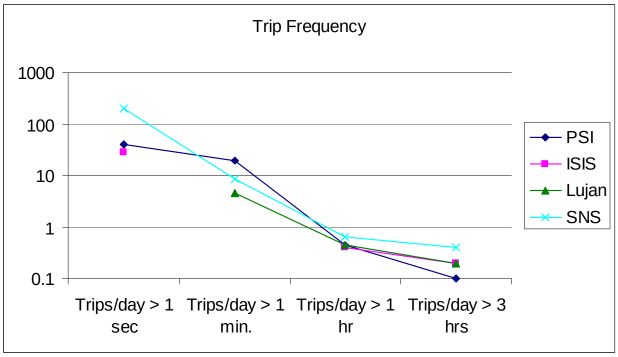

Figure 6. Trip frequency vs. trip duration for high power proton accelerators.

Machine Operational Cycles

All high power accelerators require machine maintenance, as well as beam study time. Here we report the balance these needs at different facilities. One consideration is the time required to restore high power operations after a major shutdown (i.e. one month or more). The responses are generally one to a few weeks, as described below.

- PSI takes 2-4 days tuning + 4 days equipment readiness
- ISIS and the FNAL Booster and Main injector take about 1 week per month off
- LANSCE schedules 1 month for recovery, which includes equipment readiness, RF conditioning, equipment certification processes, and beam tuning. This is done one time per year.
- SNS is in its infancy and presently schedules 10 days after 4-7 week extended maintenance but it sometimes takes longer to re-establish reliable beam.

A consequence of the difficulty in restoring high power beam operations after long shutdowns, has been the tendency for facilities to schedule the beam to remain on for extended periods to avoid this difficulty. We describe below the typical run cycle for different facilities:

- PSI schedules 3 weeks of production separated by 2-3 days for beam studies and maintenance
- ISIS has a 50-60 day cycle consisting of about 40 days production, 3 days of beam studies, a 10 day short shutdown and a 10 day startup
- LANSCE has a one month cycle with 24 days for production , 1-2 days of beam studies, 4-13 days of maintenance, and one day of recovery
- FNAL-NUMI has a 10-14 week shutdown per year, and runs the beam to component failure otherwise (note this is a single user facility)
- SNS is adopting a 3 week run cycle with 16 days production and 5 days of beam studies and maintenance.

ACKNOWLEDGEMENTS

We wish to thank the following for providing valuable information on the facility operational experiences at different sites: David Findlay from ISIS, Larry Rybarcyk from LANSCE, Ioanis Kourbanis, Bruce Brown and William Pellico from FNAL, and Deepak Raparia from BNL.