Notes From the Third NSLS-II Radiation Safety Workshop, June 2010

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On June 22, 2010, some key members of the NSLS-II project, as well as valued advisors from other synchrotrons, assembled for a third workshop on radiation safety, presenting the latest developments in NSLS-II's comprehensive radiation safety plan.

Radiation safety and accelerator experts from ALS, APS, ESRF, and SSRL participated in the review and constituted a formal review panel.

"This meeting was part of a series of workshops that are being held to discuss the extensive, ongoing work being done in the area of radiation safety at NSLS-II," said Bob Casey, NSLS-II Senior Health Physicist. "The workshops are a very useful vehicle for exchanging lessons learned and getting input from experts who have addressed these issues at their facilities."

As summarized by Ferdinand Willeke, NSLS-II Division Director for Accelerator Systems, radiation safety at NSLS-II is a comprehensive, five-part system, consisting of:

- extensive concrete and lead shielding
- a personnel protective system to turn off or prevent turn-on of accelerators in off-normal scenarios
- top-off safety measures, to prevent the electron beam from reaching a beamline's first optical enclosure
- a system of radiation monitors to confirm radiation is within acceptable levels
- a loss control and monitoring system to confirm that beam losses are within expected limits

Reviewing Recent Progress

A key part of the workshop was an update on more than 30 recommendations that had resulted from the first two workshops, held in March 2007 and April 2008. NSLS-II radiation physicist PK Job discussed the progress made so far, which has been extensive. For example, areas of high beam loss in the injector systems area have been identified using simulations, and plans for shielding those areas have been updated.

There has also been progress in calculating the expected dose rates for staff and users at certain locations, for different scenarios. An example is what would happen if there were beam loss at the front-end components when the safety shutters are closed. This is essentially an evaluation of the shutters' effectiveness, and Job reported that all calculations show that users within first optical enclosures will be protected even during the worst beam-loss scenario.

Dose rates in the event of accidents during the top-off process have also been calculated, and safety staff has determined how doses would be distributed on the experimental floor due to a horizontal beam scraper in the storage ring. Based on those results, they have made additional shielding requirements.

Job also talked about progress in the area of shielding. High loss locations within the injection and extraction regions will be locally shielded with lead and polyethylene, based on conservative estimates

of beam loss, and the beam dumps will be shielded with the same materials. Other areas where high beam loss is likely will have supplementary lead shielding and accidental losses will be dealt with using a system of interlocks.

Safety During Top-Off and at Beamline Hutches

NSLS-II accelerator physicist Yongjun Li discussed safety during top-off operations – that is, preventing the injected beam from passing through a photon beamline and into the first optical enclosure (FOE). NSLS-II project members have performed simulations to determine how this could occur and how best to protect staff and users. The results are still being analyzed, Li said, but they point to the need for stored beam current interlocks for currents greater than 25 mA, a magnet power supply interlock, and an injected beam energy interlock. Li said that staff is in the midst of determining how to implement the interlocks and are drawing on the experience of other facilities.

Beamline and Interface Manager Andrew Broadbent talked about the project beamlines, which have already gone through conceptual design safety reviews. Among his remarks was a discussion of hutch design concepts intended to control costs; such as using steel when possible, utilizing standard construction methods using standard-sized panels, keeping the hutches boxy in shape, and putting utilities on the hutch roof when possible.

Radiation safety at the hutches will include a local area monitor mounted onto the outer wall of each hutch. Placed at about beam height, the monitor will close the safety shutter for low-level radiation situations and shut down the linac gun when radiation is detected at higher levels. In some anticipated designs, in-line hutches will be isolated by interlocked beam "hatches" so that people can work at the second endstation while beam is delivered to the first.

Abnormal Operations and Local Area Monitoring

Casey presented the most current information on dealing with "abnormal operations" at NSLS-II, such as excessive beam loss in the booster ring or linac – essentially, any malfunction or accident that could cause personnel to be exposed to elevated radiation levels. He said that his team has analyzed 29 abnormal beam loss conditions and the consequences of each.

He also updated the group on NSLS-II's planned local area monitoring system, the network of detectors that will be placed around the accelerator complex to measure and alert staff to increased radiation levels created by abnormal operation. Area radiation monitors will be located in occupied areas to provide warnings locally and in the control room of increased radiation levels. In addition, the radiation monitors will also stop further injection if radiation levels exceed established action levels. The interlocked function of the monitors operates through the facility's personnel protective system. The future locations of the detectors have been determined, including one at each of the project beamlines and 30 placed at strategic points around the experimental floor. In total there will be 47 units on the floor and eight spares.

So far, Casey said, units from three different vendors have been ordered and received. They are being tested on the floor of NSLS, a process that will take nine to 12 months. Over this period, staff will gather information on the units' performance, reliability, and maintenance requirements. Staff will also be able to compare performance between units from different vendors. Over the next two years, additional units will be ordered and tested.

Top-Off Safety in Detail

In a second talk, Job further discussed the radiological consequences of injected beam loss in the front end during top-off. He presented more details on dose rates for various top-off beam loss scenarios, which have been calculated using a Monte Carlo program. The results suggest that if the full beam were lost at a single point (e.g. the front end fixed-mask or photon shutter), the total dose rate on the experimental floor would be less than 0.2 mrem/pulse. In all cases, if the dose rates reach unacceptable levels, the local area radiation monitors will trip the injection within a few pulses.

Job also examined the consequences of injected electron beam reaching the FOE – a highly unlikely event. As would be expected in the FOE, which is shielded for x-ray beam rather than the injected electron beam, the dose rate on the floor during such an event is high (approximately 30 mrem/pulse). To prevent this event from occurring, redundant and independent interlocks will be installed, as described by Li in his talk.

Personnel Protective System and Beam Loss Control & Monitoring

Project Engineer Scott Buda discussed the facility's personnel protective system (PPS), which monitors the status of critical operating parameters, prevents access into accelerator and beamline enclosures when beam is present, and also shuts down the injection system if radiation levels increase significantly. Because of the importance of the PPS, considerable effort has been devoted to providing a highly reliable design that incorporates best practices established within the DOE community. Buda reported the results of an independent failure mode analysis of the PPS, which demonstrated that the probability of a dangerous failure of the system was less than 1×10^{-6} per year.

Accelerator scientist Stephen Kramer, a member of the NSLS-II design team, presented a review of the beam loss control and monitoring (LCM) system. The LCM, currently being designed, complements the area monitoring system and will prevent excessive radiation in occupied areas by alerting operators when stored or injected beam losses increase beyond acceptable levels.

The LCM system has several components. There will be loss control apertures and slits in the booster transport line and blade-type scrapers in the storage ring injection region. Two types of current monitors will be present in the booster and main ring: The linac, linac-to-booster transfer line, and booster-to-main-ring transfer line will use integrating current transformers; the booster and main rings will have DC current transformers. These current transformers will permit quantification of beam losses during the various phases of the injection and stored beam process.

Beam-loss monitors in the main ring will detect electrons using the Cerenkov radiation signal they emit and are used to confirm that the location of beam losses is in the heavily shielded injection region. For now these units are only planned for the injection region, but more may be installed around the ring if needed. Kramer added that LCM research and development is ongoing, with a focus on improving the scrapers and Cerenkov beam loss monitors. Kramer and his group are also planning a new effort to measure the neutron signal from the injection septum as a way to gauge beam loss.

Wrapping Up

The review panel that participated in the workshop has issued a summary report of the workshop and has provided comments and additional recommendations for consideration by the project staff. In the

summary, the panel stated:

> "The committee is highly impressed with the progress that has been made to-date in working and resolving radiation safety issues for design and commissioning of NSLS-II since the last NSLS-II radiation Safety Workshop in April 2008.
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> "The committee acknowledges that the NSLS-II team has positively and actively responded to the previous review recommendations."

Casey, who organized the workshop, noted, "The independent review by others who have gone through the design, commissioning, and operation of modern light sources is very important to confirm the adequacy of our plans and analyses for radiation safety. These reviews are very valuable to NSLS-II and we take their comments seriously."