8 Personnel Protection System

8.1 Beamline Area PPS

NSLS-II will produce intense light from IR, UV, and hard x-rays. Beamlines are designed to use either the bending magnet radiation or the radiation from insertion devices located in the straight sections of the storage ring. Beamlines may have more than one station along the beamline for every port. These stations are expected to work in parallel or sequentially.

The Personnel Protection System (PPS) is an engineered system that provides a means to ensure that personnel are not exposed to the radiation in the beamline. At NSLS-II, the role of the PPS is specifically to protect personnel from prompt radiation that is present only when there are stored electrons in the storage ring. The PPS is an engineered interlock system and is expected to monitor the various devices installed in the beamline for personnel safety and to provide emergency shutdown in case of breach of the interlock.

The PPS system, along with the required shielding in the beamlines, is expected to provide personnel safety during routine operation of the facility.

8.1.1 Functionality

Beamlines will consist of stations where synchrotron radiation is expected to be admitted. The beamline stations are expected to be made of lead-lined walls and roof, as appropriate for the particular radiation characteristics. These stations will house beamline optical components or beamline experimental equipment. The stations are expected to be large enough for personnel to work with the equipment inside.

The beamlines will have one or more shutters based on the particular layout, which is expected to vary from beamline to beamline. However, the functionality of the shutters, from the Personnel Protection System perspective, is expected to be the same and they will be monitored by the PPS. All x-ray beamlines will have shutters in the front-end area inside the storage ring shield wall (see Section 7.4). The bremsstrahlung radiation emitted by the synchrotron can only be stopped by heavy metal elements such as tungsten or lead. The heavy metal device that stops the bremsstrahlung radiation is referred to as the safety shutter. For the sake of safety, the shutter is expected to be redundant. The synchrotron beam, consisting of very high total power and power density, will be stopped by a device that is water cooled, made of copper or alloys of copper, and referred to as the photon shutter. These three devices, the two safety shutters and the photon shutter, will form a shutter cluster and their positions are monitored by the PPS.

Along the beamline are beamline optical elements that will condition the beam, including, for example, monochromators and mirrors. These devices change the characteristics of the synchrotron radiation. The radiation passing through the monochromator will, in most cases, be displaced in either the vertical plane or the horizontal plane from the incident radiation and only a small fraction of the incident radiation with a band pass (of about 0.1% or less) will be passed, with little or no power. In such cases the shutters, located downstream of the monochromator, will be called monochromatic shutters. They will be made of heavy metal and will be much shorter than the safety shutters. Once again, these monochromatic shutters are expected to be redundant for safety and will be monitored by the PPS.

A major role for the PPS will be to provide a means of ensuring that no personnel are inside beamline stations when the station is opened to synchrotron radiation. Prior to admitting the synchrotron radiation inside these stations, a search of the area has to be performed by a human. It is expected that the station search will be performed by one person only. There will be PPS devices called “search boxes” inside the station which must be visited as part of the search. Search boxes are strategically placed to ensure that during the search all parts of the station are either visible or visited by the search personnel and no person is left behind inside the station. The search is completed when the station door is closed. The PPS will then lock the door.

Once the search process is started the PPS will start a beacon and audio signal inside the station, warning all personnel to exit. This signal is expected to last for some time, on the order about 20 to 30 seconds after the station door is closed. The function of the beacon and audio signal is to warn any personnel overlooked by the search person of impending danger. There will be very distinct emergency shutdown buttons placed inside the station which, when pressed, will instantly remove the presence of the prompt synchrotron radiation hazard. In addition, there will be also emergency egress buttons inside the station to unlock and open the door.

8.1.2 Design Specifications

The PPS will be designed to be robust and provide the emergency shutdown functionality to provide personnel safety from prompt radiation. Like the EPS, the PPS is expected to be based on programmable logic controllers. PLCs have numerous advantages over the relay logic scheme of interlocks. They can be reprogrammed to reflect changes in configurations and also have numerous diagnostics. The use of PLCs in safety system is very common now.

All devices attached to the PPS are expected to be designed to be fail-safe—that is, in case of failure the device will fail in such a manner as to either remove the hazard or remove the permit to generate or maintain the hazard.

Every beamline PPS will be designed under the same guidelines. The PPS will consist of two PLCs, referred to as chains A and B. The two PLCs will provide redundancy and will independently monitor all the devices.

All shutters will have two switches, one for chain A and one for chain B. There will be switches to monitor the closed and open positions. Similarly, all station doors will be monitored with two switches, one each for chains A and B.

At beamlines, there will be circumstances when a device such as a mask or photon beam stop is provided to absorb the power of the beam, while the radiation safety is provided by lead shielding as collimators or radiation stops. In such cases, the integrity of the masks and beam stops cannot be compromised, as they, in turn, protect the lead shielding which provides the personnel safety. In these cases, the mask or beam stop will be monitored by the PPS to ensure that it is not compromised. In most cases, the water flow to these components will be monitored independently by chains A and B of the PPS.

All PPS equipment will be clearly identified, and secured in locked cabinets. Cabling for the PPS equipment to field devices will be on separate closed raceways, which will be used exclusively for the PPS. All power to the PPS will be provided by uninterruptible power supplies, which will be backed up by generators.

8.1.3 Interface

The PPS must interface with numerous systems. The primary functionality of the PPS is to monitor and provide emergency shutdown.

To provide emergency shutdown, the PPS interfaces to the Accelerator Personnel Protection System. The PPS will remove a permit to the APPS to operate the storage ring. In the event of the removal of the permit by the PPS, it is the responsibility of the APPS to remove the hazard by dropping the dipole power supply and the RF to the storage ring systems.

The APPS will monitor the positions of the front-end shutters located inside the storage ring shield wall. The APPS will fan-out the status of the shutters to the PPS. There will be a provision in the APPS to remove the PPS interactions for a specific beamline. This is expected to be in the form of a Kirk Key in an interface box between the PPS and APPS for each beamline. The APPS will monitor the closed positions of the front end shutters when the PPS is not available and will remove the storage ring permit if it experiences any “not closed” activity. When the PPS is available, the APPS will ignore the status of the shutters. This scheme will allow installation, maintenance, and validation of the PPS to take place while the machine is in operation.

All PPS functions will be monitored and data archived using the control system at NSLS-II. It is expected that EPICS will interface to the PPS PLCs to monitor their functionality. The EPICS interface will be read-only; there will be no writing to PLCs from the EPICS interface. Changes to the PLC operating codes will be possible from the field devices or when the PLC software is downloaded to the PLCs during routine validation of the system.

All command and control functionality for the PPS will reside with the EPS for the beamlines and front ends. The EPS will interface to the PPS and will receive signals from the PPS prior to operation of the shutter. In the event the EPS malfunctions, the ESD procedure of the PPS will activate and will remove the permit for the machine to operate. The PPS will only provide the ESD functionality and hence it expected to be simple and easy to maintain and validate.

8.2 Accelerator Personnel Protection System

As it relates to personnel protection, the NSLS-II facility consists of an electron gun and linac enclosed in a shielded area, and a main storage ring and booster enclosed in a heavily shielded tunnel. There are also numerous beamline experimental stations located on the perimeter of the accelerator tunnel. Protection from beamline radiation will be provided by the Personnel Protection System (discussed in the previous section), from linac radiation by the Linac Personnel Protection System (discussed in this section), and from radiation from the main ring and booster by the Accelerator Personnel Protection System (also discussed in this section).

8.2.1 Linac/Gun Personnel Protection System

The Gun/Linac area will contain linac accelerating sections where electrons emitted from the gun will be accelerated to an energy level for injection into the booster. The radiation hazards present during linac operation are two-fold, resulting from: 1) a high level of RF present in the linac sections that can accelerate free electrons and produce ionizing radiation fields, and 2) the acceleration of electrons to the full linac energy. RF power is supplied through klystron amplifiers powered by pulse modulators. Turning off the RF power will stop the production of radiation.

The Linac Personnel Protection System is specifically designed to protect personnel from radiation which is present only during linac operations. The LPPS is an engineered interlock system and is expected to monitor the various devices installed in the linac for personnel safety and provide emergency shutdown in case of breach of the interlock.

8.2.1.1 LPPS Functionality

A major role for the LPPS is to provide a means of ensuring that no personnel are inside the linac when the gun is on or the klystrons are pulsing. Prior to Linac operation, a search of the area has to be performed by a human. It is expected that the linac search will be performed by one person only. There will be LPPS devices called “search boxes” inside the linac, which must be visited as part of the search. The search boxes are strategically placed to ensure that during the search all parts of the linac are either visible or visited by the search personnel and no person is left behind inside the linac area. The search is completed with the closing of the linac door. The person searching will lock the door when the search is completed and use a Kirk Key system to complete the search process.

Once the search process is completed, the LPPS system will start a beacon and audio signal inside the linac, warning all personnel to exit. This signal is expected to last on the order of about 60 to 120 seconds after the linac door is closed. The function of the beacon and audio signal is to alert any personnel who have been overlooked by the search person and trapped inside.

Emergency shutdown buttons which are very distinct will be placed inside the linac; when pressed, a shutdown button will instantly remove the radiation hazard.

8.2.1.2 LPPS Design Specifications

The LPPS will be designed to be robust and provide the emergency shutdown functionality for providing radiation safety to personnel in the linac area. The LPPS is expected to be based on programmable logic controllers. PLCs have numerous advantages over the relay logic scheme of interlocks. A PLC can be reprogrammed to reflect changes in configurations and also has numerous diagnostics. The use of PLCs in safety systems is very common and is an accepted practice at accelerator facilities across the United States.

All devices attached to the LPPS are expected to be designed to be fail-safe—in case of failure the device will fail in such a manner to either remove the hazard or remove the permit to generate/maintain the hazard.

The LPPS system will consist of two PLCs, referred to as chains A and B. The two PLCs will provide redundancy and independently monitor all the devices. To immediately stop the production of radiation, power to the modulator power supplies will be removed redundantly. This will be accomplished through the use of AC contactors, one for chain A and one for chain B.

Two critical devices will prevent radiation from entering the main ring from the linac: 1) the linac-to-main-ring stop, and 2) the bending magnet located upstream. The linac-to-main-ring stop will have two switches to monitor the closed and open positions, one switch each for chains A and B. The bending magnet upstream of the stop will be redundantly monitored for current and voltage by both chains. When the magnet is not powered it will prevent electrons from entering the accelerator tunnel area. All linac doors also will be monitored with two switches, one tied into each chain.

All LPPS equipment will be clearly identified and secured in locked cabinets. Cabling for the LPPS equipment to field devices will be separated in raceways. All power to the LPPS will be provided from an uninterruptible power source, backed by generators.

8.2.1.3 LPPS Interface

All LPPS functions will be monitored and data will be archived using the NSLS-II control system. It is expected that EPICS will interface to the LPPS PLCs to monitor their functionality. The EPICS interface will be only read-only; there will be no writing to the PLCs from the EPICS interface. Changes to the PLC operating codes will only be possible locally.

8.2.2 Storage Ring and Booster Personnel Protection System (APPS)

The storage ring and booster will coexist inside the same tunnel. The Accelerator Personnel Protection System interlock will be required to serve both the storage ring and booster. Radiation hazards during normal operations and conditioning are produced from multiple sources under different operational conditions. Operation of the RF accelerating cavities, both booster and main ring, can produce high radiation fields from secondary emissions that are accelerated by high RF fields. This radiation can be produced without electrons injected or stored in either ring.

The electron beam injected from the linac is another hazard, and, finally, stored beam in either the booster or main storage ring will produce synchrotron and bremsstrahlung radiation. The APPS must protect personnel from all conditions.

8.2.2.1 APPS Functionality

The APPS protects personnel from radiation hazards by 1) ensuring that no one is left inside the ring enclosure before operations that will produce radiation and 2) by providing a means of emergency shutdown of components, enabling personnel to stop the production of radiation in an emergency.

The ring enclosure is physically very large and will be divided into six searchable sections. Each section will be separated by a physical barrier in the form of a gate. Before operations begin, each section will be physically searched by a human. Once the search process is completed, the APPS system will start a beacon and audio signal inside the section being secured, as a warning to any overlooked personnel to exit. This signal is expected to last on the order of 60 to 240 seconds after the section gate is closed.

Emergency shutdown buttons, which have a very distinct appearance, will be placed inside the tunnel. When pressed, a shutdown button will instantly remove the radiation hazard.

The gates, along with Kirk keys, will be part of a system to allow controlled access to parts of the ring under defined conditions while other sections remain secured. With the APPS, beam will be dumped to allow authorized personnel controlled access to the ring sections while ensuring that no electron beam can be injected. Access will be monitored via a remote TV camera hookup to the control room. Each person entering the ring must remove a Kirk key; this inhibits the radiation source. A physical search of the section will be required before operations and radiation production can be resumed.

The first application of this concept defines an area around the RF accelerating cavities. The booster and storage ring cavities will need to be powered with RF for conditioning but without injected electron beam. The APPS will ensure no personnel are in the vicinity of the RF cavities during conditioning, while inhibiting electron beam from being injected into the ring. If the area is breached, the RF power source will be immediately shut off, redundantly.

During injection, while the linac-to-main-ring stop is open, if the storage ring area is breached the APPS interlock must dump stored beam and reach back to the LPPS to shut down the linac modulators.

The APPS may also be required to monitor conditions required for top-off operation of the injector. These conditions have not been determined but could include requiring a minimum stored current before top-off mode is enabled and requiring the dipole current to be at the proper energy level.

The APPS will also monitor the status of the front-end ports and will dump the beam if a port is open and the PPS detects a breach of an experimental station.

All APPS conditions and access modes are displayed and controlled from a dedicated rack in the control room.

8.2.2.2 APPS Design Specifications

The APPS will be designed to be robust and provide the emergency shutdown functionality to ensure personnel safety for the storage ring/booster area. The APPS is expected to be based on programmable logic controllers. PLCs have numerous advantages over the relay logic scheme of interlocks. A PLC can be reprogrammed to reflect changes in configurations and also has numerous diagnostics. The use of PLCs in safety systems is very common and is an accepted practice at accelerator facilities across the United States.

All devices attached to the APPS are expected to be designed to be fail-safe—in case of failure the device will fail in such a manner to either remove the hazard or remove the permit to generate/maintain the hazard.

The APPS system will consist of two PLCs, referred to as chains A and B. The two PLCs will provide redundancy and will independently monitor all the devices. To immediately stop the production of radiation, power to the RF plate power supplies and low level RF will be removed redundantly both for storage ring RF and booster RF. This will be accomplished through the use of AC contactors, one for chain A and an RF switch for chain B. The redundant means for dumping beam will also shut off the main dipole power supply through the AC contactor with both chains A and B.

The storage ring tunnel circumference is large; to avoid ground loops and EMC effects on APPS signals, fiber optic transmission of bus signals (one for each chain) will connect field I/O blocks around the ring to the main PLCs located in the control room. The control room PLCs will also connect to the RF and dipole power supply via a fiber optic I/O bus to avoid interference and corruption of signals.

The system will be designed for testability and will have built-in test features. The concept of diversity will be applied where possible.

The APPS main ring doors, emergency stops, and section gates have two switches, one each for chains A and B. All APPS equipment will be clearly identified and secured in locked cabinets. Cabling for the APPS equipment to field devices will be separated in raceways. All power to the APPS will be provided from an uninterruptible power source, backed by generators.

8.2.2.3 APPS Interface

The PLC program will incorporate a circular buffer of each scan that is triggered by an interlock breach. The buffer will be retrieved via EPICS to troubleshoot problems. All APPS functions will be monitored and data will be archived using the NSLS-II control system. It is expected that EPICS will interface to the APPS PLCs to monitor their functionality. EPICS will read data from a dedicated group of registers that reflect conditions and I/O points in the PLCs. The EPICS interface will be separate from the I/O bus. The EPICS interface will be only read-only; there will be no writing to the PLC from the EPICS interface. Changes to the PLC operating codes will only be possible locally.