Advanced Photon Source Upgrade

Advanced Photon Source Upgrade Project

Final Design Report

May 2019

Chapter 5: Storage Ring Removal and Installation

Document Number : APSU-2.01-RPT-003
ICMS Content ID : APSU_2032071

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Acronyms and Abbreviations

AC	Alternating Current
APS	Advanced Photon Source
Argonne	Argonne National Laboratory
ASD	Accelerator Systems Division
BTS	Booster-to-Storage Ring
DC	Direct Current
DLM	Doublet L-bend Multiplet
DOE	U.S. Department of Energy
EPS	Equipment Protection System
FY	Fiscal Year
HVAC	Heating, Ventilation, and Air Conditioning
LOTO	Lockout/Tagout
LLW	Low-Level Waste
MBA	Multi-bend Achromat
RF	Radio Frequency
SR	Storage Ring

5 Storage Ring Removal and Installation

5-1 Introduction

The existing Advanced Photon Source (APS) storage ring (SR) tunnel is divided into six zones, A through F, with a total of 40 sectors. Zones A through E (sectors 1 through 35), which provide the X-rays for science experiments, contain magnet girders, insertion devices, and front ends. Zone F (sectors 36 through 40) contains magnet girders, and radio frequency (RF) and injection equipment. The area above the SR is called the mezzanine; this is where power supplies, vacuum, diagnostics, and controls electronics for the storage ring are located. The existing SR and some of the components on the mezzanine will need to be removed so that the new multi-bend achromat lattice configuration can be installed.

The installation period has been defined as the period during which no X-ray beam will be available for APS experimental users and will therefore need to be as short as feasible. The goal is for the duration of this period to be no longer than 12 months. The main installation period tasks will consist of removal, installation, and testing. The preliminary schedule is shown in Figure 5.1.

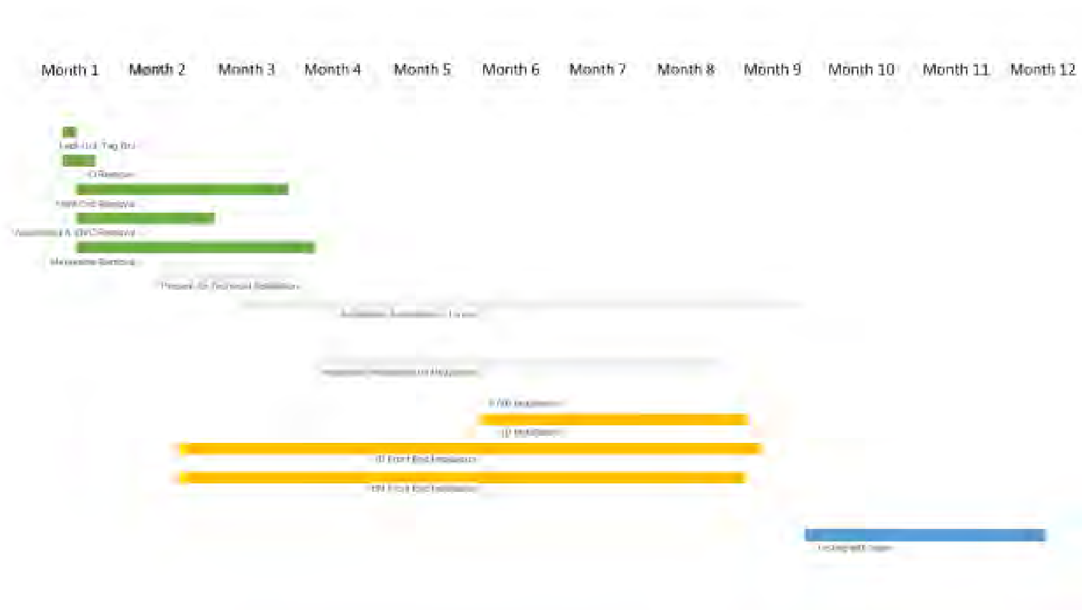


Figure 5.1. Storage ring removal and installation schedule.

5-2 Storage Ring and Mezzanine Equipment Removal

This work will require an area for the storage, reuse, or disposal of materials removed from the storage ring and the mezzanine. This area is referred to below as the disposition facility. The facility will need an estimated 5,000 square feet of indoor space for the storage and characterization of radiologically contaminated materials, and an estimated 15,000 square feet of outdoor storage yard for the temporary storage of uncontaminated materials. The project is investigating options for identifying this space, including the use of existing Argonne National Laboratory space or the building of new space on site. There is a possibility that the existing Building 367, shown in Figure 5.2, could fill this need, provided that adjoining outdoor space can be fenced in for storage use. Building 367 can be made available to the project beginning in Fiscal Year (FY) 2017.

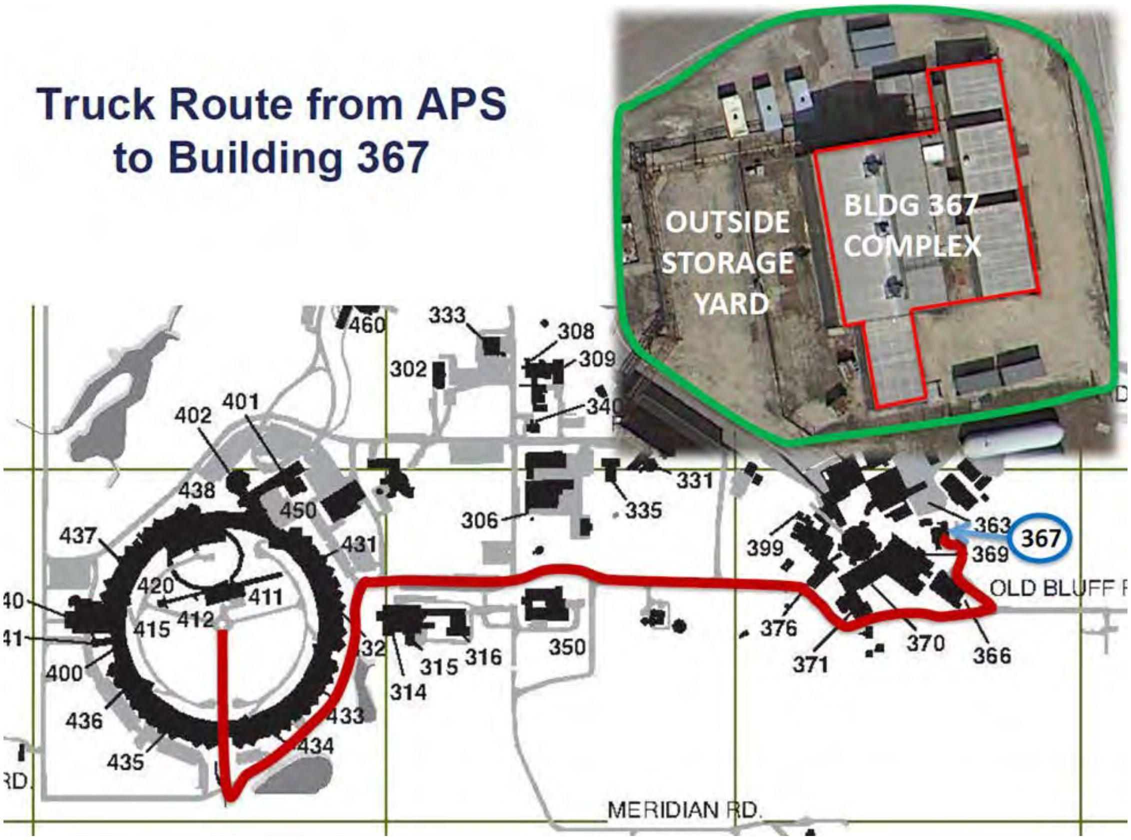


Figure 5.2. Argonne Bldg. 367 used for removed material disposition.

When the APS accelerator shuts down to begin the upgrade installation period, the standard APS shutdown lockout/tagout (LOTO) will be implemented. Established LOTO procedures and checklists will be used, and the presence of zero voltage will be verified. It will be immediately followed by additional LOTO procedures to ensure the facility is in a safe configuration for the removal and installation work. The in-tunnel SR heating, ventilation, and air conditioning (HVAC) ducting will remain in place and the HVAC system will remain functional throughout the removal and installation phases. Alternating current (AC) wall outlet power and tunnel lighting will also remain functional. Prior to removal, each individual girder will be "gapped" (i.e., isolated from all energized sources and attachments: power, equipment protection system (EPS), diagnostics and control cables, cooling water and compressed air lines). All magnet power converters on the SR mezzanine will be de-energized as part of the LOTO procedures. The SR vacuum systems will be shut down and electrically disconnected, and the power cords to the pumps will be cut. The vacuum chambers will be opened to atmospheric air. Compressed air lines to the vacuum valves will be disconnected via their quick disconnect fittings. The cooling water headers will be drained following established procedures. Cooling hoses to individual components will be cut or disconnected and drained into the tunnel floor drains. Vacuum bellows interconnecting the girders will be sheared, vacuum chamber ends radiologically surveyed for contamination, and the vacuum chamber end flanges capped.

A typical single sector of the existing SR is shown in Figure 5.3. Individual girders may be removed using established procedures and transported to the super doors using tugs as shown in Figure 5.4. The girders, and any other SR components in Zones A-E (Sectors 1-35), will be removed from the tunnel through the super doors.

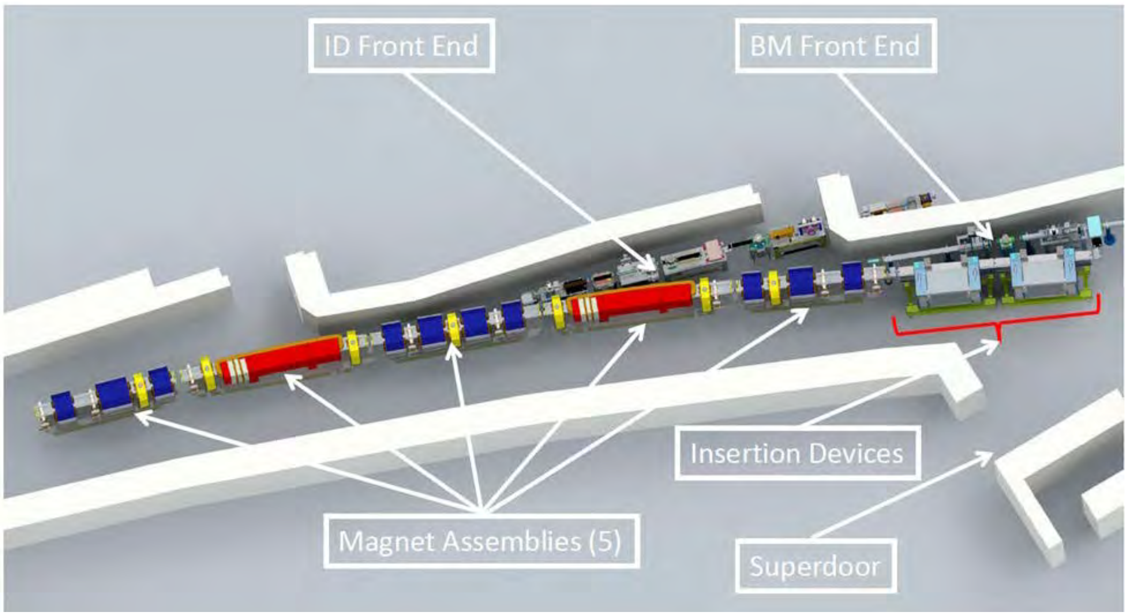


Figure 5.3. One sector of the existing storage ring.

All insertion devices (estimate: 59) will be removed using routine, established procedures and moved out of the SR tunnel through the super door. At that point, they will be transported to the insertion device work area. Insertion devices will be reconfigured for use with the new multi-bend achromat (MBA) lattice before reinstalling.

All front ends (estimate: 55) will be removed through the ratchet doors on the outboard side of the SR tunnel using routine, established procedures. At that point, they will be transported to the front end work area. Removal of the front ends is necessary to prevent damage during the SR removal, and to facilitate reconfiguration for use with the new MBA lattice before front end reinstallation. All SR technical components will be removed from Zone F, with the exception of 12 RF cavities in Sectors 36, 37, and 40 (four per sector), which must be preserved for the new MBA. These cavities will be kept in place and protected from damage during the removal and installation work. The Sector 38 RF cavities and waveguides will be disconnected and removed through the nearby super door. At that point, the components will be handed over to the Accelerator Systems Division (ASD) RF Group for use as spares. On the mezzanine, the associated waveguides and shielding will be disassembled and removed. The remaining penetrations in the floor will be plugged.

The booster-to-storage ring (BTS) system and accompanying injection equipment will be de-energized as part of the LOTO procedure, brought up to atmospheric air, and gapped with respect to power, water, air, vacuum and electronics. The disassembled equipment will be removed through the nearby super door and some transported to the disposition facility for waste stream processing while the

Figure 5.4. Moving existing SR girder with tug and dolly.

remainder are refurbished for reuse.

Remaining power, EPS, diagnostic, and control cables will be pulled down through the tunnel roof labyrinths, cut to manageable lengths, moved out through the super doors and transported to the disposition facility for waste stream processing.

The tunnel floor will be prepared for the installation of the plinths.

A typical single sector of the existing mezzanine is shown in Figure 5.5. On the SR mezzanine (the top of the SR tunnel), magnet power converter cabinets and raw direct current (DC) power supplies will remain in place.

All material removed from the tunnel will be surveyed for radioactivity before removal in accordance with Argonne Radiation Protection Program protocol and the developed waste recycling plan in accordance with the Health Physics Technical Basis Document, RS-TBD-003 Clearance Protocol for Potentially Activated Material. The results of these surveys will be used to determine any required personal protective equipment or personnel monitoring is required to continue with the removal activities. Once girders are removed, more detailed radiological characterization and disposition can be performed as non-critical-path-work at an on-site Waste Management department facility in preparation for final disposition. Radioactive waste materials will be disposed as Low-Level Waste (LLW) or Mixed Low- Level Waste (MLLW) as appropriate. Non-radioactive waste will be processed in accordance with Argonne protocol and DOE-STD-6004-2016, Clearance and Release of Personal Property from Accelerator Facilities.

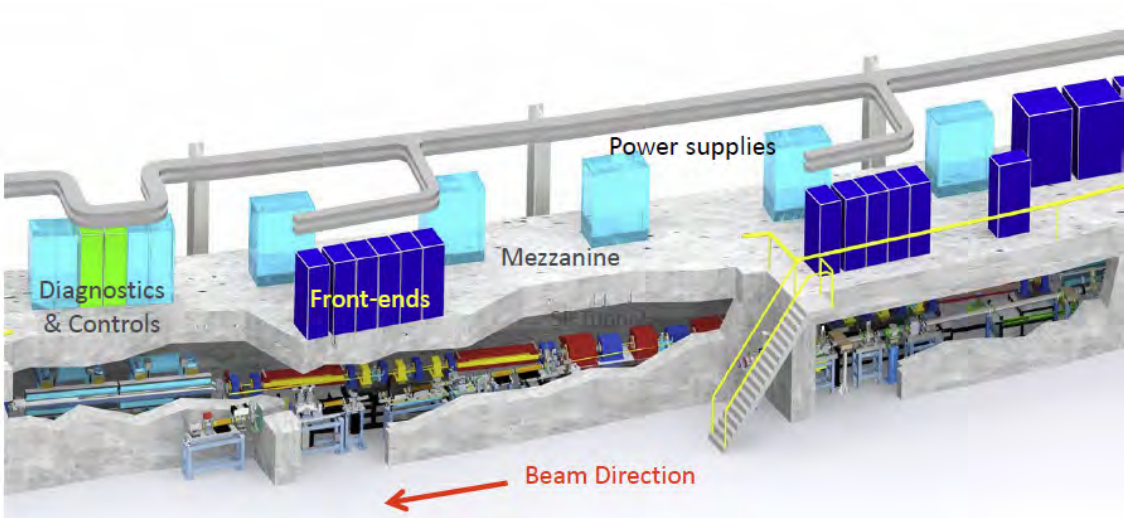


Figure 5.5. One double sector of electronic equipment on the SR mezzanine.

The disposition path for potentially activated material removed from the storage ring tunnel is shown in Figure 5.6. The current plan is to separate out the non-activated metals such as steel, aluminum, and copper for recycling. Recently, the SLAC upgrade project has removed a full kilometer of its linac, comprised of 699 tons of aluminum alignment pipes, copper accelerator tubes, and a complex maze of cables and electronics, of which about 59% (or 400 tons) of steel, scrap metal, wire, copper, and aluminum has been recycled [1].

Table 5.1. Material for disposal

Item Description	**Weight [tons]**	**Volume [cu-yd]**	**Type of Waste**	textbfQuantity	**Type of Containers**
Girder assemblies	1811	1449	Low level rad	10	B-25 Bin
			TBD metals	176	40 cu-yd dumpster
Power cables	30	20	TBD metals	4	20 cu-yd dumpster
DC converter cables	46	104	Electronics recycling	5	40 ft semi-trailer
Other electronics	24	88	Electronics recycling	8	40 ft semi-trailer
Totals	1911	1661			

Note: The numbers of bins, dumpsters, and semi-trailers were calculated by volume and adjusted by weight capacity.

Nonmetal waste will be surveyed, documented, and disposed of through the regular clean trash stream, if applicable. Nearly 200 magnet girder assemblies ranging in weight from 6.8 tons to 11.3 tons each will be removed from the tunnel and temporarily stored at the disposition facility. Nearly 1600 cubic yards of waste, weighing a total of almost 1900 tons, will be disposed of.

Removal of the SR and its associated equipment will utilize all five super doors and two shifts per day, five days per week. The schema for removal is shown in Figure 5.7.

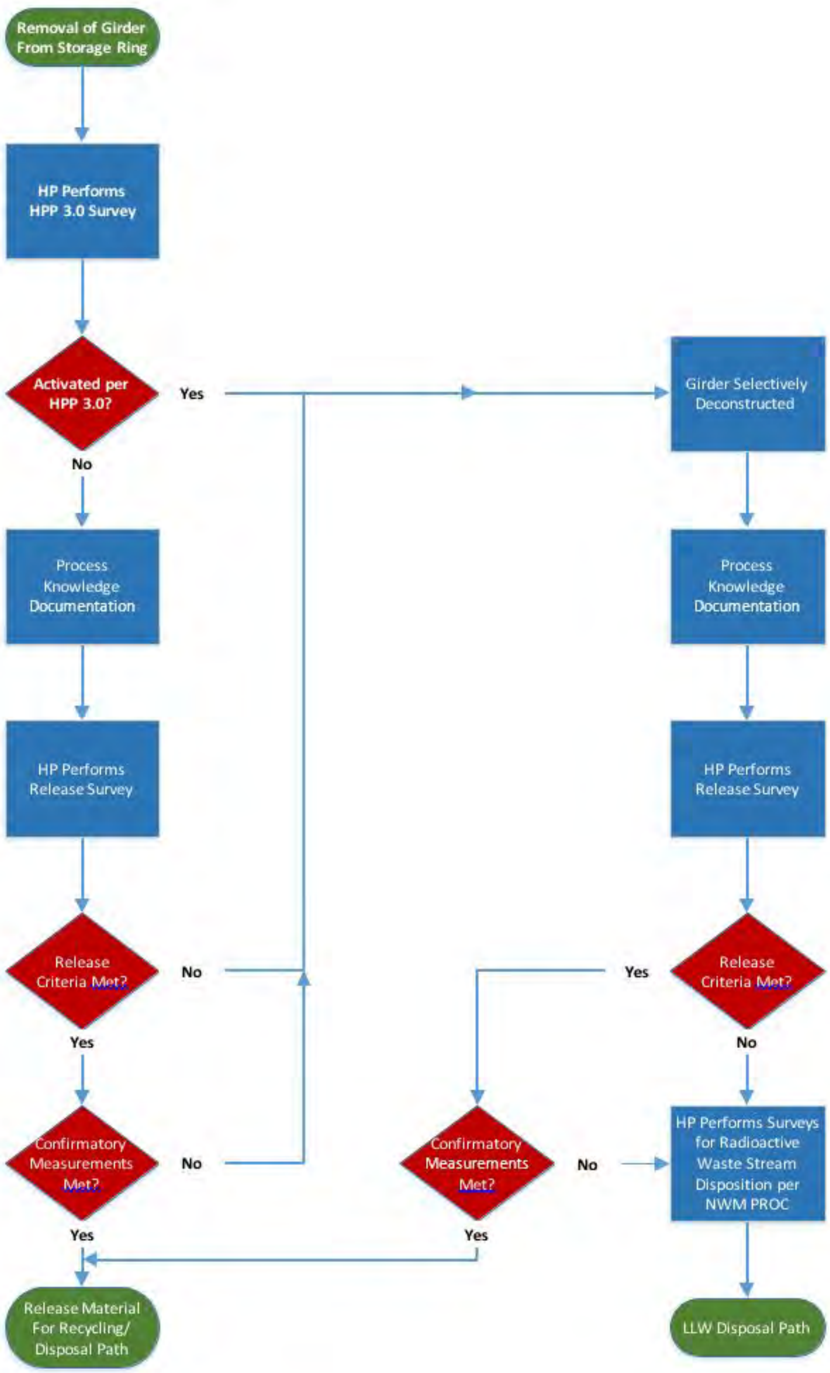


Figure 5.6. Disposition path for potentially activated material removed from storage ring tunnel.

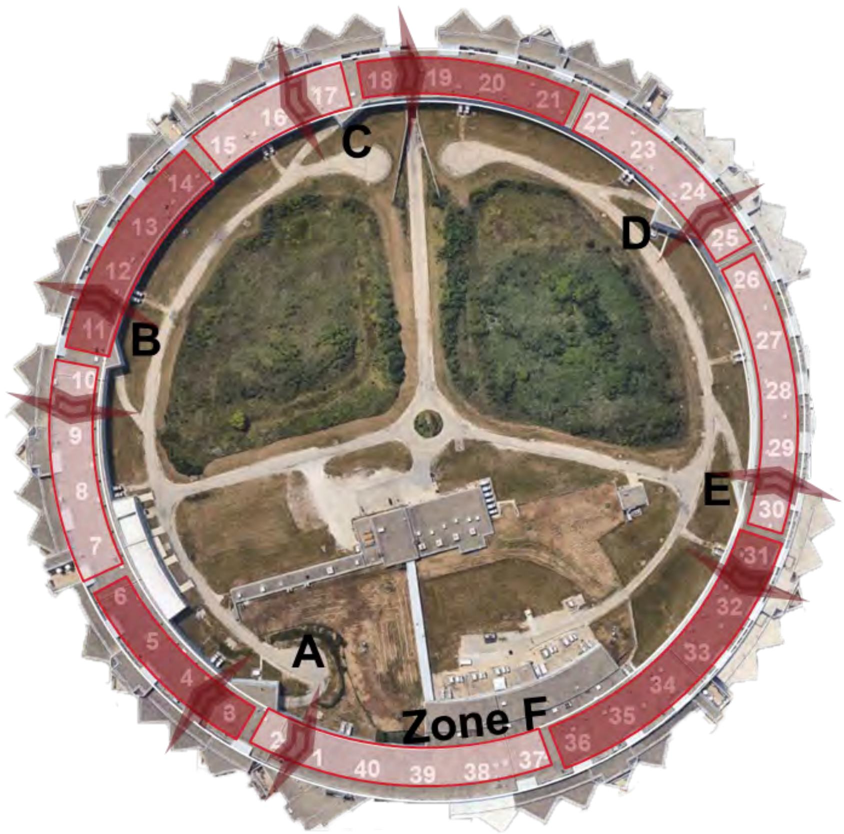


Figure 5.7. Storage ring removal schema.

5-3 Storage Ring and Mezzanine Equipment Installation

The installation period has been defined as the period during which no X-ray beam will be available for APS experimental users and will therefore need to be as short as feasible. The goal is for the duration of this period to be no longer than 12 months. The main installation period tasks will consist of removal, installation, and testing. The preliminary schedule was shown in Figure 5.1.

The staging areas to support the storage ring installation have been previously described in Section 4-3.14.3. Space needs for staging the magnet modules on support plinths, for new and reworked insertion devices, and for reworked front ends have been estimated and possible locations scouted. Transport of the magnet module assemblies from the staging location to the APS infield have been looked at with respect to weather, road weight restrictions, traffic, and congestion within the infield.

Space needs for staging the electronic equipment on the mezzanine have been estimated and locations around the mezzanine have been investigated and found to be adequate. A detailed installation plan has been developed. The plan will include the following removal activities described in Section 5-2:

- Removal of insertion devices
- Removal of front ends
- Removal of beam transfer line and injection equipment
- Storage ring removal, including all associated vacuum systems, cables, and hoses
- Removal of SR-related electronics on the mezzanine
- Power supply and cable removal
- Health physics activities during equipment removal

The plan will also cover the activities necessary to check and establish the alignment network needed for SR alignment during installation. The plan will also include the following installation activities:

- Survey and alignment activities prior to and during installation
- Front end installation
- Injection-extraction installation
- Vacuum system installation
- Diagnostics installation
- Magnet and support installation
- Power supply and cable installation
- Controls and cable installation
- ID installation

Planning for personnel ramp-up and any outside contracts needed to support the removal and installation will also be included. Prior to the start of installation, all equipment and components needed during the installation period must be tested, staged nearby, and ready for installation.

Each of the 40 sectors of the SR is composed of five magnet modules: DLM-A, QMQ-A, FODO, QMQ-B, and DLM-B. These modules are fully assembled and extensive testing is performed on them as they are assembled in the pre-installation period. As they are completed, they are prepared for long term storage (up to two years), and shipped to the offsite storage facility.

Once the SR is ready to start the installation process, the following installation sequence is assumed:

- Each of the large magnet modules (DLMs or FODO) for a given sector will be transported to the appropriate super door and placed on the traksporter.
- The traksporter will move the module into position in the tunnel to within 25 mm of its final position.
- Minicranes will be mounted to the plinth of the module and be used to align the module to within 1 mm of its final position.
- The module will then be grouted into position.
- When all the large magnet modules for a sector are installed, rough aligned, and grouted in place, the QMQ modules will be brought in via a transport cart and installed to bridge between the large modules.
- Then the DLM-A, FODO, and DLM-B modules initial alignment will occur.

After all forty sectors have their magnet modules installed, tunnel will be closed and allowed to thermally equilibrate. Two full ring measurement and smoothing passes will be performed to bring the large magnet modules of the accelerator to their final alignment tolerances. Once the smoothing is completed, the QMQ modules will be brought into alignment with the other modules.

In each sector, the next steps for installation are:

- Hi pot testing of the modules
- Hydrostatic Leveling system installation (excluding Zone F)
- BPM stand installation
- Insertion Device Vacuum Chamber (IDVC) installation, SCU installation, or Zone F straight section component installation, as appropriate.
- BPM installation
- Accelerator vacuum connections, magnet cooling water connections, then vacuum bakeout and NEG coating activation
- IDVC vacuum connections, vacuum bakeout, and NEG cartridge activation, SCU pumpdown, or Zone F straight section component vacuum connection and bakeout, as appropriate
- All remaining water and cable connections
- Final sector survey measurement

The injection/extraction system in the Zone F straight sections will be installed following routine, established procedures. A description of the injection/extraction system is in section 4-3.6.

After the vacuum systems are sealed up, the insertion device mounting stands will be installed on the floor under the IDVC. Then the installation of the insertion devices will begin, following routine, established procedures. Examples of typical insertion devices to be installed are shown in Figure 5.8.

As soon as the first FODO and downstream DLM magnet modules are installed, the installation of the front ends following routine, established procedures shall begin. Examples of the new front ends to be installed are shown in Figure 5.9.

Prior to the start of installation, all equipment and components needed for mezzanine installation

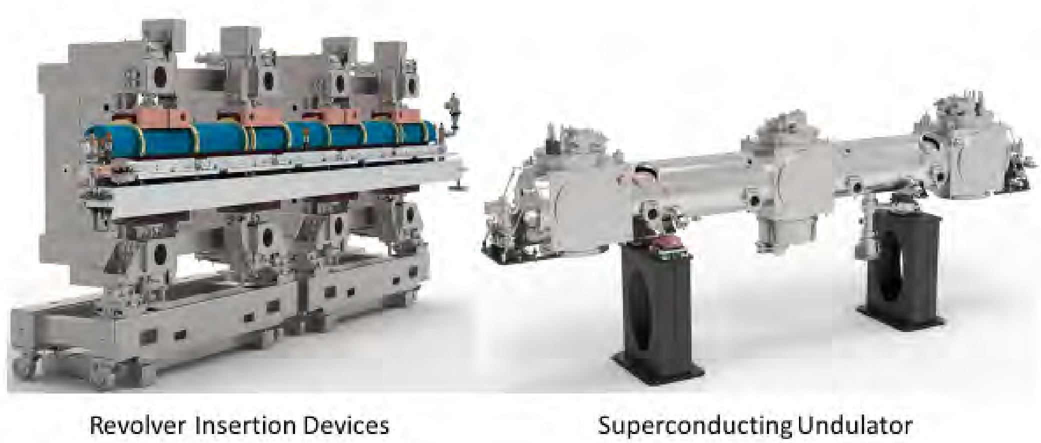
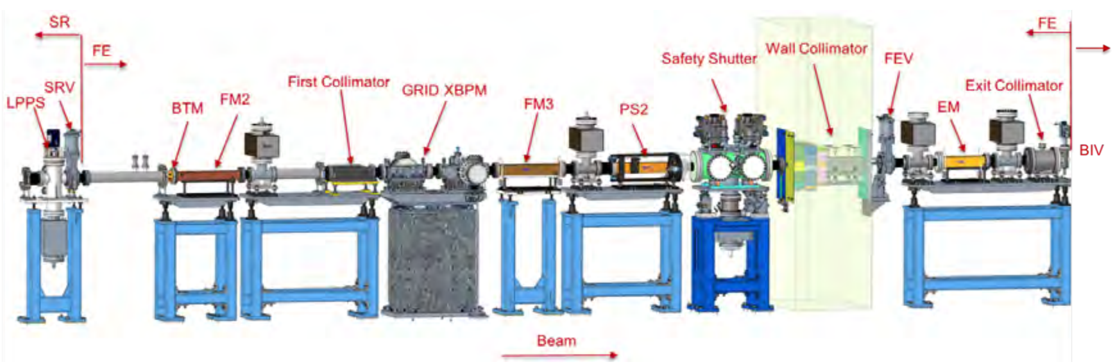
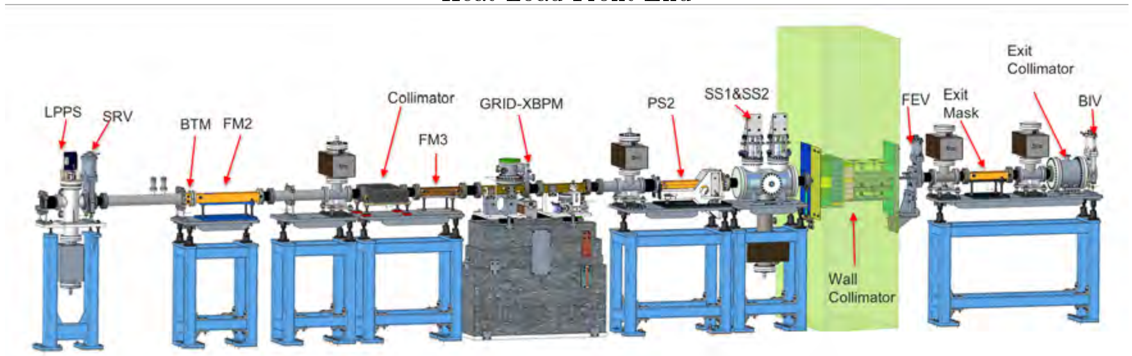


Figure 5.8. Typical insertion devices to be installed.



High Heat Load Front End



Canted Undulator Front End

Figure 5.9. New ID front ends to be installed.

during the installation period must be staged, tested, and ready for installation. The mezzanine installation will be happening in parallel to the installation work in the storage ring.

The scope of the installation work on the mezzanine is as follows:

- Install new diagnostics cabinets
- Install new power converter cabinets
- Install new power converter modules into the existing cabinets
- Install new vacuum control equipment into the existing cabinets
- Install new controls and diagnostics electronics (See Table 5.2 and Table 5.3 below.)

Table 5.2. Diagnostics installation scope

Item	**Quantity**
RF BPM hardline coax installation/sector	560 (sets for 40 sectors)
RF BPM heliax coax installation/sector	560 (sets for 40 sectors)
EMI cabinets installed	40 (1 per sector)
Libera Brilliance plus BPMs installed	560 (sets for 40 sectors)
Hydrostatic level systems	35 sets
ID x-ray BPM cable installation	105
BM x-ray BPMs cable installation	70
ID x-ray BPM electronics installation	105
BM x-ray BPMs electronics installation	70
Beam size monitor systems	2
Real-time feedback double sector controller	20
DCCT current monitor electronics	2
Bunch current monitor electronics	1 batch
Loss monitors (reinstallation)	80

Table 5.3. Controls installation scope by subsystem

Device	**Activity**
Controls Infrastructure	Timing, Moxa, DAQ, Network, and servers Equipment and cable installation Tech system checkout
Machine protection interfaces	16 thermocouple wires, 40 water/vacuum for interlock latch cards Equipment and cable installation Tech system checkout
IOC database debug	Determine that all devices are communicating and the database is correct Equipment and cable installation Tech system checkout

Canted Undulator Front End

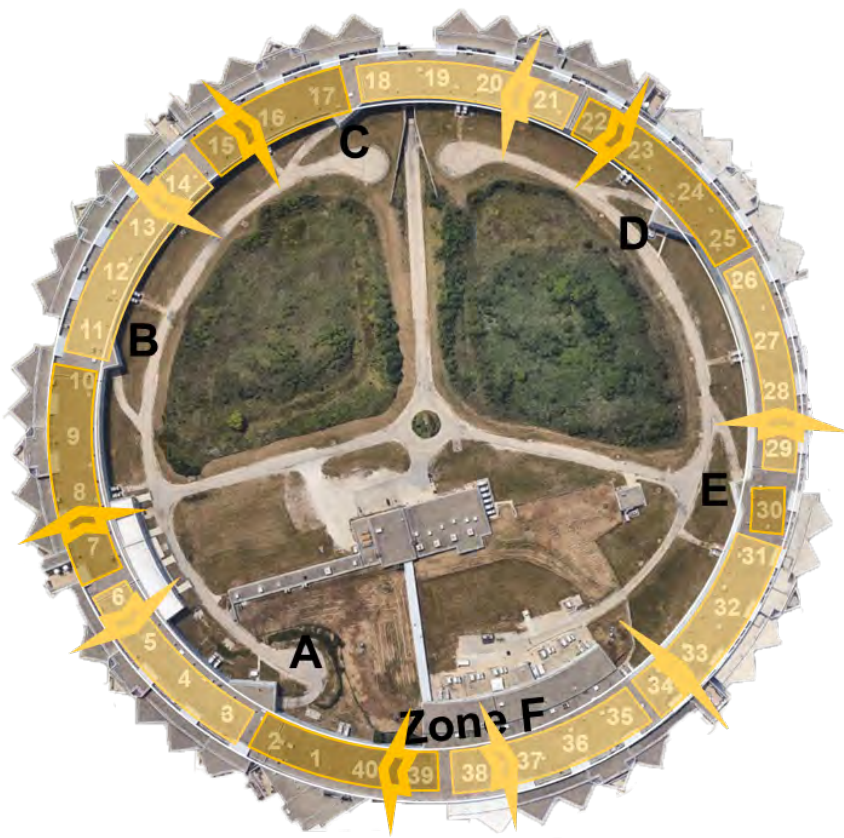


Figure 5.10. Storage ring installation schema.

References

[1] SLAC National Accelerator Laboratory. Taking Down a Giant: 699 Tons of SLAC's Accelerator Removed for Upgrade, Jan 2017.