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Revision 1

ALS

Beamline Design Requirements

A GUIDE FOR BEAMLINE DESIGNERS

JUNE 1996

Advanced Light Source
Ernest Orlando Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720

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Documentation referred to in this document and additional copies of this manual are available from the ALS User Office, 510-486-7745, Fax: 510-486-4773.

The ALS values your suggestions. Please send any comments about this publication to Jane Cross at jccross@lbl.gov.

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About This Manual

PURPOSE

This manual is written as a guide for researchers in designing beamlines and endstations acceptable for use at the ALS. It contains guidelines and policies related to personnel safety and equipment and vacuum protection. All equipment and procedures must ultimately satisfy the safety requirements set aside in the Lawrence Berkeley National Laboratory (LBNL) *Health and Safety Manual* (PUB-3000) which is available from the ALS User Office or on the World Wide Web from the LBNL Homepage (http://www.lbl.gov).

ABBREVIATIONS

BDR	Beamline Design Review
BRC	Beamline Review Committee
BRR	Beamline Readiness Review
CDR	Conceptual Design Review
EH&S	Environment, Health, and Safety
EPS	Equipment Protection System
LCW	Low-Conductivity Water
MOU	Memorandum of Understanding
PRT	Participating Research Team
PSS	Personnel Safety Shutter
RGA	Residual Gas Analyzer
RSS	Radiation Safety System
UHV	Ultra-High Vacuum

Introduction

ABOUT THE ADVANCED LIGHT SOURCE

The Advanced Light Source (ALS) is a national user facility for scientific research and development located at the Lawrence Berkeley National Laboratory (LBNL) of the University of California. Its purpose is to generate beams of very bright light in the ultraviolet and soft x-ray regions of the spectrum. Funded by the U.S. Department of Energy, the ALS is open to researchers from industry, universities, and government laboratories.

RESEARCHERS AT THE ALS

A researcher at the ALS can work as a member of a participating research team (PRT) or as an independent investigator. PRTs (collaborative groups of people from industry, universities, and/or government laboratories) are responsible for the design and construction of one or a combination of the following: insertion device, beamline, endstations (experiment chambers). Independent investigators may bring experiment endstations to the ALS from other locations, or may use endstations provided by the ALS facility or by a PRT.

In either case, any team or independent investigator who brings a beamline or related equipment to the ALS must design the equipment such that it:

- Conforms with all applicable safety regulations
- Incorporates measures for the protection of the storage-ring vacuum and of costly beamline components.

Beamline Definitions

BEAMLINE COMPONENT GROUPS

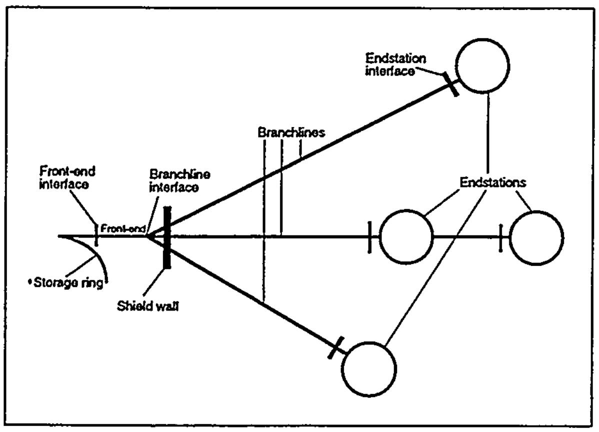
Definition of a Beamline

Beamlines are photon delivery systems that begin at the storage ring vacuum chamber and extend onto the experiment floor to include the experiment endstations. This definition of a beamline includes configurations with multiple branchlines and endstations.

A beamline might have multiple branchlines to accommodate different optical instrumentation. Each branchline might have multiple endstations to optimize timesharing of the beam. The simplest beamline configuration would have no branching and a single endstation.

Beamline Configuration

The figure below represents a generalized combination of configurations.



The three major beamline component groups are:

- Front end
- Branchlines
- Endstations

Even in the simplest configuration with no branching, the component group between the front end and the endstation will be called a branchline in this manual.

Front End

The front end begins at the storage ring vacuum chamber and ends at the branchline interface, which is generally located immediately downstream (toward the experiment) from the personnel safety shutter(s) at the shield wall. (In some cases the branchline interface may occur further downstream or further upstream.)

Each beamline has one front end shared by all branchlines. The major components of a front end are:

COMPONENT	FUNCTION
Water-cooled apertures	Pass the entire or a partial width of the beam to downstream components while protecting equipment from thermal damage.
Vacuum valves	Permit isolation of the beamline vacuum environment from that of the storage ring.
Water-cooled photon shutter	Closes to interrupt transmission of the synchrotron-radiation beam.
Personnel safety shutter	Closes to provide bremsstrahlung radiation shielding for the beamline.

Note: For bend-magnet beamlines, space in the front end will be reserved for a possible mirror chamber.

Branchlines

The branchline component group begins at the branchline interface and ends at the endstation interface, which is immediately upstream from the first endstation component.

Although the branchline section begins at the branchline interface, it need not begin branching at that point. On some beamlines with multiple branchlines, a region beginning at this interface and extending downstream for a distance may contain instrumentation that is shared by all the branchlines. For example, a single mirror tank or aperture tank may be used to service all the branchlines.

The following component types are found in branchlines:

COMPONENT	FUNCTION
Personnel safety shutter	Closes to provide bremsstrahlung radiation shielding for the branchline.
Optics	Focus and filter the synchrotron-radiation beam. Focusing mirrors and monochromators are examples.
Vacuum valves	Isolate components for installation, servicing, and equipment protection. Isolate the branchline vacuum from the attached endstation(s).
Diagnostics	Align and qualify optical components. Provide data on the properties of the beam.

Endstations

The endstation component group begins at the endstation interface. It may consist of one or more experiment stations. The components will vary depending on the type of experiments being conducted.

Certain endstations, for example those on white-light beamlines, must be surrounded by a hutch to protect personnel from radiation.

RESPONSIBILITY FOR BEAMLINE COMPONENTS

Policy
The responsibility for the design, construction, and installation of the major beamline components will be specifically defined in a memorandum of understanding (MOU) executed by the ALS Scientific Program Head and each PRT developing a beamline. In general, responsibility is assigned as follows:

COMPONENT GROUP	RESPONSIBILITY
Front end	The ALS will design all front-end components. The ALS staff or a PRT may build a front end depending on the agreement reached in the MOU for that PRT. In either case, construction of the front end will be based on designs provided by the ALS, with no modifications. The ALS staff will install the front end for all beamlines.
Branchlines	The ALS or PRT will design, build, and install all branchline components, except as stated below or in the MOU. • The ALS will design, build, and install all branchline interlocks and controls related to radiation safety. • The ALS will oversee survey and alignment of branchline components during installation.
Endstations including hutches	The PRT or an independent investigator will design, build, and install all endstation components, except as stated below or in the MOU. • The ALS will design, build, and install all endstation interlocks and controls related to radiation safety.

Guidelines For Beamline Reviews

GENERAL INFORMATION

Types of Beamline Reviews

The development of beamlines for use at the ALS is monitored by the Beamline Review Committee (BRC). Every ALS beamline is subject to three reviews:

- Conceptual Design Review (CDR) at the start of beamline development. This is an informal review at which the conceptual design of the beamline, without the engineering details, is outlined.
- Beamline Design Review (BDR) before installation of any beamline equipment. This review examines the beamline design, including the design of all equipment.
- Beamline Readiness Review (BRR) following installation of the complete beamline and prior to initial operation. The BRR includes testing to ensure that the beamline can operate safely. The ALS will oversee this testing. Final authorization for routine beamline operation is given by the ALS Director or designee.

These reviews may be repeated if modifications are made that warrant review or if significant issues require further clarification.

Purpose of Beamline Reviews

Beamlines are reviewed to ensure that their components and equipment satisfy all ALS, LBNL, and DOE requirements for safe operation. The documentation developed for the reviews and during the review processes is kept on file and is accessible for reference whenever information about the beamline is required.

Who Conducts Reviews?

Conceptual Design Reviews, Beamline Design Reviews, and Beamline Readiness Reviews are conducted by the ALS Beamline Review Committee. This committee consists of the ALS Environment, Health, and Safety (EH&S) Program Manager; the ALS Mechanical Group Leader; members of the ALS staff who have expertise in beamline design, construction, and operation; and members of LBNL's EH&S Division.

How Long Does the Process Take?

Typically, development of a beamline from concept to implementation takes many months. A Conceptual Design Review (CDR) should be scheduled as soon as the beamline concept is defined. The Beamline Design Review (BDR) should take place while the beamline is still in the design stage and before ordering components, so that no hardware will have to be altered. It is recommended that the BDR be conducted 6 months (absolute minimum is 3 months) before the tentative date of the first operation of the beamline. The documentation package for the BDR, described in the Beamline Design Review section of this document, must be received at least 2 weeks before the BDR is scheduled. The Beamline Readiness Review (BRR) takes place a few days prior to first operation. The Beamline Review Committee intends that the review process should not cause any delay to the design and implementation of a new beamline.

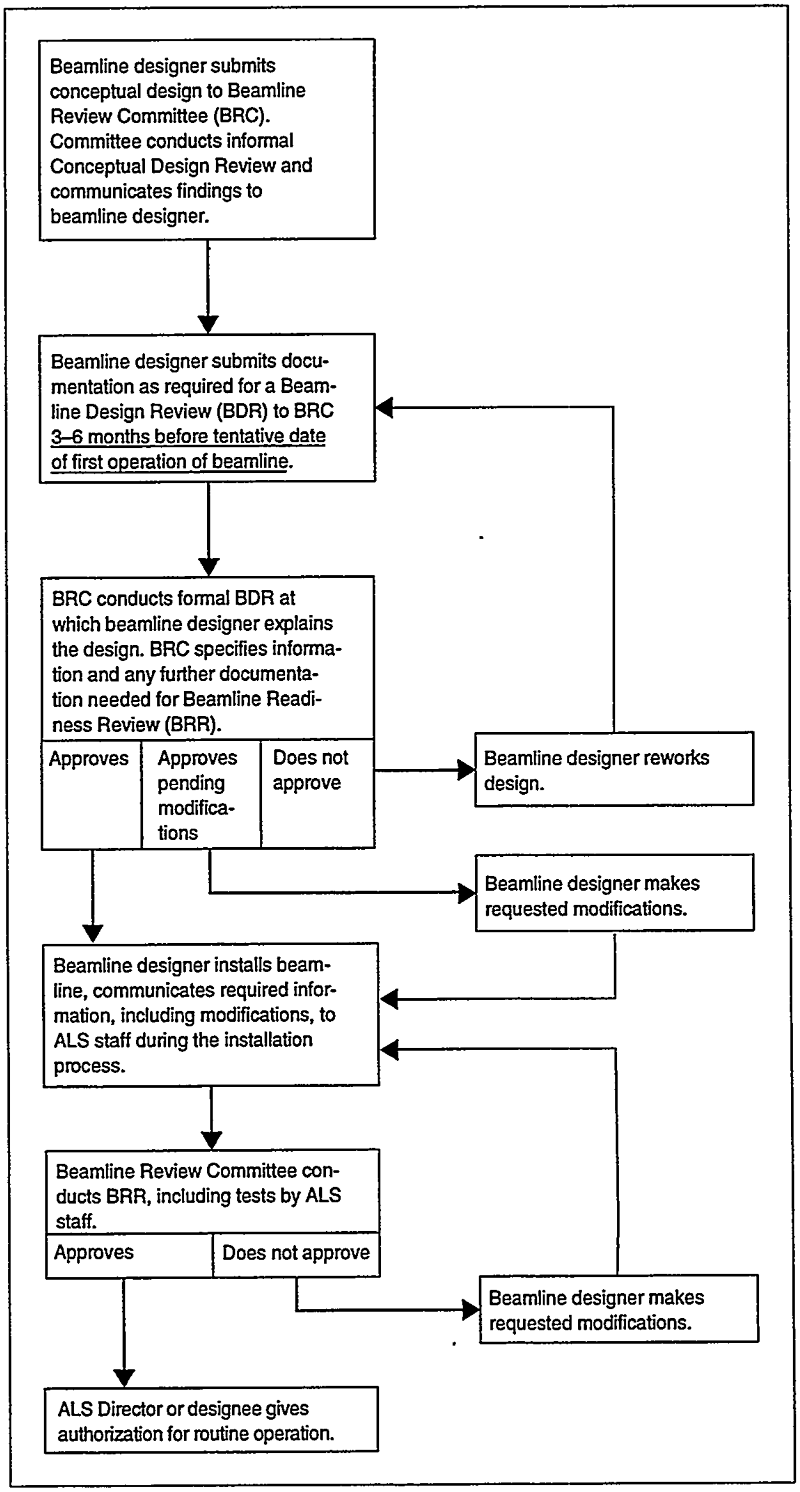
Scheduling a Beamline Review

To schedule a review, please contact the head of the Beamline Review Committee. This position rotates annually; for the name of the current chair contact the ALS Administrator:

Elizabeth Saucier
ALS Administrator
Advanced Light Source, MS 80-101
Lawrence Berkeley National Laboratory
Berkeley, CA 94720
(510) 486-6166
(510) 486-4960 [Fax]

REVIEW PROCESS

The beamline review process is outlined in the following flowchart:



Conceptual Design Review

GENERAL INFORMATION

Definition and Purpose

The Conceptual Design Review (CDR) is an informal review conducted by the Beamline Review Committee at the earliest possible stage of beamline development. It is intended to:

- Allow the beamline designer to communicate the conceptual outline of the proposed beamline, minus the engineering details, to ALS staff.
- Give ALS staff the opportunity to examine the preliminary designs and offer suggestions on how best to utilize allocated space and materials in order to fully exploit the special properties of the ALS synchrotron radiation source.
- Establish lines of communication between the beamline designer and ALS staff to facilitate and coordinate subsequent steps in the beamline development process.

When is a Conceptual Design Review Conducted?

A Conceptual Design Review (CDR) should be scheduled as soon as the beamline concept is defined.

Beamline Design Review

GENERAL INFORMATION

Definition and Purpose

At the Beamline Design Review (BDR), the beamline designer presents the detailed design to the Beamline Review Committee which examines the design of all equipment before installation begins to ensure that the beamline will:

- Operate safely in accordance with all applicable regulations on radiation, electrical safety, fire safety, hazardous materials, and seismic safety.

- Maintain the quality of the vacuum in the storage ring and protect costly components of the beamline itself.

- Be configured to allow access or egress to/from surrounding areas, conform with space allocation, and not interfere with the safe operation of the ALS.

A Beamline Design Review is distinct from an Experiment Safety Review. The former evaluates "permanent beamline components," whereas the latter evaluates the equipment and materials brought to the ALS to conduct specific experiments. Only one BDR per beamline will be required unless substantial changes are made to the beamline design. In contrast, an experiment safety review will be conducted for each experiment performed on a beamline.

When is a Beamline Design Review Conducted?

The Beamline Design Review for a beamline will be conducted before any equipment is installed on the ALS floor. <u>It is recommended that the BDR be done 6 months (absolute minimum is 3 months) before the tentative date of first operation of the beamline</u> (and before funds are committed to fabricate expensive components). Thus, the beamline developers should schedule the BDR through the Beamline Review Committee well before any beamline equipment is due to be installed on the ALS floor. A beamline is also subject to a Beamline Design Review after its installation if substantial modifications have been made.

DOCUMENTATION PACKAGE

Contents of Package

Each item on the following list (if applicable) must be prepared by the beamline designer and 11 copies of the complete documentation package must be submitted to the Beamline Review Committee at least two weeks before the BDR is scheduled. See Appendix E for persons to contact for specific items on the list.

1. Description of radiation shielding
2. Description of vacuum components and safety
3. Description of electrical safety measures
4. Description of utility requirements
5. Description of fire safety measures
6. Description of safety measures with respect to hazardous materials
7. Description of seismic safety measures
8. Description of mechanical safety measures
9. Description of equipment protection system
10. Description of survey and alignment fiducials on beamline components during installation
11. Drawings of beamline/endstation layout
12. Description of hutches (if used)
13. Description of a typical experiment

For More Information

The following sections give information on the details to be included in each documentation category together with additional information to assist the beamline designer. A checklist and a suggested timeline for completion of beamline documentation and construction are given in Appendix F. A sample BDR document package is available from the ALS User Office; for contact information see Appendix E. ALS User Advisories containing additional information about design and installation requirements of beamline equipment are in Appendix G.

1. RADIATION SHIELDING

Documentation

The documentation for a Beamline Design Review must describe the radiation shielding that will be used on the beamline components. Please include the following information:

- Anamorphically scaled ray-trace drawings with dimensions, showing the important lines-of-sight through the opening in the storage ring shield wall, and the shielding against bremsstrahlung radiation. These drawings will be used to verify the adequacy of the shielding and to check the location of the shielding once the beamline has been installed. All major components and shielding must be labeled using the method shown below.

- Anamorphically scaled drawings of exclusion zones and description of equipment for preventing personnel entry into line-of-sight bremsstrahlung radiation when the personnel safety shutter is open.

The ray-trace drawings are prepared by the beamline designer with assistance from the ALS Mechanical Engineering staff as required. It is strongly recommended that beamline builders start communicating the information related to shielding as soon as the preliminary design for the beamline is completed as it may take a few iterations before the shielding design is finalized.

Labels

The labels for the bremsstrahlung shielding and exclusion zones should follow the format described below.

B(number of branchline)_BSxx
B(number of branchline)_EZxx

Where xx indicates the number of the shield or exclusion zone. The bremsstrahlung shields and exclusion zones should be numbered sequentially starting from the storage ring.

Examples: B7.0.1_BS01 specifies the first bremsstrahlung shield on branchline 1 of the undulator beamline in storage ring sector 7.

B9.3.1_EZ08 specifies the eighth exclusion zone on branchline 1 of the bend-magnet beamline coming off the fourth port in storage ring sector 9.

These identifiers should be written on permanent labels and affixed to the most accessible side of the shielding or exclusion zone to provide quick and easy identification. The lettering should be at least 2 cm (.8 in) high to make the labels easy to read from a distance.

Guidelines

a. Personnel safety shutters (PSS) are installed by the ALS as part of the front end of almost every beamline. When the PSS are closed, there is sufficient overlap of shielding elements inside the storage ring shield wall to prevent any radiation from emerging onto the experiment floor during normal operation. When the PSS are opened to permit synchrotron radiation into the beamline, there is also a component of high energy bremsstrahlung which emerges along lines-of-sight from the storage ring. This radiation must be collimated by lead shields and contained inside the beampipe or exclusion zones until the synchrotron light can be deflected by a mirror so that the remaining bremsstrahlung can be intercepted and absorbed.

b. Personnel safety shutters must be fail-safe, with redundant electrical controls interlocked to position-indicator switches in order to afford maximum safety for personnel. Beamline designers are required to use an ALS design for personnel safety shutters. The ALS will also design, build, and install all personnel safety interlocks.

c. Some beamlines require a hutch because bremsstrahlung radiation is present at the end-station.

d. Routine user access may be required to the interior of hutches and to other regions in which radiation is present during beamline operation. These situations call for additional radiation safety interlock systems and possibly additional personnel safety shutters to ensure that the PSS are closed during controlled access.

For More Information

For information on preparing anamorphic drawings and additional details on requirements for bremsstrahlung shielding, see Appendix A. For contact information for assistance in designing radiation shielding, see Appendix E. Radiation safety requirements and estimates of synchrotron radiation can be found in *ALS Synchrotron Radiation Shielding* (LBL-37801), available from the ALS User Office; see Appendix E for contact information.

2. VACUUM COMPONENTS AND SAFETY

Documentation

The documentation for a Beamline Design Review must include a description of the vacuum components of the beamline and endstation(s), including the following details:

- Schematic diagram of vacuum chambers, valves, and connections
- Description of materials used in UHV systems
- Description of ion gauges
- Types of pump(s), locations, speeds, and interlock systems
- Description of vacuum isolation valves and interlock systems
- Fast-valve sensor locations
- Design of thin windows
- Design of gas cells
- Design of cooling systems.

Guidelines

Preventing contamination of beamlines and the storage ring is an important concern at the ALS. For example, as little as 0.1 cc of pump oil could permanently ruin the entire storage ring vacuum chamber. Only a single fast valve protects the storage ring from sudden beamline vacuum accidents. Beamline designers and ALS users must recognize that a high level of vacuum safety is needed for all equipment connected to the ALS vacuum chamber.

For More Information

See Appendix B, *ALS Vacuum Policy and Vacuum Guidelines for Beamlines and Experiment Endstations* (LSBL-280), for information covering all aspects of vacuum safety in beamline design, and Appendix G, ALS User

Advisories for detailed guidelines on vacuum policy, interlock requirements for turbo pumps, and vacuum safety when toxic or corrosive gases are in use. These appendices should be read before the design of the beamline begins.

3. ELECTRICAL SAFETY

Documentation

The documentation for a Beamline Design Review must list all electrical equipment that will be part of the branchline(s) and endstation(s) and give the function and specifications for each item.

Example	
Function	Specification
Ion pump power supply	Output voltage 5 kVDC
Sublimation pump power	Output current 60 amps Output voltage 10 VDC

Guidelines

All electrical equipment used in conjunction with beamlines must satisfy the electrical safety requirements established in the LBNL *Health and Safety Manual* (PUB-3000), Chapter 8, "Electrical Safety," and Chapter 21, "Lockout/Tagout," and in the current edition of *National Electrical Code*, ANSI/NFPA 70. Following are a few important guidelines from these sources.

a. Wiring installed in open cable trays must be labeled as suitable for cable trays.

b. Exposed terminals ≤ 50 volts must be isolated by enclosures, covers, screw-on panels, or by interlocked doors. Appropriate warning signs must be affixed to all doors and covers.

c. Energy-storage devices (such as capacitors) capable of storing more than 5 joules of energy must be equipped with automatic discharge devices such as shorting relays or bleeder resistors that discharge to safe voltage (≤ 50 volts) when the equipment is de-energized or when the capacitor enclosure is opened. The energy must be discharged within a time no greater than the time needed for personnel to gain access to the voltage terminals. In no case must this time be longer than 5 minutes.

d. To eliminate the danger of lethal voltages appearing between the vacuum chamber and electronic ground when ionization gauges and ion pumps are in operation, the vacuum chamber must have a common electrical ground with the gauge control or ion pump power supply.

e. Beamline components must be properly grounded, especially during bakeout. All heaters used for bakeout must be protected by a ground fault circuit interrupter (GFCI). The ALS routinely installs GFCI at convenient locations along the beamline.

f. Split heater-tape connectors must be permanently bonded together to form one assembly or replaced with a single, unified connector; split connectors are not allowed.

g. Due to the high voltage supplied to ion pumps, certain cables and connectors may require an ALS retrofit. For example, where exposed cables could be damaged on vacuum systems using Perkin-Elmer equipment exclusively, the high-voltage cable (RG142 coax) must be contained along with a #12 ground wire in a 5/6" (21 mm) flexible armor conduit. A specially designed safety cable clamp (ALS #23W1734) is installed on the ion pump end of the high-voltage cable and a conduit clamp is installed on the controller end. The ground wire is then terminated to both the ion pump and the controller. Similar protective measures may be required for other manufacturers' equipment; contact ALS Electrical Engineering staff for more information.

When terminating cables with connectors intended for use on circuits with hazardous voltage such as ion-pump cables, care should be taken to terminate the supply end last. If the load (pump) end is being modified or re-terminated, the supply-end connector should be isolated in a lock-out device.

For More Information
Additional information on electrical safety at the ALS can be found in ALS User Advisories in Appendix G, and in the *ALS Safety Handbook* (PUB-745), available from the ALS User Office; see Appendix E for contact information.

4. UTILITY REQUIREMENTS

Documentation
The documentation for a Beamline Design Review must provide a list of all utility requirements for the beamline including:

- Electrical power requirements
- Distribution layout
- Compressed air or nitrogen distribution requirements
- Low-conductivity water (LCW) requirements including flow, temperature and pressure
- Exhaust manifold layout.

Guidelines
Utilities and services available at the ALS include:

- Electrical power: 480VAC, 208VAC, 120VAC, single and 3 phase, 60 Hz
- Low-conductivity (deionized) water
- Compressed air or nitrogen
- Exhaust manifold system
- Machine shops, including plating and welding
- UHV facilities, including vacuum brazing
- Electrical and electronic fabrication shops.

Beamline utility racks should be numbered as described in *ALS Beamline Rack Numbering Scheme* (LSEE-107A), available from the ALS User Office; see Appendix E for contact information.

5. FIRE SAFETY

Documentation

The documentation for a Beamline Design Review must describe the following:

- Any flammable chemicals and solvents that may be used in the operation or maintenance of the beamline, apart from those used in individual experiments.
- Electrical equipment containing flammable fluids or to be used routinely in association with flammable fluids.
- The layout of escape aisles around experiments and beamlines.

Guidelines

Please do not plan on storing flammable or otherwise hazardous chemicals in cabinets in the immediate beamline area, even in small amounts. Such materials may be used in an experiment; however they must be stored in designated locations provided by the ALS. The number of cabinets allowed for storing such materials on the ALS floor is limited by fire regulations.

6. HAZARDOUS MATERIALS

Documentation

The documentation for a Beamline Design Review must provide the following information concerning hazardous materials:

- A list of any hazardous materials that will be used in the structure, regular operation, or maintenance of the beamline, apart from those used for particular experiments. Please describe how each material will be used.
- A list of any hazardous materials that may be pumped through the system.
- A description of any beryllium windows used.

Guidelines

a. A hazardous material is one that can potentially pose a health hazard (e.g., radioactive materials, carcinogens, toxic agents, irritants, corrosives, or hazardous biological substances) or a physical hazard (e.g., flammables, cryogenics).

b. Hazardous materials are not allowed in the ALS experiment area without prior approval. If hazardous materials are approved for use with your beamline, please do not plan on storing them in the immediate beamline area, even in small amounts. They must be stored in designated locations provided by the ALS.

c. Cleaning procedures requiring the extensive use of solvents must be conducted in the laboratory provided for this purpose and not in the experiment area. It is therefore recommended that equipment be designed to be disassembled for cleaning.

d. Hazardous pump exhaust must be vented through the exhaust system provided by the ALS.

e. All beamlines must satisfy the chemical safety requirements in the LBNL *Health and Safety Manual* (PUB-3000), Chapters 5 and 30, and in the LBNL *Chemical Hygiene and Safety Plan* (PUB-5341). The latter publication contains regulations for specific chemicals.

7. SEISMIC SAFETY

Documentation

The documentation for a Beamline Design Review must describe the measures taken for seismic safety. Please include the following information:

- A description of the beamline and endstation components and equipment from the standpoint of seismic stability. Include an estimate of the mass and the height of center of gravity for each component.
- A description of the containment to prevent dispersion of chemical reagents: radioactive, infectious, pyrophoric, flammable, or toxic materials.

Guidelines

All experiment equipment installed at the ALS must be in compliance with the seismic-safety criteria specified in the LBNL *Health and Safety Manual* (PUB-3000), Chapter 23. The intent of these criteria is to ensure that the equipment is designed to resist, without collapse, earthquakes of magnitude 7.0 Richter on the Hayward fault and those of magnitude 8.3 Richter on the San Andreas fault. For convenience these criteria are summarized here; however, this summary is not intended to be comprehensive.

For equipment which, due to size or unique structure, requires specialized seismic stabilization, additional criteria may be required. Any such criteria will be reviewed by ALS Engineering staff.

General Criteria. Objects not easily restrained by one person must be prevented from lateral movement and from overturning without reliance on friction when the object is subjected to a 0.7 g lateral acceleration through its center of gravity. It is recommended that equipment be designed to withstand a lateral acceleration of 1.0 g or greater.

Dynamic Analysis. For heavy equipment or other objects mounted on support stands, the dynamic load during an earthquake may, because of resonance, greatly exceed the maximum ground acceleration. Support structures should be designed with enough rigidity to achieve natural frequencies above 20 Hz. For structures with natural frequencies below 20 Hz, the effect of the resonance can be significant. Structures in this category may require a dynamic structural analysis to be done by the ALS Engineering Group.

For More Information

Refer to ALS User Advisories 1 and 4 in Appendix G for additional information regarding seismic safety requirements for user equipment.

8. MECHANICAL SAFETY

Documentation

The documentation for a Beamline Design Review must describe any potentially hazardous mechanical components so as to document the associated safety measures. Examples of such potential hazards are:

- Lifting fixtures and rigging
- Vacuum viewports which are custom designed or have apertures that are >15 cm (6 in.)
- Moving components with potential to injure personnel
- Pressure vessels
- Enclosed spaces
- Ladders and steps
- Platforms and gantries.

9. EQUIPMENT PROTECTION SYSTEM

Documentation

For a Beamline Design Review, the documentation of the equipment protection system for a branchline or endstation should include:

- An instrumentation diagram describing all major equipment protection components
- A complete description of all equipment-protection interlocks
- A description of the interface between the beamline equipment protection system; and the ALS-designed parts of the beamline control system and the ALS-designed radiation safety system (RSS).

Guidelines

The purpose of an equipment protection system for a beamline is to prevent damage to components that would be very expensive to replace and to protect the storage-ring vacuum.

a. Beamline designers are expected to design, build, and install equipment protection systems (including interlocks) to work on all branchlines. These systems must automatically respond to equipment-protection faults, which generally fall into two categories: vacuum and thermal. Vacuum interlocks must be provided to protect the integrity of the beamline vacuum. Thermal interlocks and water-flow interlocks must be provided to protect cooled components.

b. The equipment protection system should perform three major functions:

- Permit operation of the beamline only if protection devices are operating correctly. If the equipment protection devices fail, a control fault is produced and the equipment protection system takes appropriate action in response to the fault. For example, if an ion-gauge controller detects a leak in the vacuum system, valves must close to isolate the leak and the photon shutter must close to protect the valve from beam heating.

- Partition selected areas with beam stops so that sources may operate while some beamlines/ branchlines are off-line for maintenance or experiment setup.

- Mediate signals between the branchline's equipment protection system and the radiation protection control system.

c. The equipment protection systems for beamlines designed by the ALS use programmable logic controllers and interface with the operator station and instrument-control system through a dedicated RS485 network. Beamline designers may wish to take the same approach.

d. The use of manual vacuum valves along the beam path is strongly discouraged because they interfere with effective automated EPS responses.

e. Equipment protection systems that require action in the front end (for example, those that require the photon shutter to close) must communicate with the ALS front-end control system. This communication can be implemented by the following signals which interface the equipment protection system (EPS) of the front end (FE-EPS) with that of a given branchline (BR-EPS):

	SIGNAL	FUNCTION
INPUTS FROM BR-EPS TO FE-EPS	BRFE_VAC_PERMIT	Indicates safe vacuum conditions in the branchline. When FALSE, the front-end EPS will close the branchline isolation valve BR_VVR1, the first vacuum isolation valve for the branchline.
	BRFE_NONVAC_PERMIT	Indicates safe non-vacuum conditions in the branchline. When FALSE, the front-end EPS will close the branchline photon shutter BR_PS1.
OUTPUTS TO BR-EPS FROM FE-EPS	BRFE_VAC_OPEN	Indicates that branchline isolation valve BR_VVR1 is open.
	BRFE_VAC_CLOSED	Indicates that branchline isolation valve BR_VVR1 is closed.
	BRFE_NONVAC_OPEN	Indicates that branchline photon shutter BR_PS1 is open.
	BRFE_NONVAC_CLOSED	Indicates that branchline photon shutter BR_PS1 is closed.
	BRFE_PASS_BEAM	Indicates that beam may pass through front end to branchline.

10. SURVEY AND ALIGNMENT DURING INSTALLATION

Documentation

If ALS survey and alignment is required, the documentation for a Beamline Design Review should show which components will be fiducialized and the locations of the fiducials. If fiducials will not be used, please describe the plans for alignment.

Guidelines

a. In general, the components of a branchline that require precision alignment (e.g., mirrors, slits, masks, and gratings) are inside vacuum chambers and not accessible from outside for survey and alignment. Consequently, these components require "fiducialization" during the assembly of the branchline, that is, the position of important internal features must be measured relative to accessible fiducial references outside the vacuum chamber. These fiducials are then used for survey and alignment at installation. For a given component, fiducialization generates a set of Cartesian coordinates (*U*, *V*, and *W*) for each fiducial in a local coordinate system. The location of the fiducial origin (i.e., the mirror center, etc.), and a direction must be specified in the beamline coordinate system.

b. Three fiducials are required for placing a component in space with 6 degrees of freedom, but four fiducials are highly desirable for redundancy, allowing a check on the survey and alignment. Fiducials are usually a 1/4 inch precision hole which accepts a "tooling ball" for mechanical contact and measurement. The fiducials should be located with as large a separation from each other as possible and a clear vertical path above for accessibility.

c. The optical targets are constructed such that their optical center exactly coincides with the center of the tooling ball when interchanged in the same hole. This center point is the fiducial point with the coordinates *U*, *V*, and *W*.

d. Weld-on fiducial posts that accept the optical targets and the tooling balls are described in LBNL Mechanical Engineering Drawing 20 Q 5363. These fiducial posts have been used successfully throughout the ALS and are recommended.

For More Information

See Appendix C for additional details on the ALS system for survey and alignment.

11. BEAMLINE/ENDSTATION LAYOUT

Documentation

The documentation for a Beamline Design Review should include drawings of the overall beamline layout. Drawings should show locations of:

- Storage ring
- Front end
- Beamline shielding, showing labeling
- Exclusion zones, showing labeling
- Vacuum valves, with names as used for the EPS
- Ion gauges, with names as used for the EPS
- Fast valve sensors, with names as used for the EPS
- RGA locations, with labeling
- Water flow switches and other equipment protection devices
- Hutches (if appropriate)
- Endstations
- Support equipment (e.g., racks, tables, etc.)
- Walkways around beamline and endstation(s), and an escape aisle.

Guidelines

a. All major components and shielding must be labeled. Shielding and exclusion zone labels should be labelled according to the format described both in the Radiation Shielding section of this document, and in Appendix A. EPS components should be labeled with EPS system mnemonics.

b. In addition to the detailed beamline drawings, a plan drawing of the entire beamline, including control racks and space requirements, must be provided to the ALS in electronic form. ALS staff will apply the "footprint" of the new beamline to the ALS master floor layout drawing.

12. HUTCHES

Documentation

The documentation for a Beamline Design Review should include a description of the hutch design, if applicable, including the following details:

- Materials used (specify thickness)
- Penetration lengths
- Window materials
- Door security
- Fire safety measures
- Ventilation system
- Structural stability.

Guidelines

A hutch is required whenever routine access is to be available to an area in which radiation is present during beamline operation, and the method of access does not preclude a radiation hazard. At the ALS this situation arises when access is required to an area which receives bremsstrahlung radiation on a line-of-sight through the opening in the storage ring shield wall or when high energy synchrotron radiation passes into the atmosphere through a thin window. Hutches may admit personnel, or smaller enclosures may be necessary which admit only hands and arms. In either case, the ALS will design and build a special radiation safety system to ensure safe access. Access to a vacuum enclosure in a low energy beamline in a location where there is no bremsstrahlung and where the synchrotron light cannot penetrate the vacuum valves is not a hazard in this category.

Interlocks to ensure radiation safety must be developed such that their circuits and components are fail-safe to the greatest extent practicable. That is, in case of a component or power failure in the interlock system, it must react to render the area safe. The interlock system must also be redundant; that is, two independent sets of components and circuits must be developed to ensure safety in the event of a failure of one circuit. Because these systems are so critical to personnel safety, the ALS will design, build, install, and test the radiation-safety interlocks for hutches.

For More Information

Additional information regarding estimates of ALS synchrotron radiation and radiation safety requirements can be found in *ALS Synchrotron Radiation Shielding*, (LBL-37801), available from the ALS User Office; see Appendix E for contact information.

13. TYPICAL EXPERIMENT

Documentation

Briefly describe a typical experiment conducted on the beamline. Describe the following as appropriate.

- Major pieces of equipment particular to the experiment and how they are used
- Duration of the experiment
- Pressures and temperatures at various locations in the endstation
- Hazardous equipment and protection
- Hazardous materials used or generated.

Note: The BDR does not review the planned experiments. That review is requested via an *ALS Experiment Form* available from the ALS User Office. This form requests specific information about potentially hazardous materials to be used or generated and about potentially hazardous equipment to be used. A form must be completed for each experiment.

Construction Begins

GENERAL INFORMATION

Overview

After the Beamline Design Review (BDR), construction of the beamline may begin. It is expected that the beamline designer will remain in close contact with ALS staff during beamline construction. To ensure that the beamline being developed is installed in the most efficient way, it is important that the beamline designer communicate details related to all aspects of the beamline to ALS staff in a timely manner, as outlined below. Requests for modifications of anything approved during the BDR must be submitted to the Beamline Review Committee chair before the modification is made.

Communication Items During Beamline Installation

The following information should be communicated to ALS staff during beamline construction (see Appendices E and F for contact and scheduling information).

a. Beamline instrumentation details, including the location of all vacuum valves, photon shutters, fast sensors, position monitors, ion gauges, residual gas analyzers, and motors.

b. Electrical requirements including wireway layout, rack profile, cables/terminations, and electrical power requirements. Beamline utility racks should be numbered as described in *ALS Beamline Rack Numbering Scheme* (LSEE-107A), available from the ALS User Office; see Appendix E for contact information.

c. Vacuum requirements, including all vacuum needs related to clean room facility, assembly of components, bakeout requirements, and installation.

d. Radiation safety systems are designed and implemented by ALS staff and are unique to each beamline. The beamline designer must inform the ALS staff of special requirements.

e. Details of the equipment protection system (EPS) and branchline control system (hardware and software). One of the most important aspects is the installation and testing of the fast valve sensors.

f. Interlock checkout procedures for the equipment protection system.

Note: The execution of these procedures may require a specific sequence and may be carried out only on shutdown days.

g. A key-enable checklist must be provided by the beamline designer in collaboration with ALS staff. This is a list of checks to be performed by the ALS Operations Coordinator each time the beamline operator requests that the beamline be enabled for operation. The first key-enable is performed as part of the BRR. Subsequently, the beamline will need to be enabled after each instance when it is taken off-line for maintenance.

Beamline Readiness Review

GENERAL INFORMATION

Definition and Purpose

Each beamline must undergo a formal Beamline Readiness Review (BRR) to verify that the beamline has been built according to the design approved at the Beamline Design Review. The BRR has two parts—a review of documentation submitted to the BRC, and a walkthrough of the beamline to check the installation prior to first-time operation. A sample copy of the *Beamline Readiness Review Walkthrough Procedure* (BL 08-07) is included as Appendix D.

When is a BRR Conducted?

A BRR for a new beamline will be conducted after the beamline is installed, usually a few days before it is scheduled for first operation. An operational beamline must undergo a BRR whenever it is modified.

BRR Walkthrough

A comprehensive walkthrough inspection of the beamline is conducted by the ALS once all documentation and design requirements have been satisfied. The BRR Walkthrough follows the *ALS Beamline Readiness Review Walkthrough Procedure* (BL 08-07). Items checked or executed during this procedure include:

1. Radiation shielding. The position and size of the bremsstrahlung shielding and exclusion zones are checked against the approved shielding drawings.
2. Radiation safety system (RSS) specific to each beamline. These systems are tested by ALS staff every six months.
3. Electrical safety qualification to ensure safety of electrical components and wiring and to check for proper grounding and connections to vacuum vessels.
4. Mechanical qualification to check for hazards related to motorized motions and seismic safety.
5. Vacuum qualification to ensure that ion gauge readings and the residual gas analyzer (RGA) scan conform to vacuum requirements and that protection systems are in place.
6. Equipment protection system (EPS) qualification, specific to each beamline.
7. Key-enable procedure. The beamline is enabled for the first time.
8. Radiation survey of the beamline to check for measurable levels of scattered bremsstrahlung radiation.

Authorization for Routine Operation

Following a successful walkthrough, the ALS Director or designee gives authorization for routine operation. Future modifications to the beamline will require another BRR to examine the modified components.

Appendix A – Criteria For Beamline Bremsstrahlung Shielding

INTRODUCTION

This document describes the bremsstrahlung radiation shielding criteria for insertion-device and bend-magnet beamline designs outside the storage ring shield walls. These criteria are very similar to those proposed at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory[1] and by earlier work here.[2,3] The front-end shielding (inside the storage ring shield wall) has been designed such that beamline shielding designers need only know the source size, the distance to the shield wall, and the size of the penetration through the shield wall.

Each beamline must undergo a Conceptual Design Review, a Beamline Design Review, and a Beamline Readiness Review by the ALS Beamline Review Committee. Beamline designers must prepare a package of documentation for these reviews. Among the most important components of this documentation package are bremsstrahlung shielding anamorphic drawings. These are drawings on which perpendicular directions have differing magnifications or scales. These drawings allow easy visualization and verification of ray tracings since beamline lengths are many times greater than their pertinent transverse dimensions. These drawings will be used during the Beamline Design Review to ensure all bremsstrahlung radiation has been adequately attenuated, and during the Beamline Readiness Review to ensure proper installation of the shields.

As a point of clarification for previously written or in-progress ALS documentation, two terms are defined: primary shielding and secondary shielding. Primary shielding is the shielding required to maintain the bremsstrahlung dose outside the shield wall to less than 40 mrem for a single worst-case catastrophic event. This was the basis for the design of the transition walls, and it is therefore applied to the design of the front-end shielding. Secondary shielding is the shielding required to reduce the normal, continuous gas bremsstrahlung dose rates outside the storage ring shield walls to less than 200 mrem (2000 hr) per year. This document considers only secondary shielding and does not address primary shielding (front-end shielding) or the design of personnel safety shutters.

SOURCE SIZE

During injection, the personnel safety shutters on a beamline are closed. Once they are opened, the major source of unwarranted radiation to the experiment area results from electrons scattering off residual gas molecules and creating highly forward-peaked bremsstrahlung photons. This radiation is termed "gas bremsstrahlung." The source size is dictated by the cross-sectional area of the electron beam—a few millimeters horizontally and about three times smaller vertically. However, for conservatism, it should be assumed that the minimum gas bremsstrahlung source size is a rectangle 4 cm (1.6 in.) high and 6 cm (2.4 in.) wide, representative of the entire electron beam vacuum chamber excluding the antechamber. The location of the source depends on the type of front end:

Insertion-device front ends

- The source is to be located 2.7 m upstream of the outside surface of the storage ring exit flange for port 0. This corresponds roughly to the entrance to the first bend magnet.

Bend-magnet front ends

- The source for the first port should be located 3.5 m upstream of the outside surface of the storage ring exit flange for port 1, along the centerline of the beam port. This corresponds roughly to the downstream end of the first bend magnet.

- The source for the second port should be located 3.3 m upstream of the outside surface of the storage ring exit flange for port 2, along the centerline of the beam port. This corresponds roughly to the midpoint of the second bend magnet.

- The source for the third port should be located 3.5 m upstream of the outside surface of the storage ring exit flange for port 3, along the centerline of the beam port. This corresponds roughly to the downstream end of the second bend magnet.

SHIELD DIMENSIONS

All lead radiation shields required to reduce the gas bremsstrahlung must have at least 254 mm (10 in.) of lead along the longitudinal path[4] and 50.8 mm (2 in.) of lead as the minimum transverse distance between the extreme ray and the outside of the shield.[5] This is shown in Figure 1. No partial credit is taken for rays passing through less than the full 254 mm lead equivalent in any one shield. The 254 mm lead-equivalent requirement is meant to apply to all beamline designs, whether they are bend-magnet or insertion-device beamlines. Beamlines which have been bent by beamline components such as monochromators, and which penetrate the shield wall above or below the belly band, may not require additional shielding outside the shield wall if the front-end shielding is shown to be adequate.

Other shielding materials may be used if shown to be of equivalent thickness. The equivalent lead thickness is calculated as the ratio of the mean free paths at the Compton-minimum in the photon cross sections.

Gas bremsstrahlung dose rates are directly proportional to the length of the straight section traversed by the electron beam. Due to the shorter drift length of bend-magnet beamlines, lower dose rates downstream would be anticipated. However, for conservatism, consistency, and to eliminate any possibility of crosstalk between insertion-device and bend-magnet beamlines, the 254 mm lead requirement applies to both.

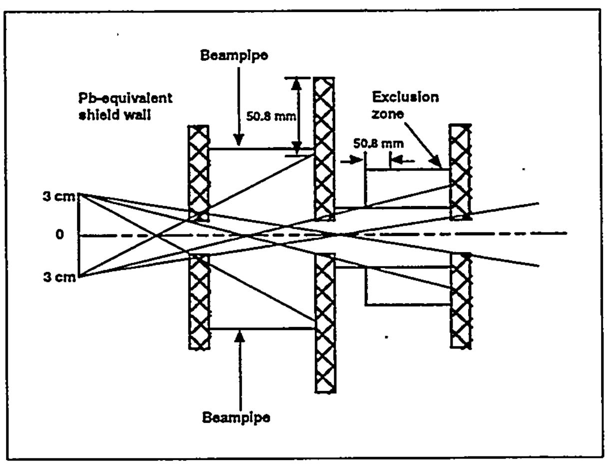


***Figure 1.** Example of extreme ray layout plan view for a beamline (azimuthally symmetric).*

ANAMORPHIC DRAWING

The anamorphic drawing is used by the Beamline Review Committee to verify the adequacy of the shielding and to check the location of all shielding once the beamline has been constructed. An example of an anamorphic shielding drawing is shown in Figure 1. All drawings should include a Beamline Review Committee approval box, either drawn or created by use of an appliqué that will be available at the ALS. The drawing should show the extreme trajectories of bremsstrahlung x rays from the source model described above, through the penetration in shield wall, and then through the beamline collars/shields to the backstop. As described above, all bremsstrahlung shields should be 254 mm thick and extreme rays should be no less than 50.8 mm from the outside of the shield. Extreme rays are those rays that define the extent of the bremsstrahlung cone (one set for plan views, one set for elevation views) which passes through the required 254 mm lead equivalent (see Figure 1).

The divergence of the bremsstrahlung radiation for beamline shielding is defined by the size of the source (given above) and the distance from the source to the inside corner of the penetration through the shield wall. The drawings must include both plan and elevation views. The elevation view should represent the view from the most accessible side of the beamline. Each should fit on a single, large, standard-size sheet of paper such as an E-size drawing. The drawing should start from the bremsstrahlung source and extend to a point where all bremsstrahlung x rays have been attenuated by the required lead equivalent of 254 mm. Note that in some cases this may extend to a hutch backstop at the end of the beamline, whereas in other cases it may extend only to the point at which the synchrotron radiation has been deflected from the bremsstrahlung cone and terminated in a lead shield wall.

When preparing the drawing, all bremsstrahlung shields must be labeled and must show transverse and longitudinal dimensions, as well as the distance from the source point, the storage ring shield wall, and the beampipe centerline. Both the longitudinal and transverse scales should be indicated. All bremsstrahlung shields should have unique designations associated with them.

The labels for the bremsstrahlung shielding and exclusion zones should follow the format:

B(number of branchline)_BSxx (for shielding)
B(number of branchline)_EZxx (for exclusion zones)

Where xx indicates the number of the shield or exclusion zone. The bremsstrahlung shields and exclusion zones should be numbered sequentially starting from the storage ring. For example: B7.01_BS01 specifies the first bremsstrahlung shield on branchline 1 of the undulator beamline in storage ring sector 7, and B9.3.1_EZ8 specifies the eighth exclusion zone on branchline 1 of the bend-magnet beamline coming off of the fourth port in storage ring sector 9.

Shields should have their composition and density specified either individually or in a general note. Shielding should be designed such that it cannot be inadvertently moved by simple means (e.g., carrying away lead bricks). Lead shields should be coated to prevent excessive lead exposures. The ALS Environmental Health and Safety Program Manager should be notified before installation of all lead shields (see Appendix E for contact information). All shields should comply with seismic safety rules and procedures established in the LBNL *Health & Safety Manual* (PUB-3000). Examples of ALS anamorphic drawings can be requested from ALS Mechanical Engineering.

EXTREME RAYS

The extreme-ray bremsstrahlung cone, shield wall, beampipe, and hutches/endstations should be clearly identified on all views. In any area where the bremsstrahlung cone is outside the beampipe or shield, access must be limited. Such an area is called an exclusion zone.

Physical barriers preventing access to an exclusion zone must be constructed and may consist of materials such as corrugated metal or Plexiglas to eliminate possible exposure to bremsstrahlung x rays. All exclusion zones should be clearly labeled on the anamorphic drawing and their overall dimensions should be indicated. It is acceptable to use the beampipe itself as an exclusion zone. In certain areas it may be desirable to oversize the beampipe to include all extreme rays. However, this practice is not recommended through the shield wall because it may result in an unnecessarily large opening in the transition wall.

A sketch of an extreme-ray bremsstrahlung cone is shown in Figure 2. Note that the extreme rays are defined from the inside corner of the lead shield. No partial credit is taken for rays passing through less than the full 254 mm lead equivalent in any one shield. In addition, no credit is taken for longer path length through the lead due to the ray's oblique incident angle (which appears greatly exaggerated on the anamorphic drawing). As mentioned earlier, the

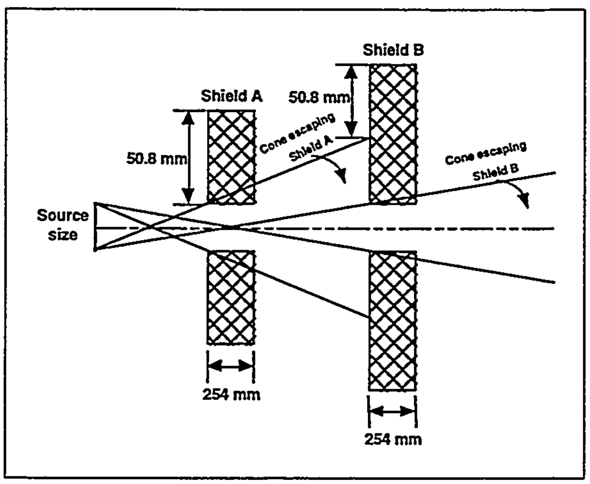


***Figure 2.** Example of extreme rays through two bremsstrahlung radiation shields.*

transverse distance from the extreme ray incident on a shield to the outside of the shield should not be less than 50.8 mm. As can be seen from Figure 2, exclusion zones will most often be required just upstream of shields where the bremsstrahlung cone has reached its largest transverse extent. The distance from the extreme ray to the outside of the exclusion zone should also not be less than 50.8 mm (2 in). The "2 inch" rule is meant to apply in cases where the extreme ray has been intercepted by a shield, flange, or beampipe, and does not apply when the extreme ray is contained inside the beampipe.

Figure 3 shows that sometimes simple plan and elevation views are not enough to identify exclusion zones. It is the responsibility of the designer to identify all problem areas.

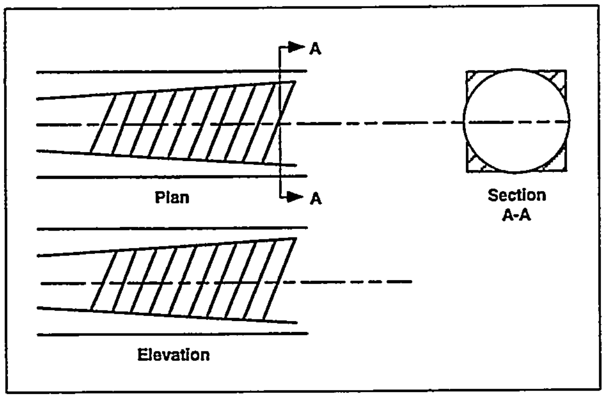


Figure 3. Plan and elevation views show the bremsstrahlung core clearly confined, while the section view shows a portion of the core outside the beampipe, requiring the identification of an additional exclusion zone.

R.J. Donahue
July 1993, revised May 1996.

[1] P. Stefan, NSLS-BNL, personal communication.
[2] T. Warwick, "Bremsstrahlung Collimation and Shielding for ALS U5 and U8 Beamlines," (LSBL-058A).
[3] T. Warwick, et al., "Radiation Safety Shutters, Collimation and Shielding for ALS Beamlines," (LSBL-073).
[4] R.J. Donahue, "Gas Bremsstrahlung Estimates for ALS Hutch Backstops," (LSBL-162).
[5] P. Stefan, op. cit.

Appendix B – Advanced Light Source Vacuum Policy and Vacuum Guidelines for Beamlines and Experiment Endstations (LSBL-280)

Advanced Light Source Vacuum Policy and Vacuum Guidelines for Beamlines and Experiment Endstations

Revision 2

Beamline Review Committee
August 22, 1995
(Supersedes LSBL #116)

Contents:

Abbreviations:

BRC Beamline Review Committee
CDR Conceptual Design Review
EPS Equipment Protection System
LCW Low Conductivity Water
PRT Participating Research Team
PSS Personnel Safety Shutter
RGA Residual Gas Analyzer
RSS Radiation Safety System
UHV Ultra High Vacuum

Front end Front end components serve to define a beam aperture for synchrotron radiation and provide necessary beam on/off, radiation safety, and vacuum-isolation systems for each beamline for both insertion device and bending magnet sources. The front end components generally reside inside the storage ring shielding and physically connect the ring vacuum chamber to the first valve of the beamline.

1. Introduction

The purpose of this document is to:

1. Explain the ALS vacuum policy and specifications for beamlines and experiment endstations.
2. Provide guidelines related to ALS vacuum policy to assist in designing beamlines which are in accordance with ALS vacuum policy.

This document supersedes LSBL-116.

The Advanced Light Source is a third generation synchrotron radiation source whose beam lifetime depends on the quality of the vacuum in the storage ring and the connecting beamlines. The storage ring and most of the beamlines share a common vacuum and are operated under ultra-high-vacuum (UHV) conditions. All endstations and beamline equipment must be operated so as to avoid contamination of beamline components, and must include proper safeguards to protect the storage ring vacuum from an accidental break in the beamline or endstation vacuum systems.

The primary gas load during operation is due to thermal desorption and electron/photon induced desorption of contaminants from the interior of the vacuum vessel and its components. The desorption rates are considerably higher for hydrocarbon contamination, thus considerable emphasis is placed on eliminating these sources of contaminants.

All vacuum components in a beamline and endstation must meet the ALS vacuum specifications. The vacuum design of both beamlines and endstations must be approved by the ALS Beamline Review Committee (BRC) before vacuum connections to the storage ring are made. The vacuum design is first checked during the Beamline Design Review (BDR) held before construction of the beamline equipment begins. Any deviation from the ALS vacuum specifications must be approved by the BRC prior to installation of the equipment on the ALS floor. Any modification that is incorporated into a vacuum assembly without the written approval of the BRC is done at the user's risk and may lead to rejection of the whole assembly.

***Note:** All pressure values described in this document are N_2 equivalent values, i.e., all pressures are measured setting the sensitivity in the ion gauge controller for N_2 gas.*

2. Policy and Requirements

2.1 Storage Ring Vacuum

The ALS storage ring vacuum system consists of all-metal, chemically cleaned, bakeable components. It generally operates at pressures of less than 2×10^{-10} mbar (2×10^{-8} Pa, 1 mbar = 0.76 torr) without beam, and at pressures of less than 1×10^{-9} mbar (1×10^{-7} Pa) with beam.

2.2 Means Used for Ensuring the Quality of the Storage Ring Vacuum

The main objective of the ALS vacuum policy is to ensure that the vacuum connection of any beamline and its associated experiment endstations will not degrade the quality of the storage ring vacuum. Generally, beamlines may be separated into two broad categories. The ALS vacuum requirements differ for each category.

Category 1: **UHV beamlines** that share the same vacuum as the storage ring.

Category 2: **Non-UHV beamlines** in which the vacuum is completely or partially separated from the front end components and storage ring vacuum by using either a window or differential pumping.

For both categories, the storage ring vacuum integrity is ensured by checking that the following three items meet the requirements described in detail in Section 2:

a. The base pressure in various parts of the beamline.
b. The contribution of high mass gases to this pressure at appropriate places as checked by the residual gas spectral analysis (RGA), if and when required.
c. The vacuum interlocks which protect the storage ring in the event of accidental vacuum failure.

For non-UHV beamlines, it may also be necessary for users to provide calculations ensuring that, in case of a vacuum failure, the vacuum interlocks will adequately protect the ALS vacuum integrity.

All beamline components are required to be manufactured according to the guidelines described in Section 5 of this document.

2.3 ALS Vacuum Requirements

This section describes the three requirements that must be met for both categories of beamlines:

2.3.1 UHV Beamlines (Category 1)

This category of beamline normally shares the same vacuum as the storage ring and operates under UHV conditions.

(a) Pressure Requirement
The base pressure in all vacuum components that will be directly exposed to the storage ring vacuum must be less than 2×10^{-9} mbar (2×10^{-7} Pa) and it is expected that this pressure requirement will be maintained during the normal operation. However, during the initial scrubbing period of the beamline components with synchrotron radiation, an increase in pressure by an order of magnitude may be allowed, with the exception that at the storage ring exit port, the pressure must be 2×10^{-9} mbar or less at all times.

(b) Residual Gas Analysis (RGA) Requirement

The beamline or the vacuum system must be checked for gas analysis, using a residual gas analyzer (RGA), before it is opened to the storage ring vacuum. For beamline qualification, the RGA check is generally done downstream of the first vacuum isolation valve outside the shielding wall. For experiment chambers, the test may be done in the chamber itself or in the first beamline chamber upstream of the experiment system. The RGA used must be sensitive to a partial pressure of 1×10^{-14} mbar (1×10^{-12} Pa) or less and be capable of scanning in a range of at least 1-200 atomic mass units (AMU). The RGA scan must indicate that the sum of the partial pressures of gases having a mass of 46-and-greater (46 AMU) does not exceed 1×10^{-11} mbar (1×10^{-9} Pa).

All new systems as well as beamlines that have been changed and brought up to air must be checked to ensure that they meet the above vacuum and RGA requirements before they are allowed to be opened to the storage ring vacuum.

However, under certain conditions as determined by the ALS vacuum group, a waiver for RGA requirements may be provided to a beamline and/or experiment endstation which normally operate under UHV condition. These conditions include opening of a beamline vacuum chamber or experiment chamber for minor changes, such as replacing a burnt ion gauge filament, and changing solid samples which have similar outgasing characteristics. In all cases, a waiver will only be granted to vacuum systems which have previously been qualified at least once for meeting RGA requirements, and have achieved a pressure below 3.0×10^{-10} mbar (3×10^{-8} Pa) after necessary pumpdown and bakeout.

In any case, it is at the discretion of the ALS Vacuum Group or BRC to make the decision regarding a waiver.

(c) Vacuum Interlocks Requirement (Protection in the Event of Vacuum Failure)

The storage ring vacuum is protected from accidental vacuum failures by fast sensor interlocks in case of catastrophic failure, and by ion gauge pressure interlocks in the event of a relatively slow leak.

Each beamline has one or two fast sensors. The recommended distance for the fast sensor to be from the fast valve is 10 m or more, to allow enough time for the fast valve to close before arrival of the gas wave front in the event of a vacuum break. The fast sensors are interlocked with the front-end valves and shutters. The front end contains one or more all-metal isolation valves, a fast-closing valve, and a pneumatically actuated photon shutter (which is between the storage ring and the fast valve).

If there is an accidental break in the beamline vacuum system, a fast-response vacuum sensor will detect the break, and the fast valve will close in less than 10 ms. This also requires the stored beam on insertion device beamlines to be dumped to protect the fast valve from being exposed to the large power of synchrotron radiation. The primary vacuum isolation valve between the storage ring and the beamline will pneumatically close and seal the ring vacuum in about 3.5 seconds. The photon shutter located between the storage ring and the isolation valve will also close. These components are controlled by the Equipment Protection System (EPS) for the front end and the beamline. More details related to the EPS are given in *"ALS Beamline Design Requirements,"* PUB-3114.

All vacuum interlocks on beamline components supplied by experimenters must meet ALS design specifications. The ALS will advise users about vacuum requirements and interlock procedures for monochromators and endstations. Generally, these should operate under UHV conditions similar to those of front ends and the storage ring. Electrical connections between user vacuum interlocks and front-end components will be made and tested by authorized ALS staff. Fast sensors should be installed outside of the shielding wall and downstream of the monochromators in positions approved by the BRC.

For each beamline there must be at least one fast sensor located downstream of the first isolation valve near the outside of the shield wall. Another fast sensor may be located upstream of the endstation (a suitable place would be downstream of an exit slit or any other conductance-limiting component).

The fast sensors are set as follows:

Fast Sensor Set Point: A set point of 1×10^{-5} mbar (1×10^{-3} Pa) protects against catastrophic failure. If the pressure at any sensor is above this value, the corresponding fast valve/s is triggered, which simultaneously closes the photon shutter and the isolation valve. On insertion device beamlines, the stored beam must be dumped to protect the fast valve from being exposed to the large power of synchrotron radiation, as well as to protect personnel from bremsstrahlung radiation.

In addition, ion gauges (located on either side of the isolation valve) are interlocked (using ion gauge controllers at set values) to protect the storage ring against high pressure due to excessive outgasing, a slow leak, power failure, etc.

The ion gauge controller interlock set points are such that:

Ion Gauge Controller Set Point: Set at 2×10^{-8} mbar (2×10^{-6} Pa) or lower such that, if the pressure exceeds this value, the isolation valve upstream of the ion gauge will close and seal. The fast valve may remain open. The stored electron beam will not be affected.

Please note that the above pressure values set for interlocks are higher than the normal operating pressures.

If any one of the interlocks is triggered, the isolation valves along with other shutters will close. They should not be re-opened unless:

1. The pressure in that section is below the pre-approved limit, and
2. The pressure in the front end is below 2×10^{-9} mbar (2×10^{-7} Pa).

If the fast sensor is triggered, the operations coordinator will have to be contacted before beamline can be brought back on line.

2.3.2 Non-UHV Beamlines with Vacuum Window/s or a Differential Stage (Category 2)

A beamline downstream from the front end may operate in a helium atmosphere or oil-free rough vacuum under the following conditions:

i. A window capable of withstanding at least 1 atmosphere pressure isolates the storage ring vacuum from the beamline vacuum.
ii. A thin window with appropriate interlocks isolates the storage ring vacuum from the low vacuum side of the beamline.
iii. Efficient differential pumping allows downstream components to operate at higher pressure without affecting the low vacuum requirement of the front end.

The design of these devices must be approved by the BRC.

(a) Pressure Requirement

The base pressure in all vacuum components upstream of non-UHV equipment which is directly exposed to the storage ring vacuum must be less than 2×10^{-9} mbar (less than 2×10^{-7} Pa). This pressure requirement must be met at all times during the normal operation of the beamline.

However, during the initial scrubbing period of the beamline components with synchrotron radiation, an increase in pressure by a maximum of an order of magnitude may be allowed.

The maximum pressure downstream of the vacuum window or differential stage or conductance limiting component may be of any sub-atmospheric value, as long as the above condition is always maintained.

(b) Residual Gas Analysis (RGA) Requirement

The vacuum system is to be tested using a residual gas analyzer (RGA) upstream of the vacuum window or the differential stage. The RGA used must be sensitive to a partial pressure of 1×10^{-14} mbar (1×10^{-12} Pa) or less and be capable of scanning in a range of at least 1-200 atomic mass units (AMU). The RGA scan must indicate that the sum of the partial pressures of gases having a mass of 46-and-greater (46 AMU) does not exceed 1×10^{-11} mbar (1×10^{-9} Pa). The RGA scan must be performed by the ALS Vacuum Group for each new experiment before the isolation valve is opened. For experiments involving materials of potential hazard, the RGA will be monitored either continuously or intermittently during operation (at the discretion of the ALS beamline coordinator and or vacuum group).

(c) Vacuum Interlock Requirements (Protection in the Event of Vacuum Failure)

The storage ring vacuum is protected from accidental vacuum failures by fast sensor interlocks in case of catastrophic failure, or by ion gauge pressure interlock(s) in the event of a relatively slow leak.

For non-UHV beamlines, one fast sensor must be installed and it is recommended that two be installed. The first must be downstream of the first isolation valve outside the shield wall. The second sensor should be at a place with potential vacuum break, such as just upstream of a vacuum isolating window or differential stages.

All vacuum interlocks on beamline components supplied by experimenters must meet ALS design specifications. Electrical connections between user vacuum interlocks and front end components will be made and tested by authorized ALS staff members.

Both fast sensors and ion gauge controllers are set as follows:

i. **Fast Sensor Set Point:** If the pressure at any sensor is above 1×10^{-5} mbar (1×10^{-3} Pa), the corresponding fast valve/s is triggered, which simultaneously closes the photon shutter and the isolation valve. On insertion device beamlines, the stored beam must be dumped to protect the fast valve from being exposed to the large power of synchrotron radiation, as well as to protect personnel from bremsstrahlung radiation.

ii. **Ion Gauge Controller Set Point:** Set at 2×10^{-8} mbar (2×10^{-6} Pa) or lower on all ion gauge controllers measuring the pressure upstream of the vacuum isolation window or differential stage. If the pressure exceeds this value, the isolation valve upstream of the ion gauge will close and seal. The fast valve will remain open. The storage ring will not be dumped. Ion gauges located downstream of the window or differential stage may be set at any value, provided the above conditions are met.

Please note that the above set points for interlocks are considerably higher than the normal operating pressures.

If any of the interlocks is triggered, the isolation valves and the other shutters will close and must not be opened unless:

1. The pressure in that section is below the pre-approved limit, and
2. The pressure in the front end is below 2×10^{-9} mbar (2×10^{-7} Pa).

If the fast sensor is triggered, the operations coordinator will have to be contacted before beamline can be brought back on line.

3. Performance Test

The beamline and/or front end must be checked for compliance with the three ALS vacuum requirements (Vacuum, RGA scan, and Vacuum Interlocks) by the ALS Vacuum Group, if:

i. The front end is to be opened to the storage ring for the first time.
ii. The branchline is to be opened to the front end for the first time.
iii. Any part of the beamline is changed or brought up to air and is ready for re-connection to the storage ring vacuum.

For UHV beamlines, the RGA requirement may be waived under special circumstances. (When it is decided by the ALS Vacuum Group and/or BRC that checking the RGA requirement is unnecessary and would not provide information of any practical use. See Section 2.3.)

4. Review of Vacuum Design

The vacuum design of each beamline is reviewed by the BRC during a beamline design review. The experiment group (PRT) must demonstrate that the design will not degrade the quality of the storage ring vacuum and that it follows the ALS vacuum policies outlined in this document. The PRT should submit:

i) Beamline assembly drawings or suitable sketches to scale.
ii) A list of vacuum components and materials of construction.
iii) A list of pumps, their specifications, and locations.
iv) Information related to vacuum interlock system.
v) Calculations showing that in case of a vacuum failure, the vacuum interlock will adequately protect the ALS vacuum integrity.

The PRT must obtain BRC approval before ordering any non-standard, non-UHV vacuum components and before fabricating any beamline components.

Approval of a PRT beamline design by the ALS Beamline Review Committee does not allow the PRT group to bypass the performance tests outlined in Section 3.

5. Vacuum Guidelines for Beamline and Endstation Experiment Chamber Vacuum Systems

ALS beamlines must have all-metal, hydrocarbon-free front end components. UHV design criteria must be used for the hardware downstream of the front end, if the hardware and the front end share a common vacuum. The BRC must approve any deviations from the requirements in this section.

The following is a partial list of items which will help in developing a UHV system compatible with ALS requirements. Questions or requests for additional information should be directed to the BRC or the ALS Vacuum Group.

5.1 Materials

Standard UHV-compatible materials must be used in all beamlines sharing the same vacuum as the storage ring. The following is a list of materials that are and are not acceptable for UHV. Any material not listed must be approved.

Acceptable	Not Acceptable	Marginal
Pure metals: aluminum copper (incl. Glidcop) gold silver molybdenum tungsten titanium Stainless Steel: 300 series (preferred types are: 304, 316, 321, and 347). Alloys: Ampco 18 beryllium copper inconel 600 or 718 mu-metal Kovar Ceramics: Alumina ceramics sapphire machinable glass ceramic	Zinc- and cadmium-bearing metals and alloys are not UHV-compatible. Organic materials are not permitted unless they are specifically authorized by the BRC.	Stainless Steel: SS containing excessive amounts of sulfur or selenium must be avoided. Elastomers such as viton may be allowed in the seat of a gate valve with metal bonnet seals. These valves are only allowed in the places where there is no chance for the elastomer to be exposed to radiation.

All components must be inspected and leak-tested after fabrication.

5.2 Bellows

Both welded and formed bellows are allowed, provided they are manufactured using UHV standards.

Since welded bellows are made of thin stainless steel diaphragms welded on the inside and outside diameters to form a series of convolutions, proper UHV techniques are required during manufacturing to avoid trapping of hydrocarbons or contaminants in the crevices of the convolutions. It is strongly recommended that the bellows be chemically degreased and baked in vacuum before being installed in the beamline.

Formed bellows are relatively easy to clean, but must be fabricated for UHV applications.

5.3 Feedthroughs

Ceramic-to-metal type electrical feedthroughs are allowed for making electrical connections into the vacuum system. No glass-to-metal feedthroughs are permitted. Voltages and current carried through the feedthroughs must not exceed the manufacturer's ratings. External covers and cable restraint are required to protect against the accidental breaking of ceramics (which is a major cause of vacuum failure).

Bellows-type mechanical rotary and linear feedthroughs manufactured for UHV applications are allowed. **Feedthroughs with a single elastomer seal are not permitted.** However, two-stage differentially pumped feedthroughs with elastomer seals may be allowed, with approval by BRC.

5.4 Gauges

Glass ionization gauges are not permitted in beamlines. Nude ionization gauges with two independent filaments and controllers with electron bombardment degassing capability are recommended. It is recommended that the cable connection to the gauge head be bakeable to 200° C and have an enclosed connector or cable restraint. Cold cathode, thermocouple, or Vactron gauges may be allowed, if they meet UHV requirements.

5.5 Vacuum Pumps

Any one or combination of the following primary pumps may be used:

Sputter-ion pumps: Ion pumps (either diode, triode, or differential ion) are the most reliable pumps for UHV use. Differential ion pumps which contain both titanium and tantalum filaments are recommended, due to their ability to pump inert gases.

Titanium sublimation pumps (TSP): TSP, in combination with ion pumps, are very effective in creating UHV.

Non-evaporable getter (NEG) pumps: NEG pumps are made of UHV-compatible, active metals which pump by chemisorbing gases.

Cryo pumps: May be used with appropriate isolation valves and interlocks, which must be approved by the BRC.

Turbomolecular pumps: It is strongly recommended that both the turbo and the backing pump be oil-free. They must be equipped with appropriate interlock isolation valves for protection in case of pressure and/or power failures. The use of a turbo pump as a primary pump in the beamline is discouraged and must be approved by BRC. A turbo pump system (preferably oil-free) with appropriate interlocks may be used in the endstation experimental chamber.

Diffusion pumps: **These are not permitted due to their inherent risks of oil contamination.**

Roughing Pumps: **Only oil-free mechanical pumps may be used as roughing pumps.** Under extreme circumstances where no alternative exists, an exception may be given by the BRC. During the initial rough-pumping and/or bake-out of the beamline, turbo pumps, cryo pumps, sorption pumps and or any other oil-free pumps as approved by the BRC or Vacuum Group may be used. This is allowed only when the front end isolation valve is closed. They may also be used at the endstations. When used at an endstation, a pump must be equipped with appropriate interlock isolation valves for protection in case of a pressure and/or power failure.

Backing Pumps: **It is strongly recommended that only oil-free mechanical pumps be used as backing pumps.** Under extreme circumstances where no alternative exists, an exception may be given by the BRC.

The vacuum requirements as outlined in Section 2 must always be satisfied.

5.6 Valves and Flanges

All-metal, bakeable UHV valves, flanges, and seals are acceptable. Flanges with elastomer seals are not allowed in the beamline. Metal bonnet valves with elastomer seals are not allowed in beamlines where the seal may be exposed to direct synchrotron radiation. If approved by the BRC, they may be used in places where radiation exposure is not a problem.

5.7 Fabrication

Fabrication of any component which becomes part of the vacuum environment of the beamline directly exposed to storage ring vacuum must be done using UHV compatible materials and following UHV-accepted techniques, including:

Surface Preparation: No machining or polishing operation which might result in contaminants being embedded in the material should be used. All tapped holes should be vented.

Machining Lubrication: No cutting lubricant may be used which results in contamination that cannot be removed by standard cleaning methods. The use of cutting fluid containing sulfur or silicone compounds is not recommended. Refer to ALS engineering notes LSME-479 (Light Source Beamlines Vacuum System–General: Fabrication, Handling, and Cleaning Parts Before Brazing, Stress-Relief Annealing, or Preliminary Bake-Out at High Temperatures for Ultra-High Vacuum Service) and LSME-500B (Light Source Beamlines Vacuum Systems General: Fabrication, Cleaning, and Certification of Stainless Steel Vacuum Chambers for Weldments for UHV) for the recommended procedures.

Water Cooled Optics: Vacuum-to-water joints are not permitted in the ALS beamline vacuum systems, unless there is an intermediate guard vacuum. Refer to ALS technical note M7184 (Mirror Brazing Technique). Vacuum-to-water joints must be avoided as much as possible in the users' vacuum chamber systems.

Chemical Cleaning: All UHV components must be vapor degreased, electropolished, and/or chemically cleaned before installation in the beamline. Refer to ALS technical note LSME-421A (Light Source Photon Beam Lines—BNL/NSLS XI Beamline Mirror System M-Zero Mirror System: General Cleaning and Brazing Procedures for Furnace-Brazed U.H.V. Parts).

5.8 Assembly of UHV Components

It is highly recommended that assembly of UHV components take place in a clean room or in a clean laminar flow hood. There are many sources of contaminants. The single largest sources during assembly are perspiration, body oils, hair, perfume, etc. Thus, the use of clean gloves, face masks, lab coats, and head covers during assembly is recommended.

Lint-free paper or cloth wipes are recommended for use with UHV parts. Ethanol should be used as a wiping solvent, if necessary.

All UHV components which may get exposed to contaminants should be protected by clean, oil-free aluminum foil or lint-free paper.

No cadmium-plated, brass, lead, or wood tools should be used during assembly.

If a chamber is to be opened to air and cannot be moved to the clean room, it is recommended that the chamber be purged continuously with dry nitrogen gas. A liquid nitrogen source is the best choice to get the quantities of dry nitrogen required. The ALS will provide such a source.

5.9 Venting

If a UHV chamber is to be vented, dry nitrogen should be used for venting the system. A pressure relief valve is required in the venting system, especially to protect view ports from exploding. A safe recommendation for the relief pressure valve setting is 30 mbar (0.5 psi) above atmosphere (a recommendation by Varian).

5.10 Leak Checking and Bakeout

It is highly recommended that the whole system be leak-checked before going through the thorough bakeout. The recommended temperature for bakeout of a stainless steel chamber is 200° C. There may be other constraints which may limit the bakeout temperature to a lower value.

For a system which may give high outgassing loads, it is generally recommended that a nitrogen bake be done, followed by a vacuum bake. During a nitrogen bake, dry nitrogen gas from an evaporated liquid nitrogen source is pumped through the assembly while the components are heated.

References:

For further details concerning ultra-high vacuum practice, the user may consult:

1. *Practical Vacuum Techniques*, by W.F. Brunner and T.H. Batzer, published by Krieger, 1974.
2. *A User's Guide to Vacuum Technology*, by J.F. O'Hanlon, published by John Wiley & Sons, 1980.
3. *High Vacuum Technology: A Practical Guide*, by Marsbed H. Hablanian, published by Marcel Dekker, Inc., New York, 1990.
4. *Basic Vacuum Practice*, Third Edition, Varian Vacuum Products Training Department, Varian Associates, 1992.
5. *Vacuum Policy for ALS Beamlines and Experimental Systems,* by R.C.C. Perera, K.D. Kennedy, J.R. Meneghetti, LSBL-116
6. *Light Source Beamlines Vacuum System–General: Fabrication, Handling, and Cleaning Parts Before Brazing, Stress-Relief Annealing, or Preliminary Bake-Out at High Temperatures for Ultra-High Vacuum Service*, by D. DiGennaro, LSME-479.
7. *Light Source Beamlines Vacuum Systems General: Fabrication, Cleaning, and Certification of Stainless Steel Vacuum Chambers for Weldments for UHV*, by D. DiGennaro, LSME-500B.
8. *Mirror Brazing Technique*, by D. DiGennaro, M7184.
9. *Light Source Photon Beam Lines—BNL/NSLS XI Beamline Mirror System M-Zero Mirror System: General Cleaning and Brazing Procedures for Furnace-Brazed U.H.V. Parts*, by D. DiGennaro, LSME-421A.
10. *ALS Beamline Design Requirements*, PUB-3114.

APPENDIX C
Survey and Alignment Information for ALS Users

The survey and alignment of beamlines and experimental equipment at the ALS is based on three coordinate systems. The *Global Coordinate System* is used to describe the location of all position-sensitive items at the ALS. In addition, the *Local Coordinate System* and the *Beamline Coordinate System* can be used to describe the location of accelerator and beamline components.

Global Coordinate System

The three-dimensional Global Cartesian Coordinate System (also known as "ALS Coordinates") is aligned with the University of California grid system that is used for building construction at the University of California at Berkeley and Lawrence Berkeley National Laboratory. The Global, or ALS System has the following characteristics:

- The units of measurement are meters (m).
- The origin of the coordinate system is defined by the center point of the storage ring at nominal beam elevation (1.4 m above the floor).
- The *Y*-axis is up, or vertical, and in the direction of gravity. The *Y*-axis increases in value in the "up" direction.
- The *X*-axis lies in a level plane, points north, is 90° to the *Y*-axis, and increases in value in a northerly direction.
- The *Z*-axis lies in a level plane, is perpendicular to the *Y*-axis and *X*-axis, and increases in value in an easterly direction.

The origin of the coordinate system at the center point of the storage ring has the following values:

$X = 1500$ m
$Y = 3500$ m
$Z = 2500$ m

Large coordinate values were chosen to avoid negative numbers. Since the project extends no more than 500 meters in any direction, the coordinates $X = \underline{1}500$, $Y = \underline{3}500$, and $Z = \underline{2}500$ allow an axis to be easily identified by its leading digit.

Local Coordinate System

Three-dimensional Local Cartesian Coordinate Systems can be used to define the orientation of any individual item at any given point along the particle/photon beam path. They have the following characteristics:

- The units of measurement are millimeters (mm).

- The origin of the local coordinate system is defined by the center point (or another point on the individual part that is considered the survey and alignment origin) of the individual item at nominal beam elevation.
- The *V*-axis is up, or vertical, and in the direction of gravity. The *V*-axis increases in value in the "up" direction.
- The *W*-axis of the local coordinate system lies in a level plane, is perpendicular to the *V*-axis, points in the direction of the beam, and increases in value in the beam direction.
- The *U*-axis of the local coordinate system lies in a level plane, is perpendicular to both the *V*-axis and *W*-axis, always points in a direction away from the center of the accelerator, and increases in value in that direction.

The origin of a Local Coordinate System is defined as *V*= 0.0 mm, *W*= 0.0 mm and *U*= 0.0 mm. Negative numbers are allowed in this coordinate system.

Beamline Coordinate System

For the design and layout of beamlines, rectilinear beamline coordinates are described as (*R*, *S*, *T*) with the following characteristics:

- Units are given in both meters (m) and inches (in.).
- The (*R*, *S*, *T*) coordinates at the beamline source point are (*0*, *0*, *0*).
  (It is essential that the beamline is first defined in Global or ALS Coordinates.)
- The *R*-axis is radially outward from the storage ring.
- The *S*-axis is vertically upward, in the direction of gravity.
- The *T*-axis is the forward direction of the photon beam.

Control Network

A control network has been created to provide a reference system from which the position-sensitive items may be surveyed. The network is made up of control points, or monuments, placed in the concrete floor.

The ALS survey monuments are made up of two parts. The first part consists of a conical mount, or cup, that is set into the concrete floor, recessed from the floor surface, and provided with a protective cover when not in use. This conical mount supports a spherical adapter (sometimes called an optical tooling sphere, mounting sphere, or Taylor-Hobson ball). The adapter is made to a specific diameter and designed to hold the center of a disk type target at the exact center of the sphere.

Figure 1. Remove the protective cover of the conical mount to insert the spherical adapter.

With this type of arrangement you can rotate the sphere in any direction and the center of the target remains in a fixed location. These targets are normally used for horizontal control, but since the target holder is a sphere and extremely accurate, the ALS uses them for vertical control as well. Each monument has *X, Y, & Z* Global (ALS) coordinates.

The control network layout takes into consideration that survey instruments have limitations (e.g., minimum focusing distances of optical instruments, minimum ranging distances for distance-measuring instruments, minimum clearance requirements between walls and lines of sight, etc.). The monuments have been set out such that one can see (survey) at least two other monuments in any direction from any single monument.

Position-Sensitive Elements

Most beamline instrumentation and vacuum components must be aligned at installation. To make position surveying possible, all position-sensitive branchline components must be marked with external targets or "fiducials" as reference points for measuring equipment.

In general, the components of a branchline that require precision alignment (e.g., mirrors, slits, masks, and gratings) are inside vacuum chambers and not accessible from outside for survey and alignment. Consequently, these components require "fiducialization" during assembly, that is, the position of important internal features must be measured relative to accessible fiducial references outside the vacuum chamber. These fiducials are then used for survey and alignment at installation. For a given component, fiducialization generates a set of local Cartesian coordinates (*U*, *V*, and *W*) for each fiducial in a local coordinate system. The location of the fiducial origin (i.e., the mirror center, etc.) and a direction must be specified in the beamline coordinate system.

Three fiducials are required for placing a component in space with 6 degrees of freedom, but four fiducials are highly desirable for redundancy, allowing a check on the survey and alignment. Fiducials are generally a precision 1/4 in. hole which accepts a "tooling ball" (Figure 2) for mechanical contact and measurement and an optical target (Figure 3) for direct sighting with an optical instrument. The fiducials should be located with as large a separation from each other as possible and a clear vertical path above for elevation measurements.

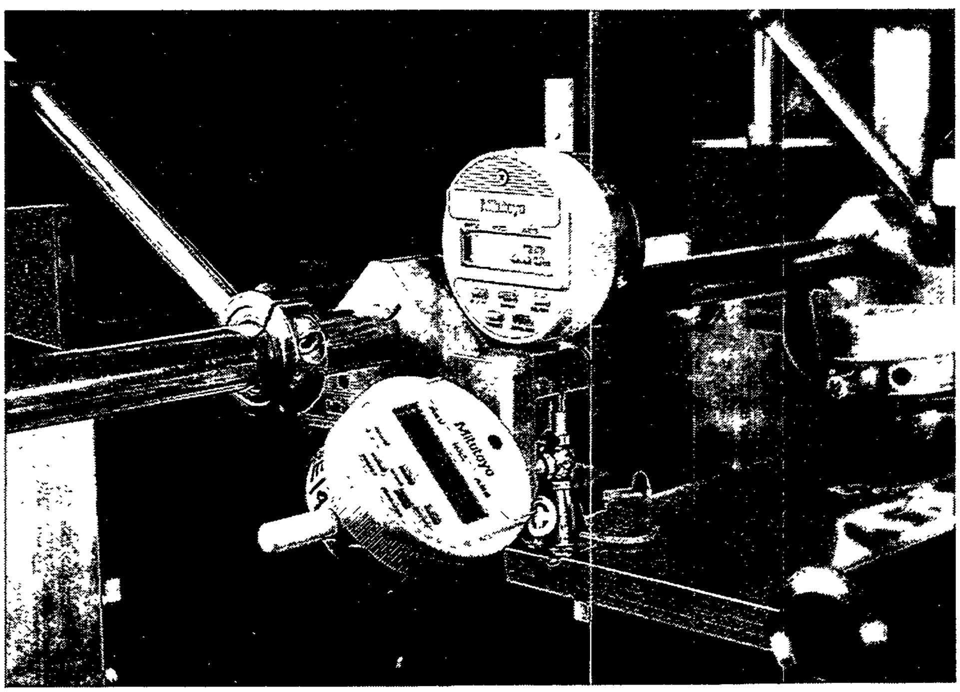


Figure 2. Fiducials must be configured to accept a tooling ball.

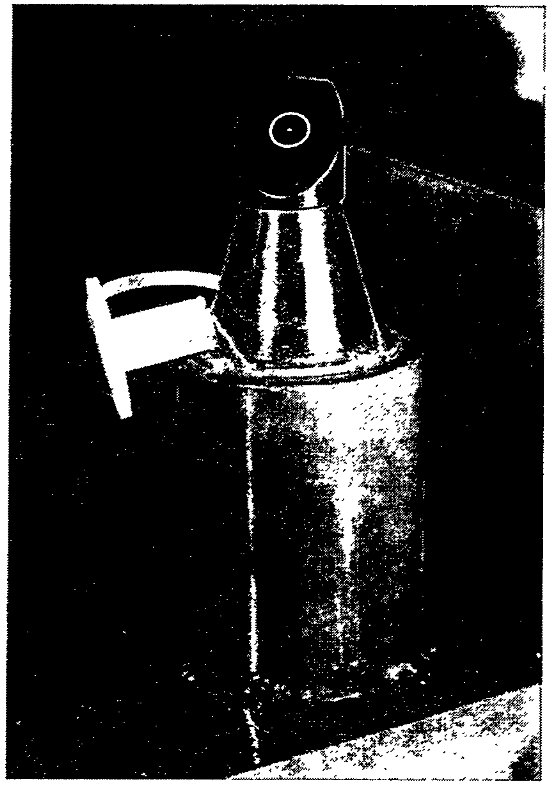


Figure 3. Fiducials must be configured to accept an optical target for direct sighting with an optical instrument.

The optical targets are constructed such that their optical center exactly coincides with the center of the tooling ball when interchanged in the same hole. This center point is the fiducial point with the local coordinates *U*, *V*, and *W*.

Convenient weld-on fiducial posts that accept the optical targets and the tooling balls are described in LBNL Mechanical Engineering Drawing 20 Q 5363. These fiducial posts have been used successfully throughout the ALS and are recommended.

Ted Lauritzen
November 1992

Revised by
William Thur
April 1996

Appendix D – Beamline Readiness Review Walkthrough Procedure (BL 08-07)

Advanced Light Source

APPROVED FILE COPY

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Number: BL 08-07	
Revision: Rev. 4	
Issue Date: December 20, 1994	
Review Period: 3 years	
Supercedes Issues: BL 08-07, Rev. 3	

Title:

Beamline Readiness Review (BRR) Walkthrough Procedure

Section where used:

Beamline Operations Section and ALS EH&S, Electrical and Mechanical Engineering Groups and Beamline User Operator

Date

1/10/95

Phil Heimann

oward Padmore

12/54

ony Warwick

Revision Log:

Rev. No.	Effective Date	Pgs. Affected	Brief Description of Revision
1	11/11/93	1, 2, 5	Pgs. 1,2, and 5, Sections. 2.0, 3.0, 5.0, BRR checklist: references to BL 08-02 deleted.
2	4/29/94	3 and 4	Pg. 3, Sec. 5.0, step [6] revised; Pg. 4, step [4] added.
3	6/2/94	1 and 2	Pg. 1, Signature block, reviewer added; Pg. 2, Sec. 2.0, caution added.
4	12/20/94	1, 4, 5	Pg. 1, Signature block, reviewer added; Pg. 4, [1], Radiation divided into shielding qualification and interlock test; Pg. 5, [5], EPS divided into sub-tests, [6] signature and date added.

1.0 PURPOSE

To provide a procedure to conduct the BRR walkthrough portion of a beamline by nominated experts to check key functions of the beamline for first-time operation.

2.0 SCOPE

The BRR ensures that the beamline has been implemented in a manner consistent with the design approved in the Beamline Design Review. It consists of two distinct parts: a review of documentation submitted to the Beamline Review Committee (BRC) and a walkthrough of the beamline by nominated experts to check key func-

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Beamline Readiness Review (BRR) Walkthrough Procedure

2.0 SCOPE, Cont.

tions of the beamline for the first time operation. This procedure provides directions for the latter.

An operations coordinator and the beamline user operator, together with representatives of the ALS EH&S, Mechanical and Electrical Engineering groups, will follow this procedure when a new beamline is completed and needs to be approved for operation. This procedure includes procedure BL 08-01, *Beamline Key-enable Procedure for Operations Coordinators*.

CAUTION: *It is imperative that the RGA scan vacuum qualification of the branchline, step [4] of the BRR checklist, be conducted* ***before*** *the EPS qualification, step [5] of the checklist, to prevent possible contamination to the front-end and storage ring vacuum.*

A copy of the completed signature list, pages 4 and 5, will be filed at the beamline and the original will be filed in the Beamline Checklist Notebook located in the ALS control room (CR), Building 80, Room 40.

3.0 REFERENCES

[1] DOE Order 5480.19, Conduct of Operations, Guidelines, Chapter 8
[2] DOE Order 5280.25, Safety of Accelerator Facilities, Guidance, Part II.C
[3] Procedure BL 08-01, Beamline Key-enable Procedure for Operations Coordinators
[4] Experimental Systems Activity Hazard Document
[5] LBL Pub. 3114, ALS Beamline Design Requirements

4.0 REQUIRED MATERIALS, EQUIPMENT, SUPPLIES, TOOLS, AND MANPOWER

[1] An official, checked drawing showing shielding and exclusion zone locations, so that the positions can be checked with a tape measure, e.g. from the edge of the beam pipe — see Example 1, "BL 7.0 Front End." The shielding will correspond to the approved locations, presented in the Beamline Design Review.

[2] A schematic drawing naming all beamline components, including: valves, ion gauges, pumps, windows, apertures, lead shielding, exclusion zones and optical chambers — see Example 2, "BL 7.0 Beamline Schematic."

[3] A specification of the logic of the beamline Equipment Protection System (EPS) — see Example 3, "BL 7.0 EPS Logic Diagram."

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Beamline Readiness Review (BRR) Walkthrough Procedure

4.0 REQUIRED MATERIALS, EQUIPMENT, SUPPLIES, TOOLS, ..., Cont.

[4] An appendix checklist from the Beamline Key-enable Procedure. This checklist must include a check of the bremsstrahlung shielding, the exclusion zones and an RGA scan and ion gauge reading of the beamline — see Example 4, "Checklist for BL 7.0.1."

[5] Documentation showing any changes to the beamline made since the Beamline Design Review.

5.0 PROCEDURE

NOTE: *This comprehensive walkthrough inspection will be conducted once before the initial beamline operation and will include initial execution of the Key-Enable Procedure. The Key-enable Procedure will be subsequently executed whenever the beamline is re-enabled and put on-line.*

[1] The BRR walkthrough will be conducted by members of the beamline operations section, the ALS EH&S program, the ALS mechanical engineering group, the ALS lead vacuum technicians section, the ALS controls section, and the ALS electrical engineering group.

[2] BRR Walkthrough — Checklist begins on page 4.

6.0 APPENDIX

Examples 1 through 4 noted in Section **4.0**.

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Beamline Readiness Review (BRR) Walkthrough Procedure

BRR Walkthrough Checklist for Beamline ______

[1] **Radiation**

Shielding Qualification: The position and size of the bremsstrahlung shielding and of the exclusion zones will be checked against the shielding drawing noted in Sec. 4.0 [1].

Comments: ____

____

____

______________________ Signature ______________ Date

Interlocks: It has been confirmed that the Radiation Safety System (RSS) has been qualified during the past 6 month period.

______________________ Signature ______________ Date

[2] **Electrical Qualification:** The beamline has been checked for electrical safety and compliance with wiring and safety standards.

Comments: ____

____

____

______________________ Signature ______________ Date

[3] **Mechanical Qualification:** The beamline has been checked for compliance with all relevant mechanical requirements for personnel safety and equipment protection such as seismic/structural safety, hazards relating to mechanical motions, pressure vessel safety, visible light hazards, and covers to protect viewports and bellows from accidental damage.

Comments: ____

____

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______________________ Signature ______________ Date

Continued on page 5

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Beamline Readiness Review (BRR) Walkthrough Procedure

BRR Walkthrough Checklist, Cont.

[4] **Vacuum Qualification:** Ion gauge readings and an RGA scan confirm that it is safe to open the beamline to storage ring vacuum.

Comments: ______________________________

____

____

______________________ ______________
Signature Date

CAUTION: *It is imperative that the branchline vacuum valve, VVR1, not be opened until the vacuum qualification is completed.*

[5] **Equipment Protection System (EPS) Qualification:** The EPS has undergone a performance test for the sector, beamline front-end, branchline front-end, and branchline.

Comments: ______________________________

____

____

Sector: ______________________ ______________
Signature Date

Beamline Front-end: ______________________ ______________
Signature Date

Branchline Front-end: ______________________ ______________
Signature Date

Branchline: ______________________ ______________
Signature Date

[6] **EPBI (Errant Photon Beam Interlock) Dynamic Test:** Performed for Insertion Device beamlines prior to initial operation. Test is documented in CR Operations Log.

______________________ ______________
Signature Date

[7] **Key-enable Procedure** has been executed for the first time.

______________________ ______________
Signature Date

[8] A **radiation survey** has been conducted.

Comments: ______________________________

____

______________________ ______________
Signature Date

Appendix E – Contacts for Additional Information and Technical Questions

Surface mail should be addressed to the recipient at:

Advanced Light Source, MS ___
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

ALS Administrator

Elizabeth Saucier
MS 80-101
510-486-6166
510-486-4960 (fax)

ALS User Office

For copies of all referenced documentation.
MS 80-101
510-486-7745
510-486-4773 (fax)

Beamline Review Committee Chair

For the name of current BRC Chair, and to schedule a Beamline Design Review (BDR) or Beamline Readiness Review (BRR) contact:

ALS Administrator
510-486-6166
510-486-4960 (fax)

Beamline Scientist

The Beamline Scientist is the person in charge of an individual beamline who has in-depth understanding of the beamline and who is the representative and contact person for the beamline. Contact the ALS User Office for the name of the person in charge a specific beamline.

Beamline Controls

Alan Biocca
MS 10-110
510-486-7700
510-486-4960 (fax)

Beamline Design

Howard Padmore
MS 2-400
510-486-5787
510-486-7696 (fax)

Malcolm Howells
MS 2-400
510-486-4949
510-486-7696 (fax)

Wayne McKinney
MS 2-400
510-486-4395
510-486-7696 (fax)

Electrical (wireway, cabling, etc.)

Barry Bailey
MS 46-125
510-486-5817
510-486-5775 (fax)

Electrical Engineering

Art Ritchie
MS 46-161
510-486-4785
510-486-5775 (fax)

Environment, Health, and Safety

Georgeanna Perdue
MS 80-101
510-486-7407
510-486-5800 (fax)

Equipment Protection System

Ken Woolfe
MS 46-125
510-486-7739
510-486-5775 (fax)

Laser Safety

Ken Barat
MS 90-2148
510-486-7658
510-486-5399 (fax)

Mechanical Engineering

Dick DiGennaro
MS 46-161
510-486-6466
510-486-4873 (fax)

Mechanical System Safety

William Thur
MS 46-161
510-486-5689
510-486-4873 (fax)

Operations Coordinator

The Operations Coordinators are the first contact for questions or assistance on the experiment floor during ALS operations. They are knowledgeable about ALS operations, safety regulations and training, and beamline inspection and documentation.

Operations Coordinator On Duty
510-486-7464

Procedures

Documents
Rita Jones
MS 80-101
510-486-7723
510-486-5800 (fax)

Interlock Procedures
Ken Woolfe
MS 46-125
510-486-7739
510-486-5775 (fax)

Key-Enable Procedure
Cheryl Hauck
MS 80-101
510-486-7885
510-486-5800 (fax)

Radiation Safety System (RSS)

Art Ritchie
MS 46-125
510-486-4785
510-486-5775 (fax)

Al Lindner
MS 46-125
510-486-7757
510-486-5775 (fax)

Radiation Shielding

Health Physics Issues
Rick Donahue
MS 71-259
510-486-5597
510-486-7304 (fax)

Ray-Trace Drawings and Shielding Construction
Dick DiGennaro
MS 46-161
510-486-6466
510-486-4873 (fax)

Radiation Survey

Keith Heinzelman
MS 80-101
510-486-6212
510-486-5800 (fax)

Seismic

William Thur
MS 46-161
510-486-5689
510-486-4873 (fax)

Survey and Alignment

William Thur
MS 46-161
510-486-5689
510-486-4873 (fax)

Technical Assistance, Work Order Requests, Hookups and Repairs

Ray Thatcher
MS 80-101
510-486-7412
510-486-5800 (fax)

Vacuum

Tony Catalano
MS 80-101
510-486-6484
510-486-4990 (fax)

Dick DiGennaro
MS 46-161
510-486-6466
510-486-4873) (fax)

Ray Thatcher
MS 80-101
510-486-7412
510-486-5800 (fax)

John Thomson
MS 80-101
510-486-7975
510-486-4990 (fax)

Utilities

Barry Bailey
MS 46-125
510-486-5817
510-486-5775 (fax)

Ken Rex
MS 46-161
510-486-6826
510-486-4873 (fax)

Operations Scheduling Meeting

ALS Operations Scheduling Meeting held Fridays, 3:30 p.m., Building 6 conference room

Chair: Bob Miller
MS 80-140D
510-486-4738
510-486-5800 (fax)

Additional Sources of Information Available From:

ALS User Office
MS 80-101
510-486-7745
510-486-4773 (fax)

ALS Beamline Rack Numbering Scheme (LSEE-107A)

ALS Experiment Form

ALS Safety Handbook (PUB-745)

ALS Synchrotron Radiation Shielding (LBL-37801)

Bremsstrahlung Collimation and Shielding for ALS U5 and U8 Beamlines (LSBL-058A)

Gas Bremsstrahlung Estimates for ALS Hutch Backstops (LSBL-162)

LBNL *Chemical Hygiene and Safety Plan* (PUB-5341)

LBNL *Health and Safety Manual* (PUB-3000); also available on the World Wide Web at:
http://ehssun.lbl.gov/ehsdiv/pub3000/

LBNL *Mechanical Engineering Drawing 20 Q 5363*

Radiation Safety Shutters, Collimation and Shielding for ALS Beamlines (LSBL-073)

Sample copy of the Beamline Design Review document package

Appendix F – Checklist and Timeline for Building a Beamline

Step	Brief Description of What is Needed	ALS Contact (Extension)	When	☑
Conceptual Design Review (CDR)	Outline of beamline concepts, minus engineering details	Beamline Review Committe Chair (Contact ALS Admin – 6166)	As soon as concept is clear	
Beamline Design Review (BDR)	Designs of beamline components and equipment presented and evaluated <u>at least 3–6 months before tentative date of first operation of beamline</u>	Beamline Review Committee Chair (Contact ALS Admin – 6166)	Submit with BDR	
	1. Radiation Shielding Final ray-trace drawings showing shielding and exclusion zone dimensions and positions	Rich Donahue (5997) Dick DiGennaro (6466)		
	2. Vacuum Components Description of vacuum components used in beamline and endstation	Tony Catalano (6484) Will Thur (5689)		
	3. Electrical Equipment Description of electrical equipment	Art Ritchie (4785) Barry Bailey (5817)		
	4. Utilities Requirements for each utility	Art Ritchie (4785) Barry Bailey (5817)		
	5. Fire Safety Measures Description of flammable chemicals and materials of fire safety concern	Georgeanna Perdue (7407)		
	6. Hazardous Materials Safety Measures Description of cryogenics and biological, toxic, corrosive, and flammable materials	Georgeanna Perdue (7407)		
	7. Seismic Safety Measures Description of seismic restraints to ensure equipment withstands 0.7 g lateral acceleration	Will Thur (5689)		
	8. Mechanical Safety Measures Provide verification of compliance with LBNL requirements for mechanical systems	Dick DiGennaro (6466)		
	9. Equipment Protection System (EPS) Description of equipment protection interlocks to maintain storage ring integrity (including fast valves)	Ken Woolfe (7739)		
	10. S&A Fiducials on Components Plan for survey and alignment of beamline and endstation	Will Thur (5689)		
	11. Beamline Endstation Layout Drawing of beamline components and overall layout including shielding, exclusion zones, valves, gauges, interlock components, and walkways	Will Thur (5689)		
	12. Hutch (if used) Description of hutch design, including access and lighting requirements	Art Ritchie (4785)		
	13. Typical Experiment Brief description of typical experiment	Beamline Review Committee Chair (Contact ALS Admin – 6166)		

Step	Brief Description of What is Needed	ALS Contact (Extension)	When	☑
Construction Begins	**1. Instrumentation Details** Implement beamline instrumentation in collaboration with ALS staff	Ken Woolfe (7739)	Before BRR	
	2. Electrical Wiring and Power Install wireways, cables, terminations, and electrical power in collaboration with ALS staff	Art Ritchie (4785)		
	3. Vacuum Needs Arrange to meet vacuum needs related to clean room facility, assembly of components, bakeout requirements, and installation of components in collaboration with ALS staff	Tony Catalano (6484) John Thomson (7975)	2 weeks before needed	
	4. Radiation Safety System Communicate special RSS requirements during design and implementation of system by ALS staff	Art Ritchie (4785) Al Lindner (7757)	Before BRR	
	5. EPS and Branchline Control System Implement EPS and branchline control system in collaboration with ALS staff	Ken Woolfe (7739)		
	6. Interlock Procedures for EPS Write EPS interlock checkout procedures in collaboration with ALS staff	Ken Woolfe (7739)		
	7. Key-Enable Checklist Provide key-enable checklist of all items to be checked by ALS staff including shielding, exclusion zones, RGA scan and ion gauges	Cheryl Hauck (7885) Ray Thatcher (7412)		
Checkout of Completed Systems	**1. Radiation Safety System** Check of Radiation Safety System (RSS) and Personnel Shutter System (PSS) by ALS staff	Art Ritchie (4785) Al Lindner (7757)	Before BRR	
	2. Beamline Front-End EPS Check of interlocks of beamline front-end equipment protection system by ALS staff	Ken Woolfe (7739)		
	3. Branchline EPS Check of interlocks of branchline equipment protection system performed jointly by ALS staff and beamline designer	Ken Woolfe (7739)		
Beamline Readiness Review (BRR)	Review of documentation submitted to BRC at the time of the initial Beamline Design Review (BDR), and discussion of BRR walkthrough procedures	Beamline Review Committee Chair (Contact ALS Admin – 6166)	When construction is complete	
	1. Changes Documentation, provided by beamline designer, of any changes to the beamline since the BDR	Beamline Review Committee Chair (Contact ALS Admin – 6166)	Decided at BRR	

Step	Brief Description of What is Needed	ALS Contact (Extension)	When	☑
BRR Walkthrough Perfomed	Walkthrough to check key functions of beamline prior to first-time operation (see checklist in Procedure BL 08-07, Appendix D)	Beamline Review Committee Chair (Contact ALS Admin – 6166)	1–2 days before operation	
	1. Radiation Shielding Final check of shielding and exclusion zones	Rick Donahue (5997) Dick DiGennaro (6466)		
	2. Radiation Safety System Final check of RSS	Art Ritchie (4785) Al Lindner (7757)		
	3. Electrical Safety Qualification Final check for electrical safety	Art Ritchie (4785)		
	4. Mechanical Qualification Final check for seismic safety and motion hazards	Will Thur (5689)		
	5. Vacuum Qualification Final check of vacuum and RGA	John Thomson (7975)		
	6. Equipment Protection System (EPS) Final check of EPS system	Ken Woolfe (7739)		
	7. Key-Enable Key-enable procedure and checklist completed to permit beamline operation	Cheryl Hauck (7885) Ray Thatcher (7412)	First operation	
	8. Radiation Survey Check during initial operation	Keith Heinzelman (6212)		

Appendix G – ALS User Advisories

This Appendix includes ALS User Advisories related to beamline design.

This list is current as of June 1996. Please contact the ALS User Office for the most current list of Advisories.

ALS User Office
Advanced Light Source, MS 80-101
Lawrence Berkeley National Laboratory
Berkeley, CA 94720
510-486-7754
510-486-4773 [fax]

Copies of all Advisories are also located on the World Wide Web at the following address:

http://beanie.lbl.gov:8001/als/user-advis/user_advis_index.html

Category	Advisory #	Title
Design, Installation, and Operation of Equipment	1	Affixing Beamline and Endstation Components to the ALS Floor: Location of Grade Beams and Conduits
	2	Electrical Cable Wire and Routing Requirements
	4	Guidelines for Meeting Seismic Requirements for User Equipment at the ALS
	9	Vacuum Policy for User Endstations for Protection of Beamline Components and Storage Ring Vacuum
	13	Inspection of Beamline Work and Repairs
Electrical Safety	3	Avoiding Overloads on AC Circuits
	5	Beamline Electrical Safety Guidelines
Laser Safety	6	Laser Safety Policies for Class 3b and Class 4 Lasers