Refer to Photon Sources Directorate procedure "Design Reviews" in the Photon Sciences Document Center for complete details and requirements for completing design reviews. Contact the PSD Quality Representative for further guidance.

<table>
<thead>
<tr>
<th>The Design Review Report shall include at a minimum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ The title of the item or system;</td>
</tr>
<tr>
<td>▪ A description of the item;</td>
</tr>
<tr>
<td>▪ Design Review Report Number;</td>
</tr>
<tr>
<td>▪ The <strong>ESH&amp;Q risk level</strong>;</td>
</tr>
<tr>
<td>▪ The design parameters;</td>
</tr>
<tr>
<td>▪ The type of design review;</td>
</tr>
<tr>
<td>▪ The date of the review;</td>
</tr>
<tr>
<td>▪ The names and association of the reviewers;</td>
</tr>
<tr>
<td>▪ The major comments and concerns of the reviewers;</td>
</tr>
<tr>
<td>▪ Any reference not appearing in the EDP used to support the design during the Design Review meeting;</td>
</tr>
<tr>
<td>▪ Completed Design Checklist</td>
</tr>
</tbody>
</table>

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**TYPE OF REVIEW:**

- [ ] CONCEPTUAL
- [x] FINAL

**TITLE of ITEM/SYSTEM:** Final Design Review of Bending Magnet Front Ends

**PRESENTED BY:** A. Hussain

**ESH&Q Risk Level:** A-2

(Application of the Graded Approach Table)

**PURPOSE/DESCRIPTION:**
The Partner & BDN beamlines will utilize bending magnet front ends to connect their beamlines to their source, which will consist of a dipole magnet or 3-pole wiggler. The bending magnet front ends are not fundamentally different from the current insertion device front ends, but do contain some differences and design upgrades.

**REVIEWERS - ASSOCIATION:**

G. Fries (Chair), Scott Coburn (PD Engineer), Lewis Doom (AD Engineer), Charlie Hetzel (Vacuum), George Ganetis (Electrical), Bernie Kosciuk (Mechanical), Amy Xia (Rad Safety).

See attendee list below.

**DISTRIBUTION:**

All reviewers and stakeholders.

**ATTACHMENTS:**

- Data Sheets
- Calculations (Checked and countersigned)
- See Continuation Page
- Design Checklist

**MAJOR COMMENTS & CONCERNS OF REVIEWERS**

Charge to the Review Committee

The specific elements of the charge are as follows:

1. Are the designs mature and technically sound to satisfy design specifications?

Yes, the majority of the designs are modified and/or improved versions of the insertion device front ends, which have been proven during operations.

2. Is the design likely to meet performance expectations?

Yes
After the FDR (upon committee suggestion), it was verified that the slit assemblies provide the required stroke.

Recommendation #1 - There is a chamber designated for beamline diagnostics but no provisions for an X-ray beam alignment flag. Experience in commissioning prior front ends have illustrated the importance of having a flag present for beam alignment during commissioning. It was discussed that the BM front ends would not be commissioned until the beamlines were ready and use the beamline diagnostics. The current FE commissioning procedure does not allow the photon shutter to be opened until the FE is fully commissioned so the process will need to be evaluated. The x-ray flags that were designed for the purpose of beam alignment should be considered in these FE designs in order to satisfy the commissioning requirement.

3. Have all the major interfaces been identified and incorporated into the design?
Yes

Recommendation #2 – Access to any part of the mirror once it is installed looks like it will be very limited. In addition, once an adjacent insertion device is in place, access to both the mirror and the rear of the ID will be very limited. Typically, wiring of the IDs is along the outboard side, which may prove difficult. This should be reviewed with the ID group.

4. Does the design meet Synchrotron and Bremsstrahlung radiation requirements and is there sufficient margin to assure safe operation of the beam lines?
Yes. The front end ray traces and beamline radiation shielding will need to be reviewed by the radiation safety committee. Note that BMM ray trace not completed in time for this review.

During the FDR, the committee asked about the power from the upstream dipole not being accounted for in the thermal analysis or the ray tracing. It was determined that the power coming from upstream dipole is insignificant, which is why it was not incorporated in the thermal analysis. The geometric envelope is being used for the ray tracing, which is the worst case scenario. Bending magnet fan will reside inside the maximum fan defined using the geometric envelope, that’s why BM fan does not need to be incorporated in the ray tracing.

As per a suggestion during the FDR, the lower limit of Bremstrahlung radiation was updated to be limited by the lead apertures and not be coming from the lower source point, as it was originally shown.

5. Are the designs of various frontend components consistent with their requirements, robust, suitable for manufacturing, and cost-effective?
Yes

Discussed the need for the active interlock envelope to be defined. The frontend is designed using geometric envelope, so it does not need active interlock envelope to protect the frontend components. Vacuum group should work with operations group to define active interlock envelop to protect vacuum components upstream of FE.

Action Item #1 – Investigate whether high pressure in G4 is a concern since it is line of sight to
Action Item #2 – Determine whether the G6 shadow shield is still needed. The G6 shadow shield is not needed for front end radiation shielding. All the front end shielding requirements were met without taking credit of the G6 shadow shield. The ESH group should be consulted to verify if G6 shadow shield is required for any other shielding requirements.

Action Item #3 – Verify that there is space for all mirror controls to reside in the SR equipment racks.

Recommendation #3 - The Photon Shutter design was presented with the concept of using bellows tension as a fail-safe system and is based on engineering data from the bellows manufacturer. A prototype shutter should be fabricated and Testing should be completed to confirm that the photon shutters will close completely upon a loss of air pressure while under vacuum.

Recommendation #4 - The design of the X-Y slits utilize vented ceramic screws to clamp the tungsten slits to the aluminum nitride insulators. The committee recommends replacing the ceramic screws with vented stainless steel screws and ceramic washers.

Recommendation #5 - A cross has been included to provide access for future diagnostics components. In multiple locations vacuum components have been connected to the large 6” port on other crosses. By adding smaller ports to the sides of these crosses for vacuum components the large top port would be available for future access to the beam.

Recommendation #6 - Access to the shutter limit switches appears to be very limited. It should be considered to move them to the sides of the assembly with clear access to the switch wiring or at a minimum, verify with the appropriate groups that there is enough access for maintenance with the current design. In addition, the switches do not appear to be configured to fail safe if they stick in an actuated condition. This should be reviewed.

Recommendation #7 – Investigate whether the tungsten beam sensing plates can be separated to allow independent vertical and horizontal measurement. A thermal analysis should be completed to confirm the maximum temperature of the tungsten sensing plates.

Recommendation #8 – CABS tolerance is assumed +/-1mm. We have used +/-2mm in the past. This requirement should be communicated to the survey group during installation.

Recommendation #9 – Consider cycle testing the Be window (cycle pressure/vacuum on one side of window).

Recommendation #10 - the connections for the stages should be moved out of the aisle way to allow passage.

Note #1 - All Front Ends (FEs) which do not have a beryllium window installed that isolates the storage ring (SR) vacuum from the FE require additional safe guards to protect the SR vacuum. Approval from the vacuum group is required prior to opening FE GV1 (exit pipe GV) for the first time or after any intervention during which the vacuum in the FE is affected. Constant monitoring of the vacuum quality and level will be performed by the vacuum group. FE GV1 will be closed if excessive outgassing or contamination is observed at any time during
Prior to opening FE GV1, the maximum allowable total pressure as measured by the first cold cathode gauge (CCG) downstream of FE GV1 is $5.0 \times 10^{-10}$ torr. To facilitate constant monitoring of the vacuum quality, a permanently installed residual gas analyzer (RGA) is required. If a mirror is to be installed in a windowless FE, a residual gas spectral analysis must be performed prior to opening FE GV1 (exit pipe GV). The RGA must be located between FE GV1 and the most upstream optical element. Prior to taking an RGA scan which will be used to allow FE GV1 to be opened, all GVs located between FE GV1 and FE GV2 (ratchet wall GV) must be open for a minimum of 10 minutes. Windowless FE spectrum must be free of fluorine, halides and chlorine (M=19, 35 or 37) as these gases will poison the NEG strips which are installed in the SR vacuum system. RGA acceptance criteria are as follows:

- The predominate gas shall be hydrogen and at least 60% of the total pressure.
- The sum of the partial pressures of masses greater than 28amu shall be less than 10% of the total pressure.
- The sum of the partial pressures for masses 19, 35, 37, 39, 41, 43, 45 and greater shall be less than 1% of the total pressure.

6. Does the design meet all the requirements of the beamline RSIs and Top-Off Safety?

RSI documents were not reviewed as part of this review and the top-off safety analysis for all FEs needs to be completed and reviewed by the safety radiation committee. All front ends need to be approved for top-off safety in accordance with PS-C-ASD-PRC-183. This final analysis has the potential of requiring changes to the component apertures. The Ratchet wall collimator is the highest risk of requiring changes.

Recommendation #11 - Consider a reduction in the manufacturing & positional tolerances for the masks. For Front ends with no mirror (and possibly for those with mirrors), top-off needs to take credit for the position of these masks. The tolerances are typically loose (2mm in the front ends), but with these large sizes, the positional tolerances may need to be tightened. These tighter tolerances may be difficult to meet.

7. Does the design meet all the requirements for interfacing to the PPS & EPS systems?

Yes, the PPS & EPS requirements are very similar to those currently in operation on the ID front ends. See the above recommendation on the shutter limit switch location.

Action Item #4 – The fixed mask is PPS device, since it will shadow the collimator in place of a burn-through device. Water cooling monitoring is not required, since analysis showed the mask can survive via natural convection. Therefore, there will no active interlocks, only position verification of the fixed mask. A memo needs to be sent to the radiation safety committee detailing this information, including the mask analysis.

8. Has the installation process been adequately considered?

Yes, for the current stage in the front end process. Further work is required on an individual beamline basis regarding installation. Each front end will require an individual plan to clarify the sequence of installation of components.

9. Is process to document the legacy equipment from NSLS that will be installed into the front...
ends adequate?

This was discussed during the FDR and the consensus was that detailed drawings are not required, but that documentation shall include the following:

- Interface drawing with overall dimensions
- Vacuum interface dimensions, flange locations, types and sizes
- Electrical schematic and connection locations with required clearances for access
- Utility requirements and connections (i.e. water flow, temperature, connections, pneumatic)
- EPS requirements (limit switches and position indicators, water flow warning and alarm limits)
- PPS requirements
- Testing required prior to installation
- Optical limits
- Controls requirements
- Incoming synchrotron limits
- Materials list in vacuum
- Service procedures

10. Has value engineering been appropriately addressed in the design process?

Yes. Several changes were incorporated to reduce cost when compared to the ID front ends. These include:
- Copper Chromium Zirconium was used in the place of Glidcop where possible
- standard size tubes where used in the ratchet wall collimators
- Shutter switch adjustment was removed
- No welding & brazing is now required during manufacturing
- Added additional room at ratchet wall collimator to allow for vacuum connection work
- Ratchet wall collimator can now be installed from the experimental floor or the SR tunnel, providing more efficient installation
- Ratchet wall collimators now include cam followers to roll into position during installation
- Ratchet wall collimator fiducials are now more accessible (they were previously located behind the gate valve), which will reduce survey time

11. Are all related ESH aspects being properly addressed?

Yes. See previous action items and recommendations.

12. Are there any other issues that have not been identified that need to be addressed?

Recommendation #12 - FE commissioning plan needs to be carefully considered as the entire FE (to photon shutter) cannot be tested without the mirror in the beam. Mirror commissioning should be done as part of FE commissioning.

FDR Attendees:
Aftab Hussain
Gregory Fries
<table>
<thead>
<tr>
<th>REVIEWED DRAWINGS / SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>See front end group for listing</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**APPROVAL:**
Review Committee Chairperson: Gregory Fries  
Date: 07/13/15

Please forward completed original to the PSD Quality Assurance Group.
Bending Magnet and 3-Pole Wiggler Frontend Final Design Review

Prepared by: Muhammad Aftab Hussain  June 25, 2015

Office of Science  National Synchrotron Light Source II  Brookhaven National Laboratory
Outline

- Introduction
- Frontend Configuration & Interfaces
- Beamline Source Parameters & Requirements
- Frontend Overall Design Approach and Challenges
- Front End Synchrotron Radiation Protection & Radiation Shielding
- Frontend Components Design
- Summary and Conclusion
Introduction

*Frontend serves the following purpose:*  
- It transports the required synchrotron radiation from the source to the first optics enclosure.  
- It protects the storage ring vacuum.  
- It removes the undesired heat from the synchrotron beam.  
- It collimates the Bremsstrahlung radiation to a safe level.
Sources for the NSLS-II BM port beamlines:

- **Source Type**: 3PW and BM

- **Nominal magnetic field at source location**: 3PW (1.2 T) & BM (0.40 T)

- **Usable photon energy range**: 1-31 keV

- **Maximum fan power (500mA current)**: 3PW (250 W) & BM (69 W)

- **Maximum Power Density**: 3PW (365 W/mrad²) & BM (115 W/mrad²)

- **Nominal Source Fan Width**: 3 mrad (Approx.)
Beamline Requirements

- **Beamline Horizontal Acceptance Fan:** 0.2-3 mrad
- **Beamline Vertical Acceptance Fan:** 0.15-0.4 mrad
- **Mirror Incident Angle:** 2.7-4.2 mrad
- **Vacuum:** < $1 \times 10^{-9}$ Torr & downstream of Be window < $1 \times 10^{-8}$ Torr.
- **Radiation Safety:** The Bremsstrahlung collimators shall restrict Bremsstrahlung radiation exiting the shield wall and the safety shutters shall block Bremsstrahlung radiation in order to allow personnel access to the beamline FOE.
- **EPS & PPS:** All the frontend system shall be interlocked to the machine EPS and PPS systems. All departures from the nominal operation settings shall inhibit the operation of the storage ring.
- **Access:** The FE must be accessible for installation and commissioning of mirror system up to size 1725mm x 710mm x 1525mm (L x W x H).
Frontend Design Challenges

- Full passive protection to the frontend PPS components using “Geometric Envelope” as opposed to “Active Interlock Envelope”.

- Large beam deviations.

- Water cooling system is not interlocked to the machine PPS system resulting in crotch absorber and exit absorber as a non-PPS device.

- Radiation safety.

- Mirror installation.

- Compressed schedule (16 months), limited budget and limited resources for six different beamlines.

- Short duration for installation of FE.
Typical BM/3PW Frontend Configuration & Interfaces

Three Pole Wiggler (3PW)

Bending Magnet (BM-B)

Gate Valve (GV1)

Bending Magnet (BM-B)

BM Photon Shutter (BMPS)

Be Window (WIN) or Fast Valve (FV)

Fixed Mask (MSK1)

XY Slits

Mirror

Diagnostics

Photon Shutter (PSH)

Safety Shutters (SS)

Ratchet Wall Collimator (RWC)

Lead Collimator (BC2)

Fixed Mask (MSK2)

Gate Valve (GV2)

Fixed Mask (MSK3)

Mirror

Fixed Mask (MSK4)

Lead Collimator (BC2)

Ratchet Wall Collimator (RWC)

Safety Shutters (SS)

Diagnostics

Photon Shutter (PSH)
Frontend Design Approach

- Ray tracing to locate and size the frontend components.
- Multiple fixed masks for the progressive trimming of synchrotron beam to protect frontend components.
- Using fixed mask as a PPS device to protect lead collimators.
- Fixed masks are double sided conflate flanges.
- Material selection for the manufacturing of frontend components to meet specific requirements. Glidcop AL-15 and Copper Chromium Zirconium (C18150) as a flange material.
- Design for Manufacturing and Assembly (DFMA) to reduce cost.
- Common components to reduce cost.
Bremsstrahlung Shielding Requirements

- Lead thickness of > 30 cm or tungsten thickness of > 20 cm is required to completely block the Bremsstrahlung radiation.
- The stopped extremal Bremsstrahlung ray should not be closer than 3 Moliere Radii (3R) from the lateral edge of the collimator or stop. Moliere radius for lead is 12 mm and that for the tungsten of density ~17g/cm³ is 8 mm.

![Bremsstrahlung Source Dimensions](image1)

<table>
<thead>
<tr>
<th>Bremsstrahlung Source Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
</tr>
<tr>
<td>+/- 12.5 mm</td>
</tr>
<tr>
<td>Horizontal Outboard</td>
</tr>
<tr>
<td>38 mm</td>
</tr>
<tr>
<td>Horizontal Inboard</td>
</tr>
<tr>
<td>Determined by the FE Collimator Apertures</td>
</tr>
</tbody>
</table>

**Table 2: Bremsstrahlung Source Locations for NSLS II Beamlines**

<table>
<thead>
<tr>
<th>Beamsources</th>
<th>Bremsstrahlung Source Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID Beamlines</td>
<td>Downstream of the ID straight section</td>
</tr>
<tr>
<td>3PW Beamlines</td>
<td>Upstream end of the second dipole magnet</td>
</tr>
<tr>
<td>Bending Magnet Beamlines</td>
<td>Nominal center of the BM source</td>
</tr>
</tbody>
</table>

![Bremsstrahlung Ray Tracing](image2)

**Figure 2: Typical Extremal Rays through Collimator and at the Stop**
CMS Frontend Layout
CMS Frontend Vertical Synchrotron Ray Tracing
CMS Frontend Horizontal Bremsstrahlung Ray Tracing
CMS Frontend Vertical Bremsstrahlung Ray Tracing
XFM Frontend Horizontal Synchrotron Ray Tracing
XFM Frontend Vertical Synchrotron Ray Tracing
XFM Frontend Horizontal Bremsstrahlung Ray Tracing
QAS Frontend Horizontal Synchrotron Ray Tracing
QAS Frontend Horizontal Bremsstrahlung Ray Tracing
QAS Frontend Vertical Bremsstrahlung Ray Tracing
XFP Frontend Horizontal Bremsstrahlung Ray Tracing
TES Frontend Layout
TES Frontend Horizontal Bremsstrahlung Ray Tracing
**Analysis Parameters**

- Distance from Source ~ 13.4m
- Total Power reflected by Mirror 1 @ 5.435 mrad = 31.4 W
- Max. Power Density = 0.004 W/mm²
- Beam footprint on collimator tube lower surface = 33.5mm x 228.5mm (W x L)
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Assumed Aluminum Thermal Conductivity = 167 W/m.K

**Stainless Steel to Aluminum Bimetallic Flanges with Aluminum Tubing.**

Temperature Contour Plot, Tmax ~ 129°C
Material Selection “Glidcop AL-15 Vs Copper Chromium Zirconium (C18150)”

Material Properties

- **Thermal Conductivity (RT):**
  - Glidcop Al25, Al15: 344 - 365 W/(m.K)
  - Cu-Cr-Zr: 314 - 335 W/(m.K)

- **Elastic Modulus:**
  - Glidcop Al15, Al25: 130 GPa
  - Cu-Cr-Zr: 123 GPa

- **0.2 % Yield Strength, (RT, Cold Worked):**
  - Glidcop Al15, Al25: 470 - 580 MPa
  - Cu-Cr-Zr: 350 - 550 Mpa

- **Coefficient of Thermal Expansion:**
  - Glidcop Al15, Al25: 16.6 µm/K
  - Cu-Cr-Zr: 17.0 µm/K

(Tests on Cu-Cr-Zr Conflat Flanges and Flare Fitting Connections)

- Cu-Cr-Zr (C18150) is 1/4th the price of Glidcop AL-15.

- Cu-Cr-Zr is readily available in different forms and sizes from many suppliers.

- Cu-Cr-Zr loses its strength rapidly if exposed to sustained temperatures > 500°C

- Glidcop is the choice if brazing is required.


Fixed Mask Design

- **Fixed mask defines the beam size and shadow collimator aperture.**
- **Fixed mask is water cooled and interlocked to the machine EPS.**
- **External fins are added to fixed mask to provide natural convection and equipment protection from loss of water flow.**
**Analysis Parameters**

- Distance from Source ~ 7.9m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Assumed film coefficient of 0.4 W/cm².°C for a flow rate of 1GPM in Ø0.375” cooling channel.

**Temperature Contour Plot, Tmax ~ 87°C**

**Glidcop AL-15 Fixed Mask**

**Cu-Cr-Zr Fixed Mask**

**Temperature Contour Plot, Tmax ~ 93°C**
Fixed Mask Thermal Analysis (Natural Convection Only)

**Analysis Parameters**

- Distance from Source ~ 7.9 m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Typically the heat transfer coefficient value for natural convection ranges from 5-25 W/m².K

**Glidcop AL-15 Fixed Mask**

Temperature Contour Plot, Tmax ~ 298°C

**Cu-Cr-Zr Fixed Mask**

Temperature Contour Plot, Tmax ~ 305°C
Beryllium Window Design

- Water cooled Be Window.
- Provide isolation to storage ring vacuum from beamline vacuum.
- Window thickness (250 µm).
- Window aperture required (35mm x 10mm)
- Prototype window (92mm x 10mm) shown below
- Polished to Ra < 100 nm RMS on both sides.
- Diffusion bonded window assembly bakeable to 450°C.
- Capable of sustaining > 2.4 bar pressure differential.
Prototype Be Window Test Results

- Leak check before and after the diffusion bonding at room temperature.
- Leak check and pressure test was performed after repeated thermal cycling up to 150°C.
- Pressure test was performed to check the window strength.

**Prototype Be Window**

**Test Setup**

<table>
<thead>
<tr>
<th>NSLS-II NexGen Beamline Front-End Beryllium Window Leak and Pressure Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Be-Window Leak Check and Pressure Test</strong></td>
</tr>
<tr>
<td>(2 identical independent sets at both sides of Be)</td>
</tr>
</tbody>
</table>

**Leak/P-test at Room Temp using helium**

| pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10^-10 |
| pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10^-10 |

**(temperature rise at rate of 50-deg C per hour)**

**Leak/P-test at 70-deg C using helium**

| pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10^-10 |
| pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10^-10 |

**(temperature rise at rate of 50-deg C per hour)**

**Leak/P-test at 120-deg C using helium**

| pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10^-10 |
| pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10^-10 |
Lead Collimator Design

- The lead collimator restricts the primary and secondary Bremsstrahlung radiation exiting the ratchet wall penetration.
- The lead collimator aperture is sized based on PPS fan size.
- The fixed mask provides full passive protection to lead collimator.
- The lead collimator is out-of-vacuum lead design.
Lead Collimator Design

NOTE: COLOR OF LEAD BRICKS ON THIS DRAWING IS USED AS A VISUAL AID FOR ASSEMBLY ONLY. MAY NOT REFLECT ACTUAL FINISH COLOR OF BRICKS.
Photon Shutter Design

- Water cooled, normal incidence design.
- Stops synchrotron beam whenever safety shutters are closed.
- Integrated into the machine PPS.

Photon Shutter/Lead Collimator (BC2) Assembly

Photon Shutter

- Open Position
- Closed Position
The photon shutter aperture (66mm x 15mm) is sized for 3mrad x 0.6mrad (HxV) fan size.

The photon shutter travels 17mm before it makes contact with limit switches for closed position.

All limit switches for closed position have 2mm over travel and limit switch for open position has 9.5° (7.5mm) over travel.
Photon Shutter Design
Photon Shutter Design

NOTES:
1. SET LIMIT SWITCH (TB1.27) PLunger (017) ALLEN BRADLEY LEVER TYPE
   FOR N.C. (NORMALLY CLOSED CONTACTS) TERMINALS (11,12)
2. SET LIMIT SWITCH (TB1.26) A. 0.850.055 (SHimming PLunger TYPE)
   FOR N.O. (NORMALLY OPEN CONTACTS) TERMINALS (11,11A, B, 16)
3. SET LIMIT SWITCH (TB1.25) R. 0.850.855 (SHimming PLunger TYPE)
   FOR N.O. (NORMALLY OPEN CONTACTS) TERMINALS (11,11A, B, 16)
4. SET LIMIT SWITCH (TB1.24) R. 0.850.057 ALLEN BRADLEY PLunger TYPE
   FOR N.C. (NORMALLY OPEN CONTACTS) TERMINALS (11,11A, B, 16)
Safety Shutter Design

- The safety shutter is redundant a pair of lead shutters.
- The safety shutter is air actuated with independent, redundant, and diverse position sensing.
- The safety shutter blocks Bremsstrahlung radiation passing through the ratchet wall collimator in order to allow personnel access to the beamline FOE.
- The safety shutter can not withstand synchrotron radiation and is protected by an upstream photon shutter.
Safety Shutter Design

NOTES:
1. USE ITEM 22 (SET SCREW) FOR HORIZONTAL ALIGNMENT PURPOSE ONLY
2. USE ITEM 20 (PADLOCK) AND ITEM 55 (MOUNT LOCK) IN CLOSED POSITION ONLY FOR LOCKOUT/TAGOUT PURPOSE ONLY.
3. USE ITEM 21 (DOWEL PINS) TO LOCATE ITEM 28 (FLAG) ON ACTUATOR PLATE (ITEM 16).

DEPARTMENT

<table>
<thead>
<tr>
<th>NO.</th>
<th>DESIGNATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>SET SCREW</td>
<td>3/16&quot; TAP SCREW</td>
</tr>
<tr>
<td>55</td>
<td>MOUNT LOCK</td>
<td>5/16&quot; x 1&quot;  3/4&quot;  5/8&quot;  1/2&quot;</td>
</tr>
</tbody>
</table>

SAFETY SHUTTER ASSEMBLY

STORAGE RING
FRONT END, SAFETY SHUTTER

NISLS-I

PERM. 03.04.07 03

A-1
Safety Shutter Design

NOTES:
1. Set limit switch (ITEM #25), P/N: 0080-0000 (Allen Bradley, Lever Type) for 2 N.O. (Normally Open) contacts (terminals 33, 34 & 43, 44)
2. Set limit switch (ITEM #23), P/N: 0080-0000 (Siemens, Lever Type) for N.O. (Normally Open) contacts (terminals 33, 34)
Safety Shutters (SR-FE-SS-4000/4001) Limit Switches Test Results (Frank Lincoln 10th Feb., 2015)

Dimensions are in inches and represent the switch over travel.

**SWITCH 1**
PI-SNSR-0039 ALLEN BRADLEY Roller Type (Open Position)

<table>
<thead>
<tr>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
<th>CONTACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.117</td>
<td>0.118</td>
<td>0.117</td>
<td>33,34</td>
</tr>
<tr>
<td>0.136</td>
<td>0.136</td>
<td>0.136</td>
<td>43,44</td>
</tr>
</tbody>
</table>

**SWITCH 2**
PI-SNSR-0007 ALLEN BRADLEY Plunger Type (Closed Position)

<table>
<thead>
<tr>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
<th>CONTACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.145</td>
<td>0.146</td>
<td>0.146</td>
<td>33,34</td>
</tr>
<tr>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>43,44</td>
</tr>
</tbody>
</table>

**SWITCH 3**
PI-SNSR-0002 SIEMENS Roller Type (Open Position)

<table>
<thead>
<tr>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
<th>CONTACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.236</td>
<td>0.236</td>
<td>0.236</td>
<td>21,22</td>
</tr>
<tr>
<td>0.078</td>
<td>0.077</td>
<td>0.077</td>
<td>33,34</td>
</tr>
<tr>
<td>0.102</td>
<td>0.102</td>
<td>0.102</td>
<td>13,14</td>
</tr>
</tbody>
</table>

**SWITCH 4**
PI-SNSR-0002 SIEMENS Roller Type (Closed Position)

<table>
<thead>
<tr>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
<th>CONTACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.263</td>
<td>0.263</td>
<td>0.262</td>
<td>21,22</td>
</tr>
<tr>
<td>0.068</td>
<td>0.066</td>
<td>0.066</td>
<td>33,34</td>
</tr>
<tr>
<td>0.146</td>
<td>0.142</td>
<td>0.144</td>
<td>13,14</td>
</tr>
</tbody>
</table>
The ratchet wall collimator restricts the primary and secondary Bremsstrahlung radiation exiting the ratchet wall penetration.

The ratchet wall collimator aperture is sized based on PPS fan size.

The fixed mask upstream of RWC provides full passive protection to the ratchet wall collimator.

The ratchet wall collimator is out-of-vacuum lead design.
Ratchet Wall Collimator Design

- **12” Thick Lead**
- **Concrete**
- **Provision for heater tape**
- **Hex Head Screw for upstream horizontal alignment**
- **Fiducial Holes**
- **Set Screws with swivel pads for upstream vertical alignment**
- **Cam Followers**
Ratchet Wall Collimator Installation

- Ratchet Wall Collimator
- Swivel Leveling Mounts
- Cart Height Adjustment

Custom Cart
- Water cooled, normal incidence design.
- Allow full independent adjustment of all four blades.
- Maximum Opening (30 mm H x 10 mm V).
- Minimum Aperture Size (-10 mm, fully closed, overlapped).
- Allow selection of any part of the beam.
- Position Resolution < 1 µm
- Aperture Stability (10 µm or better over any 24-hour period)
- Repeatability (5µm)
- Beam intensity monitoring.
X-Y Slits Design

Front View (Upstream Slit)

Back View (Upstream Slit)

Front View (Downstream Slit)

Back View (Downstream Slit)
X-Y Slits Design

Front View
- Electrical Feedthrough
- Steel blocks with set screws for blade alignment
- Tungsten Block
- Aluminum Nitride (Dielectric strength 17 volts/mil)

Back View
- Ceramic Screw Alumina (A998)
- Tungsten Blade
- Thermal Interface (99.7% purity Silver)
Summary & Conclusion

- **Full passive protection:**
  - Any beam deviation is acceptable for frontend components.
  - Progressive trimming of fan using fixed masks.
  - Fixed masks shadow lead collimators.
  - Components protection in absence of water flow by natural convection.

- **Cost effective design:**
  - No welding or brazing required for masks, slits, absorbers & photon shutter.
  - Cu-Cr-Zr is \( \frac{1}{4} \)th the price of Glidcop AL-15.
  - Cu-Cr-Zr is available in different forms (bars, sheets & plates) and sizes.
  - Standardized components for mass production.

- **Installation Plan:**
  - If required, upstream ID FE safety shutter stand will be moved temporarily to allow installation of mirror in BM/3PW FE’s.
  - Downstream components will be installed first to provide access for installation of mirror and other upstream components.
Summary & Conclusion

Project Status:

- Design of components is complete. All the components drawings are released or in review for approvals.
- Top level assembly drawings are in progress.
- Manufactured parts in production:
  - Crotch Absorbers (All six FE’s)
  - Exit Absorber Blanks (All six FE’s)
  - Fixed Mask Blanks (All six FE’s)
  - Photon Shutter Assemblies (All six FE’s)
  - Safety Shutter Assemblies (All six FE’s)
  - Fixed Mask Assemblies (CMS & QAS)
  - Be Window Assemblies (CMS, QAS & XFM)
- Vacuum purchased items (Ion pumps, controllers, gauges, TSP’s, Cables, Valves etc.) procurement is in progress. Long lead items (gate valves and fast valves) are expected to be delivered in late September or October, 2015.
- All the other purchased items (Bellows, limit switches, crosses, solenoid valves, fittings, cables, cable connectors, picometer, hardware etc.) procurement is in progress. No delays are expected at this time.
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Thank you for your attention!