LCLS Vacuum Policy

Approval:

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Revision Record

Revision	Date Revised	Description of Change
R005	December 8, 2022	Permit variance for synthetic organic lubricants in Level 3. Distinguish "operational" from "baseline requirements" variances in Section 3.4.
R004	July 19 2021	Revise Vacuum Level diagram: for Hutch 2.2, new details and new levels; for Hutch 1.3, align with actual operational practice.
R003	Jan 23, 2020	New schematic for the vacuum levels in the facility
R002	November 11, 2019	New document number. Previous number: SLAC-I-120-204-001-00
R001	January 30, 2014	Added procedure for logging operation variances in Section 3, overview of LCLS vacuum level designation in Section 4, examples of vacuum separation devices in Section 5, summary of guidelines and operation variance for each LCLS vacuum level in Section 6.
R000	May 4, 2011	Original Release.

1 Introduction

All new or modified vacuum sections, instruments, or components at the LCLS must be "qualified" before isolation valves are opened to the extended LCLS complex. LCLS operates with five distinct region classifications, found in a variety of locations, depending upon operational needs and functional isolation. Each of these classifications has a separate Level (1-5) of requirements and an associated set of procedures and criteria for qualification. Properly isolated systems, with documented approval, can work in a state of extended operational variance, where subsequent installations do not require additional evaluations. Variances to baseline requirements will be recorded and managed in separate controlled documents.

2 Qualification

Qualification is based on a comparative analysis with respect to prohibited elements, results of a Helium Leak Test, and Residual Gas Analysis (RGA) scans. Requirements for the Helium Leak Test are given in specification SLAC-I-030-714-001-01 and LCLS Procedure SLAC-I-030-714-001-03 details the process for collecting RGA data. The installed system must comply with the process and specifications pertaining to the level. Variances must be documented in a controlled document specific to the system and managed by the area manager.

Level 1 Specification: SLAC-I-030-714-001-04

Level 2 Specification: SLAC-I-030-714-001-05

Level 3 Specification: SLAC-I-030-714-001-06

Level 4 Specification: SLAC-I-030-714-001-07

Level 5 Specification: SLAC-I-030-714-001-08

3 Basic Qualification Steps for Level 1-4 Installations

3.1 Notification and System Description

All Level 1 and Level 2 installations must be baked and have RGA scans. New Level 3 installations must have RGA scans, but should **only** be baked if **no** synthetic organic grease/lubricant is used in-vacuum. (Such bakeout/RGA processing is optional for Level 4 and Level 5 installations.) Before the system in question is installed and ready for an RGA scan, notify the LCLS Vacuum Qualification Authority (VQA) (a designee of the LCLS XFO Engineering Group) and provide the following information:

1. Planned date for installation completion (i.e., system ready for RGA scan), and desired start-up date for system use at the LCLS.
2. A general description of the system in question, and its situation relative to the existing LCLS vacuum complex (by e-mail, phone call, or brief sit-down discussion).

3.2 Arrange for RGA Scan

Contact the relevant Area Manager or LCLS/MFD Vacuum Technicians and arrange for RGA scans to be performed, according to SLAC-I-030-714-001-03 "LCLS Procedure for Vacuum Qualification RGA Scans". The scan results are forwarded to the VQA.

3.3 Verification

The VQA will evaluate the qualification data for compliance, including any documented variance, and authorize opening of isolation valves, as well as communicate the status to LCLS Operations. Applicant will be informed if additional, corrective action is required.

3.4 Variances

Section 6 of this document offers guidelines for various vacuum criteria for LCLS vacuum levels. Exceptions are titled 'Variance' in the table, and they require authorization. For variances to baseline requirements, e.g., for use of elastomer-sealed vacuum flanges in a Level 3 instrument, application and authorization should occur during formulation of instrument requirements and conceptual design. An operational variance is a situation where from time to time, as part of routine operation or repair, a vacuum region may not be required to comply with a guideline. For instance, a Level 3 region containing an x-ray focusing lens assembly may not have to go through a helium leak test or RGA scan after a routine change of lenses for an experiment.
The following workflow is required for operational variance access to an existing LCLS vacuum system or installation of a new LCLS vacuum system:

3.4.1 Work in LCLS can be requested by a variety of individuals including scientists, engineers, area managers, and science and engineering associates. Work that involves accessing an LCLS vacuum section is usually carried out by the technical support staff. However, work in LCLS is always released by the relevant area manager. Before accessing an LCLS vacuum section, notify the area manager of the planned work.

3.4.2 The area manager, in consultation with the relevant engineer, checks the scope of work, the region of access and its vacuum level designation, and whether an operational variance is required.

3.4.3 If operational variance authorization is required, continue with the following steps:

3.4.4 The area manager maintains an online operational variance authorization log of each vacuum section that can have variances. The LCLS Pressure Vessel numbering system is to be used to tie in information, since it typically covers 'valve-to-valve' sections of the facility. Variance authorization logs are maintained in the same directory as the LCLS Vacuum Specification documents under SLAC's Controlled Document Management System.

3.4.5 An operational variance authorization log contains the following heading/column information:

- 3.4.5.1 Vacuum system number
- 3.4.5.2 Vacuum system location and description
- 3.4.5.3 Vacuum system level designation
- 3.4.5.4 Variance number
- 3.4.5.5 Date of variance request
- 3.4.5.6 Access description (nature of work)
- 3.4.5.7 Variance type (e.g., RGA waiver in Level 3, leak check waiver in Level 4, use of unbaked parts in Level 3)
- 3.4.5.8 Reason for variance
- 3.4.5.9 Duration of variance (if applicable)
- 3.4.5.10 Relevant engineer sign-off to authorize the variance (name, signature)
- 3.4.5.11 Date of variance authorization
- 3.4.5.12 Remarks

3.4.6 The area manager documents the operational variance in this controlled document and contacts the relevant engineer. The relevant engineer is a member of the LCLS Engineering Department who is qualified to make decisions for a particular region. For instance, an operational variance like an RGA waiver in a Level 3 region in Hutch 6 will require authorization from an engineer from the LCLS Engineering Department's Operations group who is most familiar with Hutch 6.

3.4.7 The relevant engineer's signature (digital/verbal authorization is acceptable) authorizes re-opening of section valves to the rest of the LCLS beamline.

4 LCLS Vacuum Level Designation

4.1 Overview FEE and NEH

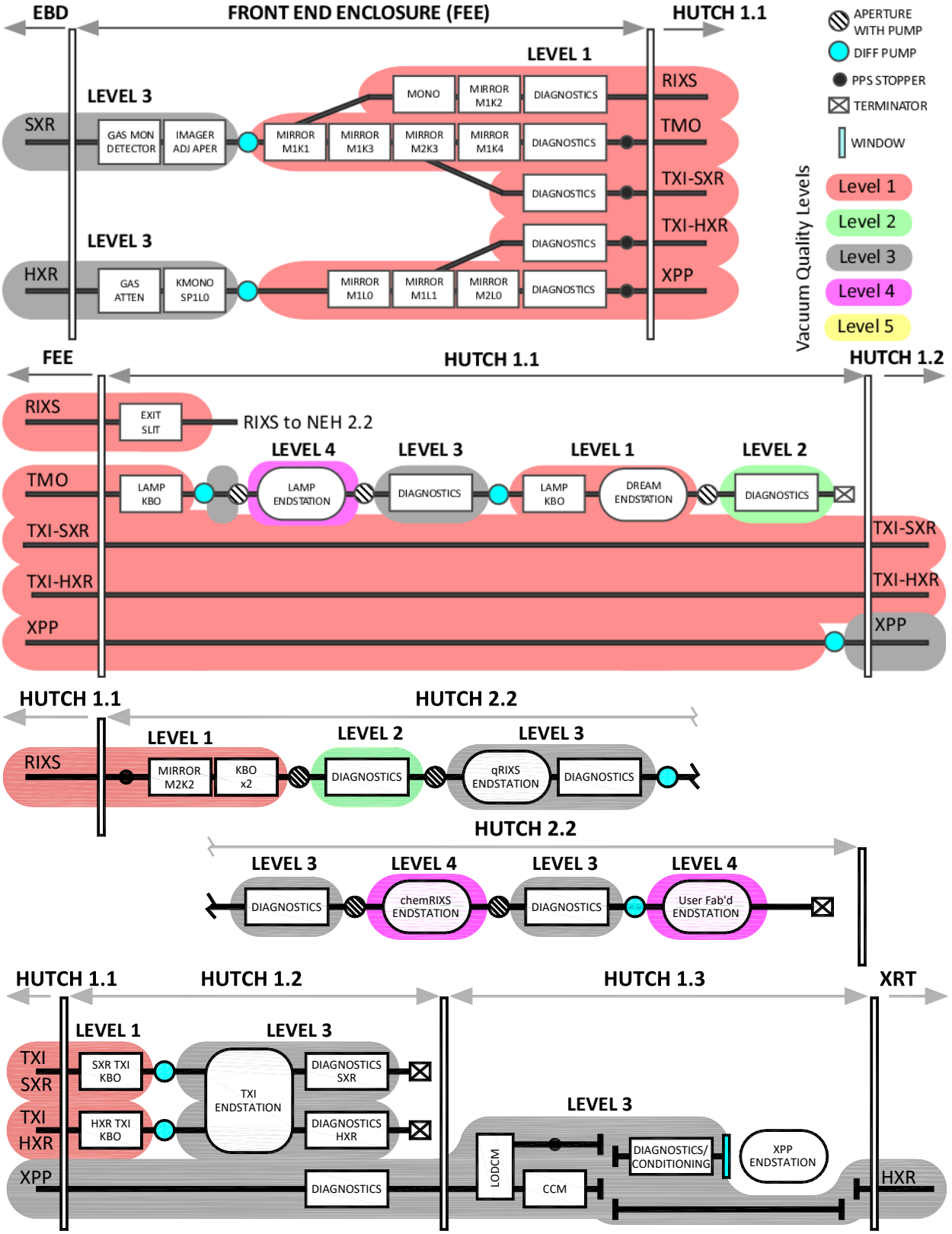

Fig 1: Schematic for the LCLS Facility Front End Enclosure (FEE) and Near Experimental Hall (NEH) illustrating the different vacuum level designations for each X-ray beamline.

4.2 Overview XRT and FEH

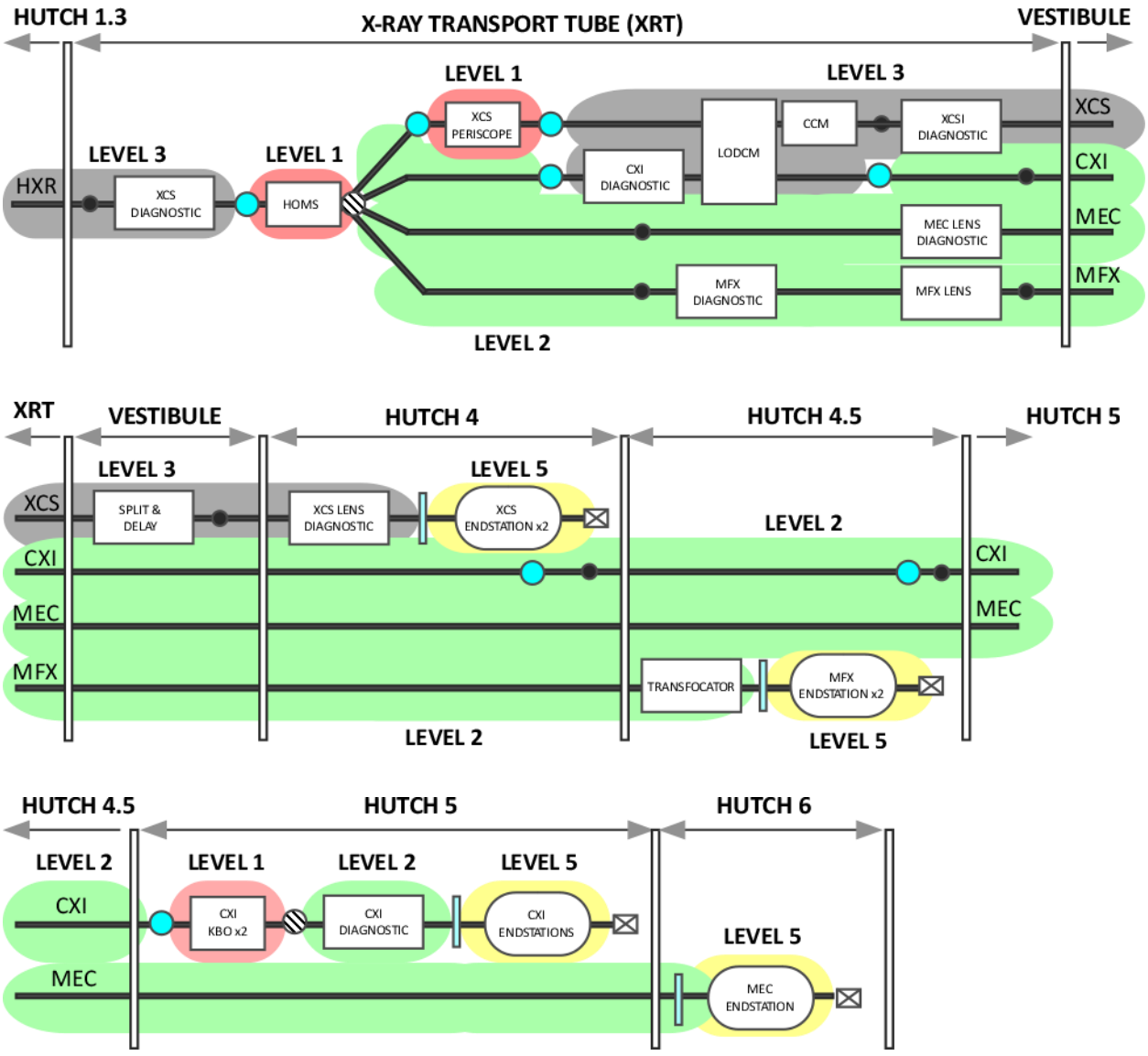

Fig 2: Schematic for the LCLS Facility X-ray Transport Tunnel (XRT) and Far Experimental Hall (FEH) illustrating the different vacuum level designations for each X-ray beamline.

4.3 Guidelines for designation and vacuum system interfaces

During operation, LCLS is generally a contiguous vacuum system, with all valves between sections generally open. Therefore, it is important to preserve the vacuum integrity of LCLS systems with specific, objective vacuum specifications. The function of a new/modified vacuum section frequently drives choices in materials, designs, etc., that in turn suggest a suitable LCLS vacuum level, i.e., Level 1, Level 2… etc. With a vacuum level tentatively selected, adjacent section vacuum levels immediately determine the vacuum system interfaces required with the new section. If this result is undesirable, the requirements and consequences of a different vacuum level selection can be explored. The following guidelines will help determine level designation, and corresponding system interfaces:

1) For windowless operation, a vacuum system must be adjacent to vacuum systems of the same level or two levels above or below.
2) If two systems with the same level designation are adjacent to each other, no differential pumps are needed between the systems.
3) If a Level 1 system is adjacent to a Level 2 or Level 3 system, or a Level 2 is adjacent to a Level 3 or Level 4 system, it must be separated either by a differential pump or permanent vacuum window. For instance, the MEC Offset Mirror in the X-Ray Tunnel is a Level 1 vacuum system. The x-ray transport tunnel system upbeam of the MEC mirror system is a Level 3 system; the downbeam is a Level 2 system. To preserve the vacuum integrity of the mirror system, a pair of differential pumps is installed upbeam and downbeam of the MEC mirror system. Similarly, soft X-ray user end-stations (Level 4) are separated with a variety of differential pumps from the instrument optics (Level 2 or Level 3). The Large Offset Double Crystal Monochromator (LODCM) in the X-Ray Tunnel (Level 3) is separated from the X-ray transport tunnel systems (Level 2) with differential pumps. Details for differential pumps used in LCLS are given in Section 5.
4) A Level 5 must always be separated by permanently installed windows. Details for windows used in LCLS are given in Section 5. This is typically the case at end stations on the hard x-ray lines in LCLS. For instance, the sample regions in CXI (target chamber), MEC (target chamber), XPP and XCS (diffractometer), are usually Level 5 regions. The LCLS optics end stations in each of these hutches have a permanently installed diamond or beryllium window on the beamline.

5 Vacuum Level Separation Devices

5.1 Vacuum Windows

The LCLS hard x-ray line uses a variety of vacuum windows to separate vacuum conditions in different systems. The most common windows are CVD diamond windows (typically 100 microns thick, see SA-391-440-04 for CVD diamond specifications). These are installed within Viton-sealed gate valves (example: SA-391-830-80, LCLS diamond window gate valve). Beryllium windows (typically 100 microns thick) are used in some experimental regions (example: SA-391-831-51, MEC beryllium window). Kapton (polyimide film) windows are used in Level 4 or Level 5 systems (example: SA-391-440-87, XCS Large Angle Detector Kapton Window). Their thickness varies (roughly between 10 microns and 125 microns), depending on experimental needs and geometry of the aperture.

5.2 Differential Pumping

Differential pumping is an effective, windowless method of providing transition from areas of high vacuum pressure to low vacuum pressure, using pumps and throttles that restrict gas flow. LCLS uses a series of differential pumps across the facility to separate vacuum systems of different levels. The typical commercial differential pump is the DP-03 differential pumps manufactured by XIA, LLC. These pumps can theoretically provide transition between ~10^{-9} torr to ~10^{-5} torr. An installation example is the Level 2/3 separation in the LCLS X-Ray Tunnel (ID-391-030-55) using the differential pump (SA-391-831-70). For other differential pump designs, see the Soft X-Ray Instrument sub-assemblies, SA-391-952-04 and SA-391-260-54.

6 LCLS Vacuum Levels and a guideline summary

Specifications and criteria for LCLS vacuum sections are in the respective documents listed in Section 2. Table 1 is a snapshot of the differences between sections of differing vacuum levels. Deviations are allowed in items marked 'variance' but they must be authorized as detailed in Section 3.4. The information presented here is not sufficient. It is offered as a starting tool for users, to guide design and processing of new or modified vacuum sections.

Table 1: Snapshot of some guidelines for LCLS Vacuum Levels

	Level 1	Level 2	Level 3	Level 4	Level 5
"Caricature"	"Best" vacuum: for mirrors and diagnostics	General transport and diagnostics	Mechanically complex systems	"Cleaner" endstation	"Dirty" endstation
Example Region	FEE: Mirrors, Diagnostics ; MEC: Mirror	Most of XRT	Optics and diagnostics in all hutches; Large Offset Mono in XPP/XRT	Soft X-ray end station; Hard X-ray sample environment needing more stringent vacuum conditions.	MEC Target Chamber, CXI Sample Chamber, XCS Large Angle Detector Tube, XPP Sample Chamber
Permanent isolation from other vacuum levels (vacuum window/air gap)	No	No	No	No	Yes
Differential pressure isolation from other vacuum levels	Yes	Yes	Yes	Yes (or vacuum window/air gap)	NA
RGA Scan required?	Yes	Yes	Variance	No	No
RGA Scan Criteria (Room Temperature)	Sum > 45 AMU < 1x10-12 Torr; Single > 45AMU < 5x10-13 Torr	Sum > 45 AMU < 1x10-12 Torr; Single > 45AMU < 5x10-13 Torr	Sum > 45 AMU < 1x10-10 Torr; Single > 45AMU < 5x10-11 Torr	NA	NA
Leak test prior to opening of section valves?	Yes	Yes	Yes	Variance	NA (Permanently separated from other sections)
Nitrogen purge during vent?	Yes	Yes	Yes	Variance	No
Parts to be baked?	Yes	Yes	Variance	No	No
Cleaning process?	Standard alkaline/acid treatment. (eg: SST: nitric/HF acid; Al: NaOH/nitric)	Standard alkaline/acid treatment.	Standard alkaline/acid treatment.	Standard alkaline/acid treatment.	Surface 'rinse': Ultrasonic bath, 5 min acetone/5 min alcohol.
Free machining stainless (sulfur/selenium additives)	No	No	Variance	Variance	Ok
Alcohol clean / degrease OK?	No	No	No	Ok	Ok
Synthetic organic grease/lubricant in motion stages	No	No	**Variance***	Variance	Ok
"Internal" Elastomers (eg. Viton Gate-Seal Valves)	No	Variance	Variance	Ok	Ok
Anodized parts in vacuum	No	No	No	No	Ok
Approximate operating base pressure	10^-9 to 10^-11 Torr	10^-8 to 10^-10 Torr	10^-7 to 10^-9 Torr	10^-3 to 10^-8 Torr	10^-2 to 10^-5 Torr
Turbomolecular pumps and/or roughing pumps	No	No	Variance	Ok	Ok
Elastomer vacuum seal flanges	No	No	Variance	Ok	Ok
Direct water/organic fluid-vacuum joints?	No	No	No	No	Ok

*As of 2022/10, some precision in-vacuum mechanics for x-ray crystal diffraction instruments cannot reliably meet their mechanical requirements without use of synthetic organic greases or lubricants. Reluctantly, a variance for this use can be considered. If granted, bakeout should then be avoided, to prevent lubricant migration, depletion, and general deposition throughout the instrument. Best practices should subsequently be followed to prevent contamination of other vacuum sections or LCLS general service equipment, e.g., RGA Carts.