S04080600-SRD10000-R00

Second Target Station Project:

QIKR Motion Systems Requirements Document

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QIKR MOTION REQUIREMENTS DOCUMENT

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Revision	Description
00	Initial Release

ACRONYMS

BL4B	Beam Line 4B, the Liquids Reflectometer instrument at FTS
FTS	First Target Station
QIKR	Quite Intense Kinetic Reflectometer
QIKR-B	Lower QIKR Beam Path & Associated Components
QIKR-A	Upper QIKR Beam Path & Associated Components
STS	Second Target Station
OTS	Off-The-Shelf (refers to commercially available components)

CONTENTS

1. INTRODUCTION

The QIKR instrument is a reflectometer intended to primarily investigate liquid samples. Although solid samples may also be used, most samples will be liquids with a free surface that cannot be inclined relative to horizontal. To provide an incident angle for the neutron beam on these surfaces, the beam itself is inclined. QIKR has two separate neutron beam paths, QIKR-A and QIKR-B, that each operate as an independent beamline (see Figures 1 and 2). QIKR-A is angled upward from horizontal by 2.5° and QIKR-B is angled downward from horizontal by 2.5°. Additional incident angles are provided by the geometry of the guide end which splits the single neutron beam into two additional components that are further angled above and below the original 2.5° beam incline (see Figure 3). QIKR-A and QIKR-B share a maintenance shield, which actuates to either allow neutrons to pass (operating position) or to block the guide and allow safe access to the bunker when the proton beam is off (maintenance position). Each beam path has its own end station. The end station is located downstream of the guide end and is intended to position both the sample and detector and to select one of the three beam components exiting the guide. Each beam path has its own shutter and beam attenuation mechanism. The shutter blocks the beam from entering the cave when users are present, and the attenuator allows the user to reduce the beam intensity by various amounts when needed for a given experiment. The attenuator must be placed in the beam prior to the sample, and the shutter must be placed in the beam prior to the cave. The last motion component for each beam path is a sample changer that will be able to position multiple samples in the beam without requiring the user to enter the cave.

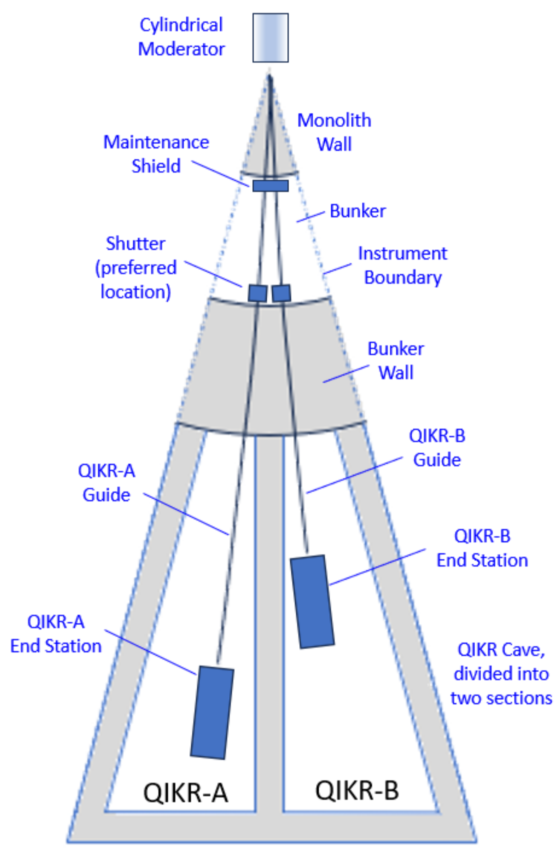

Figure 1: Top View of QIKR with space claims for motion components

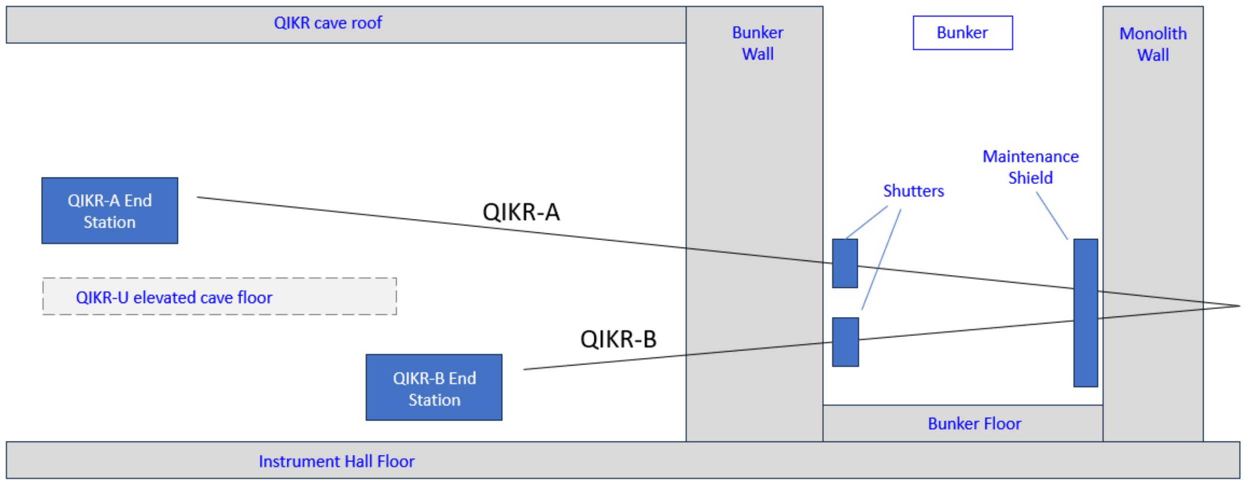

Figure 2: Side view of QIKR with space claims for motion components. The moderator face is located to the right; neutrons travel from right to left. The shutters are shown in their preferred location.

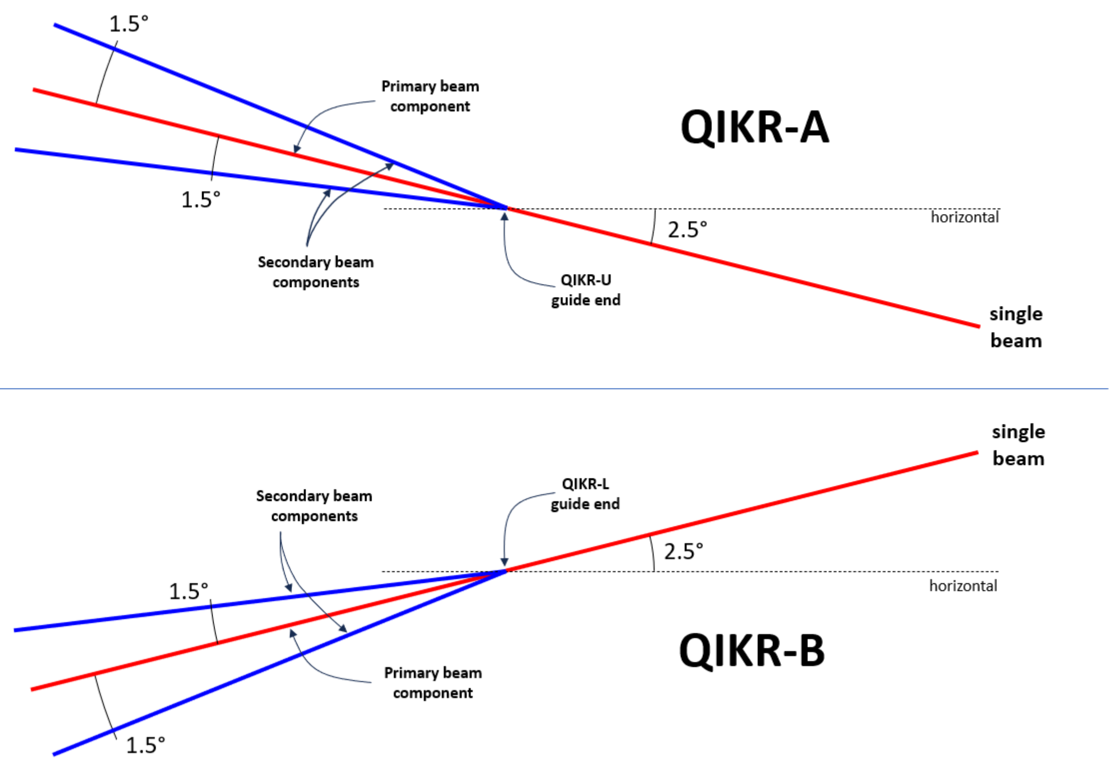

Figure 3: Each of QIKR's two beam paths are shown in red. QIKR-B is initially inclined downward from horizontal by 2.5° and QIKR-A is initially inclined upward from horizontal by 2.5°. At the end of the guides, the beams are split into three major components… the primary component (shown in red) continues along the original inclination, and the secondary components (shown in blue) angle up and down from the primary component by 1.5° starting at the guide end.

2. SCOPE

The scope includes design, fabrication, and installation of the QIKR motion components, including all documentation. Deliverables include the following:

- Functioning system which meets the requirements in this document.
- Detailed design and fabrication/assembly drawings
- Design Analysis and Calculations (DACs)
  - Static analysis of critical parts of the design structure
  - Modal and harmonic analysis of moving components where relevant
  - Calculation and sizing of motion components (motors, couplings, bearings, etc.)
  - Assembly tolerance stack-up analysis
- Failure Modes & Effects Analysis (FMEA)
- Electrical and Pneumatic Schematics for components (number of switches, motor wiring, etc.)
- Fabrication Inspection Report(s)
- Installation Plan
- Test Plan(s) and Test Report(s)
- Operations and Maintenance Manuals
- Critical Spare Parts List

3. SYSTEM CLASSIFICATIONS

Based on the completion of a Quality Checklist, the quality level of this system is Level 3 (Routine). This system is not configuration managed.

4. REFERENCES

Document Number	Document Title
S04010100-SR0001	Instrument Systems Requirements Document
S04080100-SRD10000	QIKR Requirements Document
S04080600-QAI10000	Quality Level Determination Checklist Form
S04030300-SRD10000	Standard Maintenance Shield Requirements Document
S04030300-SRD10002	Standard Light Shutter Requirements Document
S04030300-SRD10001	Standard Heavy Shutter Requirements Document
S04010000-TDO10000	STS Instrument Systems Seismic Design Guidelines
107030201-DCD10000	Motion Control System Base Requirements for NScD Neutron Instruments
S01020500-IST10118	Interface Sheet for Instrument Motion Systems and Integrated Control Systems Process Controls

5. HIGH LEVEL DESIGN GOALS & REQUIREMENTS

QIKR is the second generation version of the Liquids Reflectometer (BL4B) at the First Target Station (FTS). QIKR therefore has the advantage of being able to learn from what was done on BL4B and improve where needed. Several issues were seen on BL4B: 1) Complexity of motion components which made operation and maintenance difficult, 2) custom equipment that was expensive to purchase and difficult (or impossible) to replace when needed, 3) too small a fixed distance between the sample environment mounting surface and the sample location which made it difficult (or impossible) to use tall sample environments and still be able to rotate the sample about its center, and 4) too little space in the cave to comfortably fit auxiliary equipment for the sample environments. To address these issues, it is desirable to make the QIKR motion components as simple as possible and to utilize easily sourced off-the-shelf (OTS) components wherever possible. Using OTS components will minimize cost and make it easier to find replacement parts when needed. The components should additionally be designed with maintenance in mind… components that are likely to need maintenance (e.g. lubrication, cleaning, periodic replacement, etc.) should be easy to access and remove. Wherever possible, the number of motors needed to accomplish the end station functions should be minimized. This may be done (for example) by combining separate x,y,z axes that produce a rotation about a point into a single axis that performs the rotation directly. To maximize available space for users and auxiliary equipment, the footprint of the end station components should be kept as small as possible. To increase the number of sample environments (SE's) that can be used at QIKR, the distance between the SE mounting surface and the sample location should be greater than it was at BL4B. At BL4B, the sample environment was mounted onto a goniometer that provided support for and rotation of the sample about an axis at a fixed distance of 17cm from the goniometer surface. Smaller SE's could use thick mounting plates to place the samples at the rotation axis location, but taller SE's could not be accommodated if sample rotation was needed. For QIKR, a two-part solution is preferred: 1) provide for more than 17cm maximum distance from the sample environment mounting surface to the sample location, and 2) provide a mounting surface that can have a variable distance to the rotation axis.

All QIKR motion components should conform to the requirements specified in 107030201-DCD10000 and S01020500-IST10118 listed in the reference table unless discussed with and approved by Instrument Controls.

<u>End Station Details</u>:
The initial portion of the end station is called the incident table, the purpose of which is to select and condition one of three main beam components exiting the guide in 1.5° increments from each other (see Figure 3). The selection of the beam is accomplished via variable aperture slits that are mounted on the incident table. The conditioning of the beam is done by a frame overlap mirror located downstream of the first slit. The slits and frame overlap mirror themselves are outside the scope of this document, but their required motion <u>is</u> specified here. The second portion of the end station is called the sample table and its purpose is to support the sample environment and to allow remote positioning (linear and rotational) of the sample in the desired beam component. Liquid samples will not be rotated relative to the horizontal plane but may be rotated about the vertical Y axis (see Figures 4 and 5 for axis definitions). Solid samples may be rotated about the X or Y axes. All samples should be able to shift linearly in the X-, Y-, and Z-directions. The third and final portion of the end station is called the detector table. Its purpose is to support the detector, to allow for initial angular and linear positioning of the detector to align it with the sample location, and to allow for remote rotation of the detector about the sample position's X and Y axes. As mentioned above, space in the QIKR cave is limited, so the end station should have as small a footprint as possible to allow sufficient space for the users and auxiliary sample environment equipment. The end station is allowed to be placed below instrument hall floor level if needed. To the degree possible, it is desirable for the end station to easily accommodate future equipment upgrades… for

example, mount the components on a bread board (rather than on a plate with custom-machined holes) to allow for multiple component mounting options. Another example would be to use aluminum extrusion frames for table support (provided the frames are rigid enough) to allow easy resizing for future needs.

Shutter Details:
In the 'open' position, the shutter allows neutrons to travel along the guide to the sample location. In the 'closed' position, the shutter blocks the neutron beam to allow safe access for personnel into the cave. When in the 'closed' position, the shutter produces gamma and other photon radiation as a byproduct of absorbing the neutrons and therefore should be placed inside the bunker to make use of the shielding provided by the bunker wall. The shutter should be failsafe; meaning, if any failure in shutter operation occurs, it should automatically shift to the 'closed' position. QIKR is currently expected to use either the standard light or standard heavy maintenance shutter with customizations for both shutter thickness/length (as required by neutronics analysis) and shutter height (as required by the beam path height at each shutter location). Standard light shutter requirements are given in S04030300-SRD10002 and standard heavy shutter requirements given in S04030300-SRD10001.

Maintenance Shield Details:
QIKR is currently expected to use the standard maintenance shield with the exception of width, height and guide carrier changes that are needed to accommodate two guide paths instead of the standard single guide path. Motion components are expected to be the same as for the standard version. Standard maintenance shield requirements are given in S04030300-SRD10000.

Beam Attenuator Details:
The beam attenuator places a neutron scattering material in the beam path to reduce the amount of neutron flux arriving at the sample location. BL4B uses five polycarbonate plates of different thicknesses that can be shifted into the beam path to achieve different levels of attenuation. It is expected that QIKR will do something similar. The beam attenuator is placed in the beam path at some point prior to the sample location. The attenuator scatters neutrons and produces radiation that the detector sees as background noise; therefore, locating the attenuator in the bunker is preferred because the bunker wall would block much of the generated background noise.

Sample Handler Details:
BL4B initially used a robot arm and a sample storage box to stage samples and swap them sequentially into and out of the beam without needing manual intervention from the user. The robot arm operated well for several years but has now failed, and because it was custom-designed, it cannot be repaired or replaced within the available budget. BL4B is currently using a stack-up of commercial off-the-shelf (OTS) linear actuators to hold a plate containing multiple samples. The combined linear actuator positions the sample vertically and horizontally within the beam and has performed well so far at BL4B. QIKR may use a robot arm, a linear actuator stack, or another design as long as the chosen design is low-cost, easy to operate, and easy to maintain and/or replace when needed.

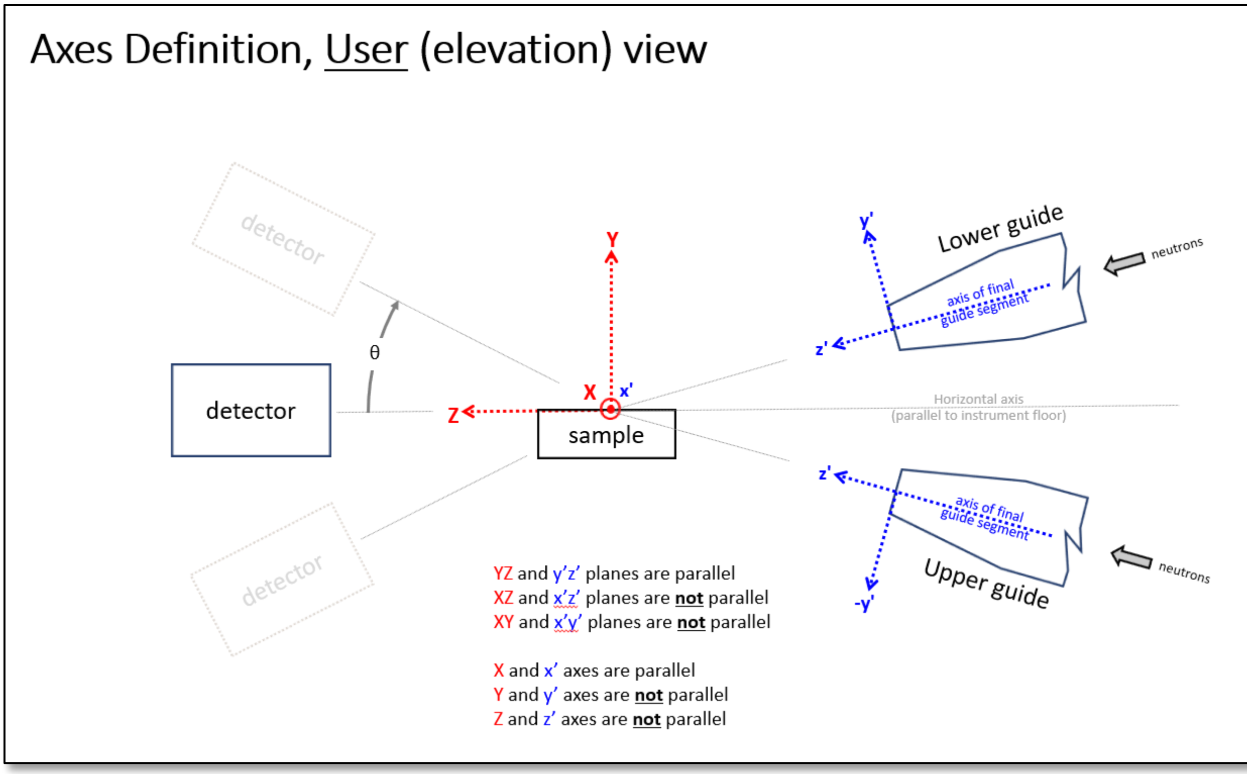

Figure 4: QIKR end station axis definitions with axes as seen from the user location (elevation view)

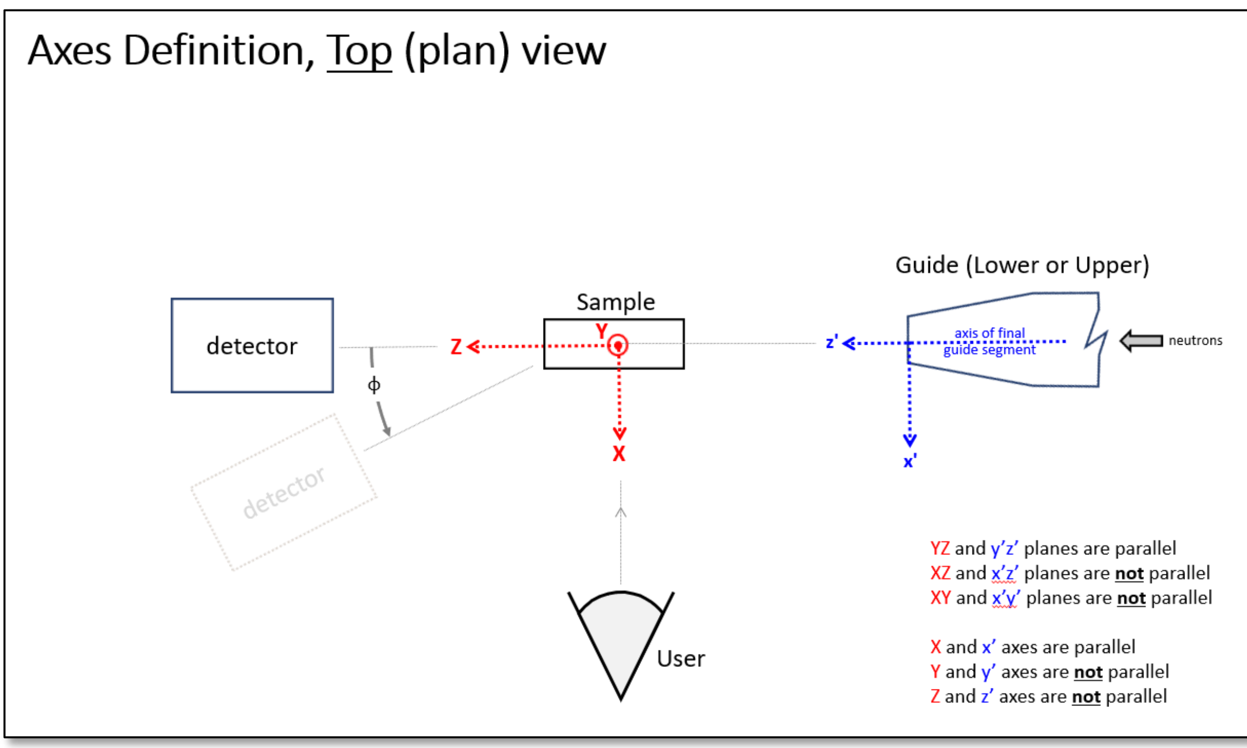

Figure 5: QIKR axis definitions with axes as seen from above the user (plan view)

Traceability of requirements in the following tables are to the Motion requirements (S.04.08.06) within the Level 3 *QIKR Requirements Document*, S04080100-SRD10000, unless otherwise noted.

Req. No.	Description	Value	Traceability (S.04.08.06)
General			
S.04.08.06-R100	End station assemblies in contact with the cave floor must be tied to the floor to prevent accidental shifting of assemblies after initial alignment.		R14
S.04.08.06-R101	End Station components weighing more than [w] or having a center of gravity greater than [c] must be secured against motion during a seismic event per S04010000-TDO10000.	181.4kg [400lbs] 1.2m [4ft]	S04010000-TDO10000
S.04.08.06-R102	End station assemblies and components must not be permanently located within the sample environment keep-out zone around the nominal sample position. *Note: Temporary positioning of components within the keep-out zone is allowed if they do not interfere with the desired sample environment in its installed position. Refer to S04080100-SRD1000 for keep-out zone dimensions.*		R15
Incident Table			
S.04.08.06-R103	Incident table must be placed between the guide end and the sample location.		R15
S.04.08.06-R104	Incident table must have a footprint in the X-dir of ≤ [d1] mm.	≤765mm	R16
S.04.08.06-R105	Incident table must support [w1] in addition to its own weight.	≥90.7kg [≥200lbs]	R12
S.04.08.06-R106	Incident table must accommodate optical components in this upstream-to-downstream order: 1st slit, frame overlap mirror, 2nd slit, 3rd slit.		R1, R2

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R107	The first slit must be located within [s1] mm of the guide end along the z' direction. *Note: Closer spacing is preferrable, z' motion is not required to be motorized.*	≤120mm	R1
S.04.08.06-R108	The second slit must be located within [s2] mm of the downstream end of the frame overlap mirror along the z' direction. *Note: Closer spacing is preferrable, z' motion is not required to be motorized.*	≤50mm	R1
S.04.08.06-R109	The first and second slits must have remotely adjustable vertical openings to within a range, accuracy, and resolution of: *Note: Negative numbers indicate amount of slit blade overlap.*	Min: -5mm Max: ≥40mm Accuracy: ±.01mm Resolution: ±.001mm	R1
S.04.08.06-R110	The third slit must be movable along the z' direction to within a range and resolution of: *Note: min/max range values are given as distances from the nominal sample location.*	Min: ≤10mm Max: ≥500mm Resolution: ±.5mm	R2, R15
S.04.08.06-R111	The third slit must have a remotely adjustable vertical opening to within a range, accuracy, and resolution of: *Note: Negative numbers indicate amount of slit blade overlap.*	Min: -5mm Max: ≥20mm Accuracy: ±.01mm Resolution: ±.001mm	R2
S.04.08.06-R112	Each slit must have remotely adjustable horizontal openings to within a range, accuracy, and resolution of: *Note: Negative numbers indicate amount of slit blade overlap.*	Min: -5mm Max: ≥20mm Accuracy: ±.01mm Resolution: ±.001mm	R1, R2
S.04.08.06-R113	Each slit must have a gap that can be centered on the nominal z' axis (through the guide end center) to within:	Vertical: ±.01mm Horizontal: ±.1mm	R1, R2

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R114	The incident table must remotely and collectively rotate all slits and the frame overlap mirror about an x axis drawn through the center of the guide glass end to within a range and resolution of: *Note: angle measured from horizontal*	Min: -5° Max: +5° Resolution: ±0.0005°	R3
Sample Table			
S.04.08.06-R115	The sample table must place the sample [d2] m from the end of the guide in the z' direction.	2m ±5mm	S.04.08.01-R26
S.04.08.06-R116	The sample table must have a footprint in X of [d3] mm.	≤765mm	R16
S.04.08.06-R117	The sample table must be able to support at least [w2] kg in addition to its own weight. *Note: Sample environments are expected to weigh under 500lbs.*	≥455kg [≥1000lbs]	R12
S.04.08.06-R118	The sample table must provide coarse positioning of the sample to one of three nominal Y locations to within [r1] mm. The Y locations correspond to the height of the three beam components of interest at the nominal sample z' distance from the guide end.	±.1mm	R5
S.04.08.06-R119	The sample table must provide fine positioning of the sample about each nominal location in the Y-dir to within a range and resolution of:	Range: ±25mm, Resolution: ±.01mm	R5
S.04.08.06-R120	The sample table must provide remote sample position adjustment in the X-dir about the nominal beam X-dir center to within a range and resolution of:	Range: ±5mm Resolution: ±.1mm	R4
S.04.08.06-R121	The sample table must provide remote sample position adjustment in the Z-dir about the nominal beam Z-dir center to within a range and resolution of:	Range: ±5mm Resolution: ±.1mm	R4

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R122	The sample table must accommodate sample environments with a mounting surface [h1] mm below the nominal sample position.	≤350mm	R5
S.04.08.06-R123	The sample table must be able to angle the sample ≥[a1] degrees about the X axis with a resolution of [r2] degrees.	Angle: ≥ |2°| Resolution: ±.002°	R6
S.04.08.06-R124	The sample table must be able to angle the sample ≥[a1] degrees about the Z axis with a resolution of [r3] degrees.	Angle: ≥ |5°| Resolution: ±.2°	R6
Detector Table			
S.04.08.06-R125	The detector table must place the center of the detector sensing surface at a fixed radial distance [d4] m from the nominal sample location.	2m ±1mm	S.04.08.01-R27
S.04.08.06-R126	The detector table must have a footprint in X of [d5] mm.	≤765mm	R16
S.04.08.06-R127	The detector table must be able to support at least [w3] kg in addition to its own weight.	≥227kg [≥500lbs]	R12
S.04.08.06-R128	The detector table must provide means to manually adjust the detector sensor surface angle to be perpendicular to a radial line drawn from the sample position to within [a2] degrees.	≤2°	R13
S.04.08.06-R129	The detector table must provide means to manually adjust the detector sensor center to within [d6] of its nominal position from the nominal sample location.	±5mm	R13
S.04.08.06-R130	The detector table must provide [a3] degrees of remote rotation about the X-axis with motion resolution of [r4] degrees. *Note: Angle measured from horizontal. This angle range provides at least ±15° of rotation about the QIKR-A and QIKR-B beam inclinations of 2.5° and -2.5° respectively.*	Angle: ±17.5° Resolution: ±.002°	R7

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R131	The detector table must provide [a4] degrees of remote rotation toward the user about the Y-axis with motion resolution of [r5] degrees.	Angle: $\geq$15° Resolution: $\pm$.002°	R8
S.04.08.06-R132	The detector table must allow installation of additional optics components in the space between the nominal detector and sample locations. *Note: It is expected that there will be a slit and a radiation shield in this space.*		R12
Attenuator			
S.04.08.06-R133	The attenuator must provide a means of remotely selecting between [n1] levels of attenuation plus an open position with no attenuation.	5	R17
S.04.08.06-R134	The attenuator material must move completely out of the beam when no attenuation is required, and completely cover the full beam cross-section otherwise. No particular motion range or accuracy is required beyond that.		R17
S.04.08.06-R135	The attenuator must provide confirmation it has arrived at its desired position.		R17
S.04.08.06-R136	Attenuator motion components must be designed to work in the radiation environment of the attenuator's chosen location. *Note: This may mean local shielding is required around the attenuator components. The radiation environment is determined by neutronic analysis.*		R17
Sample Changer			
S.04.08.06-R137	The sample changer must remotely move at least [n2] samples into and out of the beam.	12	R11

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R138	The sample changer must position each sample in the beam to within [r6] mm of the nominal position.	$\pm$1mm	R11
S.04.08.06-R139	The sample changer must provide confirmation that the sample has moved into position. *Note: Motor encoders are sufficient for this purpose*		R11
Shutter			
S.04.08.06-R140	The shutter must follow standard shutter design for general function and safety (see the shutter requirements documents listed in the reference table). Geometry may deviate as needed to accommodate the needs of each beamline at the chosen shutter location.		R10
S.04.08.06-R141	The shutter must accommodate the z' direction thickness of beam stop material specified by neutronics analysis		R10
Maintenance Shield			
S.04.08.06-R142	The maintenance shield must follow standard shield design for general function and safety (see the maintenance shield requirement document listed in the reference table) with one exception: the neutron absorber may be omitted.		R9
S.04.08.06-R143	The maintenance shield must provide the ability to manually align two guide segments within the shield.		R9
Frame Overlap Mirror			
S.04.08.06-R144	The frame overlap mirror mounting features must support [w4] kg.	30 kg [66 lbs]	R18
S.04.08.06-R145	The frame overlap mirror must allow manual vertical adjustment in the y' direction within a range and resolution of:	Min: $\leq$ 1.25cm Max: $\geq$ 1.25cm Resolution: $\leq$.05mm	R18

Req. No.	Description	Value	Traceability (S.04.08.06)
S.04.08.06-R146	The frame overlap mirror must allow manual horizontal adjustment in the x' direction within a range and resolution of: *Note: There is no need for special z' direction adjustment ranges or resolutions*	Min: ≤ 1.25cm Max: ≥ 1.25cm Resolution: ≤ .05mm	R18
S.04.08.06-R147	The frame overlap mirror must allow a manual angular adjustment about the z' axis within a range of [d7] and resolution of [r8]. *Note: Only coarse adjustment is needed here*	Min: ≤ -2° Max: ≥ 2° Resolution: ≤ 0.1°	R18
S.04.08.06-R148	The frame overlap mirror must allow motorized angular adjustment about the x' axis within a range, accuracy and resolution of: *Note: Angle measured from the z' axis. This is the mirror's most critical adjustment, followed by coarse adjustments about the z' axis. There is no need for finer positioning about the y'-axis beyond what normal machining tolerances of the mirror support components will provide.*	Min: ≤ 5° Max: ≥ 5° Accuracy: ≥.005° Resolution: ≤ 0.001°	R18