Common Mechanical Requirements for BTA Quadrupole Magnets

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A		BTA Release for Procurement Support

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ALS-U BTA Quadrupole Magnet Scope

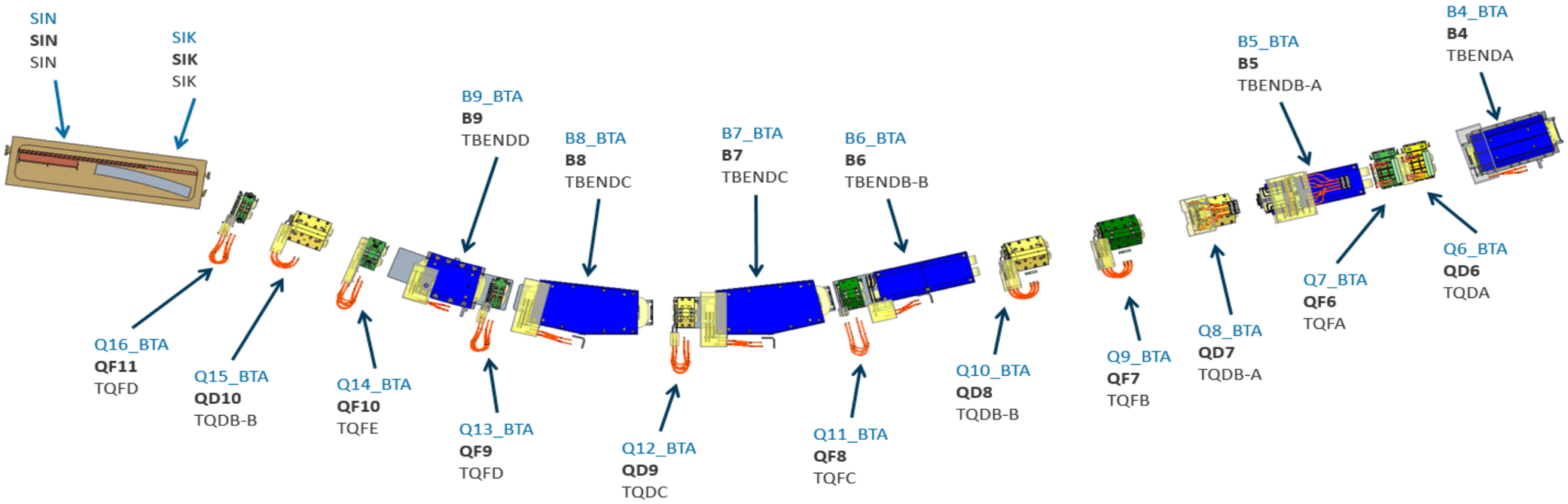
Number	Description
Scope 001	This document covers the common mechanical requirements associated with the quadrupole magnets specified for the Booster to Accumulator Ring (BTA)Transfer Line.
Scope 002	Magnet naming conventions, nomenclature, has been developed to appropriately describe each magnet assembly in the transfer line using the physics, controls and CAD identifications to convey necessary function to appropriate
Scope 003	The BTA transfer line will utilize six dipole magnets defined by five unique mechanical configurations.
Scope 004	The BTA transfer line will utilize eleven quadrupoles magnets defined by nine unique mechanical configurations.
Scope 005	General mechanical requirements cover common specifications pertaining to the accelerator environment, various interfaces, materials, design principals, and maintenance.
Scope 006	Coil mechanical requirements cover common specifications pertaining to the general interfaces, conductor and insulation materials, design, structural supports, and the interpretation of the reference design.
Scope 007	Bus Leads mechanical requirements cover common specifications pertaining to the electromechanical interfaces, interface maintenance, interconnections, design principals, mechanical joint brazing requirements, lead identification, fasteners and structural support.
Scope 008	Electrical safety mechanical requirements cover common specifications pertaining to grounding, electrical standards on components, insulation, standoff cover requirements for terminal blocks, and maintenance access.
Scope 009	Enclosure mechanical requirements cover common specifications pertaining to insulation, standoff cover requirements, and maintenance access.
Scope 010	Cooling mechanical requirements cover common specifications pertaining to the magnet cooling system's hydraulic requirements, design, interfaces, hoses, manifolds, fittings, thermal switches, and maintenance access.
Scope 011	Assembly level requirements cover common specifications pertaining to the magnets basic functionality such as splitting, mechanical reproducibility and assembly precision during rebuild, the frequency of fundamental vibrational modes, magnet mass, seismic, and maintenance access requirements.
Scope 012	Yoke level requirements cover common specifications pertaining to mechanical poles, materials, assembly splitting in the midline, mating interfaces, fasteners, main, and intermediate lift point interfaces, supports, and support interfaces, and maintenance access requirements.
Scope 013	Alignment requirements cover common specifications pertaining to fiducial references, spherical mount reflectometer (SMR) nests, midplane assembly splitting, maintenance, and alignment pins.
Scope 014	Hardware requirements cover common specifications pertaining to mechanical standards, counterfeit materials, threads, thread lubricants, tapped holes, and fasteners.
Scope 015	Lifting requirements cover common specifications pertaining to rigging standards, safety, maintenance access, and shipping.
Scope 016	Documentation requirements cover common specifications pertaining to paper and electronic documentation, solid models, drawings, procedures, the basis of design, component fabrication, materials certifications, commercial off the self (COTS) parts, and nonconformance procedures.
Scope 017	Marking requirements cover common specifications pertaining to general labeling, coil identification, main magnet circuit identification, corrector and/or trim circuit identification, water manifolds, hoses, terminal blocks, yokes, and poles, serialization, and steel surface anticorrosion treatment.

(end section)

26-Feb-21
Reference AL-1346-1757: ALS-U Magnet Nomenclature for latest revisions.

BTA 3/3
BTA Magnets

Ref ASSY: AL-1425-6563



XXX = AP lattice nomenclature
YYY = Controls nomenclature
ZZZ = CAD nomenclature

ALS-U BTA Quadrupole Magnet Generic Design Requirements

Number	Type	Description	Value Reference
General 001	**Shall**	Specifications: Unless otherwise specified, information in drawings and specifications are to be interpreted as "SHALL" requirements. Information in "REFERENCE DESIGN" CAD models are to be interpreted as "SHOULD" or "MAY". Information in "INTERFACE CONTEXT" CAD models are to be interpreted as "WILL".	N/A
General 002	**Shall**	Specifications: The drawings package includes some components defined by "space claim" volumes. For these components, the vendor has significant freedom in completing the design. While LBNL is providing a solid model "Reference Design" for these components as a guide, the vendor has the freedom to alter those designs provided they remain entirely within the specified volumes, meet the requirements listed in specifications and in the drawing notes, and meet the non reference dimensions controlled by the drawing.	N/A
General 003	**Shall**	Specifications: The drawings package includes some components defined with specific dimensions. These dimensions are shown at the assembly or interface level. For these components, the vendor shall adhere to the dimensions and design intent of the interface drawings, while filling in the detailed piece-part level design, and ensuring that the magnet meets requirements, standard practices, and is fit for service.	N/A
General 004	**Shall**	Specifications: Where a the vendor uses all or part of the LBNL provided design, it is still the vendors responsibility to ensure that those components meet all requirements, standard practice, and are fit for service. This holds for components defined by both "space claim" volumes AND components defined by specific dimensions. The reference design provided by LBNL is not approved for fabrication, and has not been through the full rigor of a final design review.	N/A
General 005	**Shall**	Accelerator Environment: The intended operating life for the magnet assembly is 7500 hours a year for 25 years.	N/A
General 006	*Should*	Accelerator Environment: The magnet assembly will be operated in a high radiation environment (X-Rays), and radiation resistant materials and components should be used wherever not cost prohibitive.	N/A
General 007	**Shall**	Accelerator Environment: Polymeric based materials or others material types susceptible to radiation degradation, shall not cross the midplane of the magnet. This includes, but is not limited to electrical insulation, water hoses, terminal block housings, etc. *Exception: Insulation contained within an electrical safety enclosure.* *Exception: QTY 2x corrector coil bus jumpers which must cross the midplane for circuit continuity.* *Other exceptions may be granted based on specific approval from LBNL.*	N/A
General 008	*Should*	Accelerator Environment: Polymeric based materials or others material types susceptible to radiation degradation, should not cross the midplane of the Accumulator Ring. The Accumulator Ring is nearby interfacing equipment shown in the "interface context models".	N/A
General 009	*Should*	Accelerator Environment: Polymeric based materials or others material types susceptible to radiation degradation, should ideally remain this far above or below both magnet midplane and the Accumulator Ring midplane.	50mm
General 010	**Shall**	Accelerator Environment: Hydrocarbon containing lubricants or other high vapor pressure volatiles shall not be used without explicit approval of LBNL, due to the proximity of ultra high vacuum equipment.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements

General 011	**Shall**	Accelerator Environment: During vacuum baking operations, magnet will see increased temperature due to heating of adjacent equipment. Magnet must be designed to withstand this temperature without degradation or disruption of alignment. During vacuum baking, magnet can assumed to be unenergized, and with the normal operation flow of cooling water flowing through coils.	50 C at pole tips, temperature of rest of assembly to be based on estimated conduction from pole tips and convection to ambient
General 012	*Should*	Materials: Preferred metallic materials for non-fastener components include austenitic stainless steels, mild steels, C101 copper, and aluminum 6061-T6.	N/A
General 013	*Should*	Materials: Preferred nonmetallic materials for nonfastener components include G10, FR4 and polycarbonate.	N/A
General 014	**Shall**	Materials: Vendor shall place appropriate magnetic permeability limitations on materials in order to facilitate achieving the magnet field requirements.	N/A
General 015	May	Design Principles: Use of standard imperial dimensions for the size of geometric features are allowed, provided other requirements to use metric units are followed. For instance, a stock plate thickness of 0.25 inches can be used, provided it is dimensioned in metric.	N/A
General 016	*Should*	Design Principles: Features, parts, hardware, and fittings should be standardized as much as reasonably possible among different components, subassemblies, and magnet families	N/A
General 017	*Should*	Design Principles: Vendor should make a best effort to minimize magnet equipment obscuring visible line of sight to SMRs fiducials nests.	N/A
General 018	*Should*	Design Principles: Individual components should be designed in such a way that they avoid crossing over the midplane of the magnet as much as possible, in order to facilitate splitting magnets into upper and lower halves. If components must cross the midplane of the magnet, they should by mounted in such a way that they can easily be removed and reinstalled, even within limited space.	N/A
General 019	**Shall**	Design Principles: Minimum chamfer size on sharp edges within 30mm of electrical insulation, to avoid accidental damage of insulation.	3 mm
General 020	**Shall**	Design Principles: Sharp edges, corners, and other cut or bump hazards shall be avoided where possible, or be broken with chamfers or rounding for the safety of personnel who will need to work in the confined space environment of the magnet in the accelerator tunnel.	N/A
General 021	**Shall**	Maintenance: If custom tooling is required for alignment, assembly, coil replacement, lifting, or other maintenance operations foreseeable over the course of the operational life, vendor shall provide LBNL with that tooling, along with solids models, drawings, and instructions for use.	N/A
General 022	**Shall**	Maintenance: Vendor shall supply production spares for the following components: hoses, thermal flow switches, alignment pins, terminal blocks, any nonstandard or specially coated hardware. For these items, the quantity of spares shall be the greater of: 1x of each type/size, or 20% overage across all magnet assemblies.	N/A
General 023	**Shall**	Maintenance: Vendor shall supply production spares for the following materials: JIC fitting crush gaskets, thermosetting bus insulating tape, approved lubricants, and electrical contact aid (if used). For these items, the quantity or spares shall be equal to the quantity used in the magnet assemblies.	N/A
General 024	**Shall**	Maintenance: Vendor shall supply 1x extra coil for each quadrupole. On this extra coil, bus leads shall be left unbent, and with length equal to the longest bus lead on the magnet. Labels which would depend on the placement of the extra coil, e.g., field direction arrows, shall be left blank	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements

General 025	*Should*	Maintenance: Vendor should supply spares for any other difficult to purchase items which may conceivably need replacement over the lifetime of the magnet.	N/A
General 026	*Should*	Maintenance Access: Vendor should make a best effort to maintain general accessibility to components within the context of the nearby equipment in the accelerator tunnel, by reviewing the "Interface Context Models" throughout the design phase. Specific components that shall have maintenance access are called out in the relevant sections.	N/A
General 027	**Shall**	Maintenance Access: Vendor shall make a best effort to not obstruct access to vacuum equipment which is near to, and transits through the bore, of the magnet to allow for flange assembly, leak checking, vacuum support adjustment, etc. This includes minimimizing protrusion of equipment (e.g. bus leads, enclosures, coil supports, etc.) into the axial space between magnets, as well as being cognizant of pumps, vacuum supports, and other equipment which will be near the magnets when they are installed in the accelerator tunnel. See the "Interface Context Models".	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Coils

Number	Type	Description	Value Reference
Coils 001	**Shall**	Interface: Coil and coil supports shall fit entirely within the "spaceclaim" volumes defined by the drawings.	See master spec list for drawing number
Coils 002	**Shall**	Interface: The electrical bus lead shall egress from the coil in a place that is consistent with the "spaceclaims" defined by the drawings. Note that the main coil bus egress and the corrector coil bus egress are on opposite sides of the coil.	See master spec list for drawing number
Coils 003	*Should*	Interface: Coil size should made as small as reasonable while achieving other requirements, due to limited space between magnet assemblies once installed in the tunnel.	N/A
Coils 004	**Shall**	Design: Vendor shall design an appropriate coil winding pattern, conductor size, insulation build up, resin type, and potting process compatible with other magnetic, electrical, and hydraulic requirements. Stated below are the LBNL reference values which were used for concept development.	N/A
Coils 005	**Shall**	Design: In addition to the main coil circuit, each Quadrupole shall include a horizontal field corrector circuit and a vertical field corrector circuit, per the electrical and magnetic requirements.	N/A
Coils 006	**Shall**	Design: Vendor shall choose coil winding helicity. Winding helicity shall be standardized, and consistent with other requirements.	N/A
Coils 007	**Shall**	Design: Corrector coil windings shall be cooled via internal conduction to the main coil windings. The placement, design, and insulation thickness of the corrector circuits shall maintain their temperature below the maximum allowed coil casting temperature (as stated in the cooling requirements section).	N/A
Coils 008	**Shall**	Design: Coil conductor shall be of the following material, for good conductivity, and especially for compatibility with deionized water systems.	CDA C101
Coils 009	*Should*	Design: Preferred copper hardness	1/4 Hard
Coils 010	**Shall**	Design: Coils shall be free of resin rich areas, resin poor areas, and voids. Internal volumes of coils not occupied by conductors shall be filled with G10 spacers or epoxy filled glass roving.	N/A
Coils 011	**Shall**	Design: Minimum insulation voltage hi-pot	2X Max Operating Voltage + 1000V
Coils 012	**Shall**	Design: Minimum insulation resistance via megger	2 Gohm
Coils 013	**Shall**	Coil Supports: Coil shall be securely clamped in place by appropriate supports. These supports shall provide a preload force which seats the coil against the yoke. Support shall resist magnetic forces, gravity forces, motion due to changing magnetic fields, misalignment during transport.	N/A
Coils 014	*Should*	Coil Supports: G10 shims should be used between coils and surfaces they seat against, to protect the coil surfaces, and to provide capability for fine adjustment of coil position. G10 is selected for known resistance to synchrotron radiation, mechanical stability/creep resistance, and insulating characteristics	N/A
Coils 015	**Shall**	Coil Supports: Coil supports and shims shall be designed in such a way that the removal and replacement of a coil is repeatably located, and that the coil is protected from any point loads or undue stress.	Coil positioning repeatability: 0.5 mm
Coils 016	**Shall**	Coil Supports: Coil supports shall be made of hard tempered aluminum and/or G10 due to avoid undesirable magnetic effects proximate to the good field region	N/A
Coils 017	*Should*	Reference coil design: Build type	VPI
Coils 018	*Should*	Reference coil design: Potting compound	DGEBA epoxy

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Coils

Coils 019	*Should*	Reference coil design: Main circuit, turn insulation, 1st layer, material	Mylar tape
Coils 020	*Should*	Reference coil design: Main circuit, turn insulation, 1st layer, wraps	1x layer, half lapped total thickness 0.1mm
Coils 021	*Should*	Reference coil design: Main circuit, turn insulation, 2nd layer, material	E-Glass or S-Glass tape
Coils 022	*Should*	Reference coil design: Main circuit, turn insulation, 2nd layer, wraps	2x layers, half lapped total thickness 0.4mm
Coils 023	*Should*	Reference coil design: Main circuit, layer to layer insulation, material	Omitted in point design. May be included per vendor discretion
Coils 024	*Should*	Reference coil design: Each corrector circuit, insulation type	coated magnet wire, polyester-polyimide
Coils 025	*Should*	Reference coil design: Each corrector circuit, insulation thickness	heavy build, minimum NEMA class 200
Coils 026	*Should*	Reference coil design: Ground wrap:	total thickness 1mm

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Bus, Leads, and Jumpers

Number	Type	Description	Value Reference
Bus 001	**Shall**	Interface: The bus leads shall fit entirely within their "spaceclaim" volume as defined by the drawings. Note that there are separate spaceclaims for main coil bus leads and corrector coil bus leads, which shall be located on opposite sides of the coil.	See master spec list for drawing number
Bus 002	**Shall**	Interface: Terminal blocks shall be provided with sufficient terminals for thermal flow switches and corrector coil bus jumpers, per the electrical schematic.	See master spec list for drawing number
Bus 003	**Shall**	Interface, Maintenance: Terminal blocks shall fit entirely within their "spaceclaim" volume as defined by the drawings. Note that separate terminal blocks shall be provided for the upper and lower magnet halves.	See master spec list for drawing number
Bus 004	**Shall**	Interface: Appropriate bus jumpers for the corrector coils shall be provided, as indicated in the electrical schematic, with the same insulation scheme as for the corrector coil bus themselves.	See master spec list for drawing number
Bus 005	**Shall**	Interface: Bus leads flags must be sized to accept the main power electrical lug stated in the electrical design requirements section.	N/A
Bus 006	**Shall**	Design: Air cooled bus jumpers (for the main coil circuit) shall be sized for the following temperature rise. This sizing shall make consideration for restricted airflow within the electrical safety enclosure, electrical contact resistance, and spreading resistance. Bus jumper cooling may take credit for conduction from nearby water flow. Sizing may be done per code, calculation, or test.	30 C temperature rise over a 40 C ambient
Bus 007	*Should*	Design: The following is a reference ampacity of bus bars routed through enclosures. Vendor may use other ampacities as justified by code or calculation.	1000 Amps / in^2
Bus 008	**Shall**	Design: Bus routing for both main circuit and corrector circuits shall follow the electrical schematic. See drawing:	See master spec list for drawing number
Bus 009	**Shall**	Design: The reference CAD design shows the electrical bus routing standardized across magnet variants such that for Focusing Quadrupoles, the upper lug is "-" and the lower lug is "+", and vice-versa for De-Focusing Quadrupoles. Vendor may flip this convention, if necessary for winding helicity, but it must remain standardized and otherwise follow the electrical schematic.	N/A
Bus 010	*Should*	Design: It is preferred that water cooled bus lead water fittings are brazed onto the copper conductor, to ensure a leak tight seal. Fittings are described in the cooling requirements section.	N/A
Bus 011	*Should*	Design: Vendor should follow the electrical schematic for the terminal blocks wiring (jumpers and bus power location). However, an electrically equivalent routing using different physical terminals for connections is also acceptable. The electrical schematic is located on the magnet top level assembly drawing.	See master spec list for drawing number
Bus 012	**Shall**	Flags: Bus lead and electrical flag contact design should follow an appropriate industry practice regarding size, contact area, clamping force, fastener torque, fastener size, surface finish, flatness, hardness, bus flag thickness, and other practical design factors.	CDA Publication 22 or other recognized standard practice
Bus 013	**Shall**	Flags: Braze joints between copper bus and lead flags shall be designed appropriately to achieve the temperature requirements listed above.	N/A
Bus 014	**Shall**	Flags: Vendor shall determine where an appropriate plating or contact aid between electrical contact surfaces, and incorporate into the design as appropriate. Use of high vapor pressure or non-UHV compatible materials requires LBNL approval.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Bus, Leads, and Jumpers

Bus 015	**Shall**	Fasteners: Electrical contacts for bus flags, power cable lugs, and bus jumpers shall be designed with through holes. Bolts for electrical contacts shall be fastened with a nut with washer, or nut plate. Copper surfaces must be protected from bearing of the nut or bolt head with a hardened flat washer. Washers and nut plates shall be large enough to promote even clamping force.	N/A
Bus 016	**Shall**	Fasteners connecting electrical contacts for bus flags, power cable lugs, and bus jumpers shall be 316 stainless steel.	N/A
Bus 017	**Shall**	Fasteners connecting electrical contacts for bus flags, power cable lugs, and bus jumpers shall include belleville washer(s). Belleville washers shall be sized such that the required joint clamping force is achieved before the bellevile washer is flat, to allow residual travel to compensate for thermal expansion without loss of preload.	N/A
Bus 018	**Shall**	Routing: Bus lead routing should follow best practice to minimize field errors, and aid in achieving the magnet field requirements specified elsewhere. This includes maintaining reasonable distances between the leads and the good field region and routing "+" and "-" leads adjacent to each other.	N/A
Bus 019	**Shall**	Routing: Water cooled bus routing shall minimize the number and sharpness of bends as much as reasonable, to reduce coolant turbulence. Minimum allowed bend radius is twice the conductor OD (side length for square conductors).	N/A
Bus 020	**Shall**	Routing: The position of the main electrical power cable interface points in the reference design have been selected to allow the large diameter cables to route over the edge of the welded structures to which the magnets are mounted ("rafts") without tight bend radii. This feature must be maintained. See "Interface Context Models".	N/A
Bus 021	**Shall**	Routing, Maintenance: Routing of bus leads shall facilitate splitting the magnet assembly into upper and lower halves. Bus leads on the lower magnet half must not interfere with removing the upper magnet half by hoisting it vertically. Bus leads which cross the midplane must be disconnectable. The amount of bus which crosses the midplane shall be minimized.	N/A
Bus 022	**Shall**	Routing, Maintenance: Corrector coil jumpers (power side of terminal block) shall be routed or bundled in a way that protects them from inadvertent bumps or snags, e.g., in fireproof polymer split loom, or similar.	N/A
Bus 023	**Shall**	Support: Water cooled bus leads shall have bracketry providing mechanical fixation to the yoke, near the point of bus egress from the coil. These supports shall protect the point of egress from any stresses due to motion of the bus leads	N/A
Bus 024	**Shall**	Support: Water cooled bus leads shall have bracketry providing mechanical fixation to the yoke, near the water fittings which join to coolant hoses. These supports shall protect the bus leads from any stresses due to hose motion or tightening of fittings.	N/A
Bus 025	*Should*	Support: Water cooled bus lead support brackets near water fittings should grasp the fitting, and not the bus lead.	N/A
Bus 026	**Shall**	Support: Water cooled bus leads shall have bracketry which support the weight of the main circuit power cable, to prevent gravity induced creep. These brackets may be designed to grab the cable itself or the bus lead.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Bus, Leads, and Jumpers

Bus 027	**Shall**	Support: Corrector coil bus leads shall have support brackets or secure ties fastening them to yoke. Ties shall be made of either metal or radiation resistant polymer materials. Leads should have at minimum two mechanical support points. The first shall be near the egress from the coil, to prevent any stress on the fragile egress point. The second shall be near the terminal block, to prevent any motion or bumps of the lead from loosening the terminal connection. Additional intermediate supports may be added as appropriate.	N/A
Bus 028	**Shall**	Support: Corrector coil jumpers shall be secured to either the yoke or the terminal block support bracket, e.g., by ties made of metal or radiation resistant polymer, or similar fixation. A fixation point shall also be provided for the power cables energizing the terminal blocks.	N/A
Bus 029	**Shall**	Support: All bus lead support shall grasp the lead firmly to prevent any relative motion or wiggling, for instance, by wrapping the lead with glass cloth shim to ensure a tight fit up, or other method.	N/A
Bus 030	**Shall**	Maintenace Access: Terminal blocks should be positioned and oriented to maintain access as best as reasonably achievable. The routing of wires, corrector coil bus leads, and corrector coil bus jumpers to terminal blocks shall be done in such a way that they may be easily removed and replaced in the context of crowded accelerator tunnel. See "Interface Context Models" for references.	N/A
Bus 031	**Shall**	Maintenace Access: The design of bus leads, bus bars, and other components inside of the electrical enclosure shall allow sufficient access for wrenches, removal of power cables, and disassembly of bus bars, with a minimal removal of the electrical enclosure. This disassembly must be possible within the crowded context of nearby equipment in the accelerator tunnel - see "Interface Context Models"	N/A

(end section)

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ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Safety

Number	Type	Description	Value Reference
Elec Saf. 001	**Shall**	Grounding: All metal components not intentionally designed to be electrically energized shall have a path to ground	N/A
Elec Saf. 002	*Should*	Grounding: A single ground point for the entire assembly is preferred, e.g., on the base plate, with all grounded components electrically connected. Preferred ground point location is shown on the "Magnet Assembly" drawing.	See master spec list for drawing number
Elec Saf. 003	**Shall**	Grounding: Ground wire size	#2, AWG
Elec Saf. 004	**Shall**	Grounding: Ground point lug interface must be compatible with both of these lug parts, by including an appropriate tapped hole and either a spot face or an area free of paint/anticorrosive.	Vendor: Blackburn Parts: CTL1-14 and CTL2-14
Elec Saf. 005	**Shall**	Standards: All current carrying conductors, electrical junctions, and energized surfaces shall EITHER be insulated according to an appropriate nationally recognized standard, OR have exposed surfaces contained within an electrical safety enclosure . This includes, for instance, water fittings and thermal flow switches at the same potential as electrical bus.	N/A
Elec Saf. 006	**Shall**	Standards: Electrical safety enclosures shall protect workers from electrical hazards, according to the following standards, and be "finger safe", including at the areas where conductors, cables, or hoses cross its boundary.	IEC 60529 IP2X Finger
Elec Saf. 007	**Shall**	Standards: COTS Electrical components must be ROHS compliant.	N/A
Elec Saf. 008	**Shall**	Standards: COTS electrical components must either be UL listed, or meet an equivalent safety standard, and be appropriately rated for their service ampacity.	N/A
Elec Saf. 009	**Shall**	Insulation: Bus leads, where not otherwise contained within an isolation enclosure, shall be insulated with half lapped glass cloth tape, which has a pressure sensitive thermosetting rubber adhesive. This includes main coil water cooled bus as well as corrector coil air cooled bus and jumpers. The preferred brand, listed here, shall be used unless otherwise approved.	3m Tape 27, 7 mils thick
Elec Saf. 010	*Should*	Insulation: Preferred insulation material for miscellaneous wires, e.g., thermal flow switches, etc. Bus lead insulation is stated above.	NEMA Class 200MW 36
Elec Saf. 011	**Shall**	Insulation: Electrical insulating material not otherwise contained inside of an isolation enclosure shall not cross over the midplane of the magnet, to avoid material degradation due to X-Ray radiation. *Exception: QTY 2x corrector coil bus jumpers which must cross the midplane for circuit continuity.*	N/A
Elec Saf. 012	**Shall**	Bump Cover: Terminal blocks shall include a "bump cover" to protect electrical junctions. This bump cover may also serve as an electrical safety barrier if the terminal block is not already "finger safe" per code.	N/A
Elec Saf. 013	**Shall**	Maintenance Access: Main circuit air cooled bus jumpers, bus electrical joints, and energized hose fittings shall be uninsulated, and contained with an electrical safety enclosure. This is to allow easy maintenance access and adequate convective cooling	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Isolation Enclosure

Number	Type	Description	Value Reference
Encl. 001	**Shall**	Interface: Electrical isolation enclosure shall fit entirely within its "spaceclaim" volume as defined by the drawings.	See master spec list for drawing number
Encl. 002	**Shall**	Interface: The electrical isolation enclosure shall provide an ingress/egress point for the main circuit power cables at the nominal location marked in the "spaceclaim" drawings. The cable parameters are described in the Electrical Design Section.	See master spec list for drawing number
Encl. 003	**Shall**	Interface: The electrical isolation enclosure shall provide an ingress/egress point for water cooled bus leads at a position which is consistent with the coil lead "spaceclaim" volume.	See master spec list for drawing number
Encl. 004	**Shall**	Interface: The electrical isolation enclosure shall provide an ingress/egress point for water hoses at a position which is consistent with the hose "spaceclaim" volume.	See master spec list for drawing number
Encl. 005	*Should*	Interface: Electrical isolation enclosure size should made as small as reasonable while achieving other requirements, due to limited space between magnet assemblies once installed in the tunnel.	N/A
Encl. 006	**Shall**	Design: The items to be contained in the electrical isolation enclosure and the standards it shall be designed to are listed in the electrical safety requirements section.	N/A
Encl. 007	**Shall**	Design: Electrical isolation enclosure shall be made of the following materials	Polycarbonate and/or G10 Laminate
Encl. 008	**Shall**	Design: The electrical isolation enclosure shall be robustly mounted and secured, such that loads due to routine work do not damage it, or compromise its electrical safety. These include, for instance, bumps during lifting and handling, dropped tools, or workers accidently walking into or striking colliding into it with a cart.	N/A
Encl. 009	*Should*	Design: The electrical isolation enclosure should have vent holes to allow air flow, to facilitate meeting the temperature requirements stated in the bus lead section. These holes shall be small enough that they are considered "finger safe" per the electrical safety requirements.	N/A
Encl. 010	**Shall**	Design: Inside of the electrical isolation enclosure: Uninsulated surfaces at different voltages which are closer than specified distance must be protected from short circuiting due to mechanical motion or sagging/creeping. This includes surfaces at ground, such as the yoke, coil supports, or fiducial nest mounting posts. This protection may be achieved, e.g., by using mechanical supports which prevent mechanical motion, small shims of G10 or films of polycarbonate to prevent electrical contact, etc., and requires LBNL approval.	18 mm
Encl. 011	**Shall**	Maintenance Access: The electrical isolation enclosure should allow quick, convenient access for key maintenance operations with a minimum of disassembly. This includes installing and removing power cables, checking bus connection bolt torques, splitting magnets into upper and lower halves, removing and reinstalling water hoses, and performing voltage checks to confirm de-energization for lock out/tag out.	N/A
Encl. 012	**Shall**	Maintenance Access: The lead box electrical isolation enclosure shall be capable of complete disassembly and removal in the accelerator tunnel, given the context of the surrounding equipment. The surrounding equipment will be provided to the vendor as part of the "Interface Context" solid models.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Electrical Isolation Enclosure

Encl. 013	*Should*	Maintenace Access: The "reference design" electrical isolation enclosure has been carefully laid out to allow complete dissassembly in the confined space of the accelerator tunnel. While the detailed final design has not been completed, and changes and improvements are allowed, the vendor should maintain the same general assembly structure, hardware locations, and the direction components are removed during disassembly.	N/A
Encl. 014	*Should*	Maintenace Access: The reference design shows the energized water fittings located in a different compartment of the enclosure from the electrical bus. This is preferred, because access to hoses to fix leaks are the most common maintenace operation. However, it is not strictly nessecary, provided other stated requirements for isolation, maintenance access, and dissassembly are met.	N/A
Encl. 015	**Shall**	Maintenace Access: Electrical isolation enclosures shall be at least partially transparent, to enable visual inspection of contents.	N/A
Encl. 016	*Should*	Maintenace Access: Whenever practical, fiducial nests should have line of sight visibility without requiring the disassembly of electrical covers. (Fiducial measurements cannot be taken through enclosures, even if they are transparent.)	N/A
Encl. 017	**Shall**	Maintenace Access: In cases where fiducial nest mounting posts extend through holes in the electrical enclosure, the conival seat of the nest shall be slightly proud of the enclosure to ensure visibility. The enclosure shall be carefully designed such that it can still be removed over the fiducial nest post within the context of the crowded accelerator tunnel. See "Interface Context Models."	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Coolant System and Hydraulic Design

Number	Type	Description	Value Reference
Cooling 001	**Shall**	Hydraulic Design: Water coolant shall be used for the main winding circuit. Coolant flow shall be sufficient that the temperature rise of the water coolant across the coil is less than the following number.	15 C
Cooling 002	**Shall**	Hydraulic Design: Coolant flow shall keep the entire coil casting, including internal conductors for both main and corrector circuits, below this maximum temperature	45 C Max assuming coolant inlet at 20 C
Cooling 003	Will	Hydraulic Design: Nominal pressures of the low conductivity water system feeding magnet manifolds	Inlet: 100 PSI Outlet: 20 PSI
Cooling 004	**Shall**	Hydraulic Design: Coils and magnet assemblies shall be designed such that they meet all requirements under any pressure drop within this range	65 PSI to 80 PSI
Cooling 005	**Shall**	Hydraulic Design: Allowed range of operational water velocity inside conductor, to protect against erosion corrosion from deionized water.	1.5 to 3.3 m/s
Cooling 006	*Should*	Hydraulic Design: Preferred range of operational water velocity.	1.5 to 2.5 m/s
Cooling 007	**Shall**	Hydraulic Design: If necessary to keep the water flow within the allowed bounds under the range of operating pressure drop, a flow restrictor shall be used. If used, flow restrictors shall be fabricated from coiled tubes. Orifice type flow restrictors are not permitted due to tendency to cause clogs.	N/A
Cooling 008	**Shall**	Hydraulic Design: Mass flow of water through parallel flow paths shall be matched within	5%
Cooling 009	*Should*	Hydraulic Design: Coolant water should enter the coil lead which is located on the ID of the winding, and exit on the OD of the winding to minimize thermal gradient induced deformation at the pole tips. Note that meeting this may require modification from point design CAD models.	N/A
Cooling 010	**Shall**	Interface: Hoses shall fit entirely within their "spaceclaim" volumes defined by drawings.	See master spec list for drawing number
Cooling 011	**Shall**	Interface: Water manifolds shall fit entirely within its "spaceclaim" volume defined by the drawings. The nipple connections to hoses shall be compatible with the hose "spaceclaim"	See master spec list for drawing number
Cooling 012	**Shall**	Interface: The inlet and outlet connections of the water manifolds to the utility services shall be located at the points marked in the spaceclaim drawings.	See master spec list for drawing number
Cooling 013	**Shall**	General: Coolant will be deionized water. Coolant distribution components shall be compatible with DI water.	N/A
Cooling 014	*Should*	General: The number of fittings and joints should be minimized as much as reasonable to prevent potential leaks, by avoiding separate adapters, or making them in a way that is permanently joined.	N/A
Cooling 015	**Shall**	General: Small apertures in the ID cooling flow path, e.g. through fittings, or flow restrictors, should be avoided as much as possible to prevent clogging. The minimum allowed aperture diameter is	3 mm
Cooling 016	**Shall**	General: Hoses and their deionized water coolant provide electrical isolation between the bus leads and the distribution manifolds. Electrically energized fittings must be contained within a electrical safety enclosure.	N/A
Cooling 017	**Shall**	Hoses type. This hose type has been selected based on electrical resistivity and compatibility with radiation environment and deionized water.	Swagelok 7N-6 hose
Cooling 018	**Shall**	Hoses nominal size	3/8 in
Cooling 019	**Shall**	Hoses: Allowed minimum hose bend radius, measured on inner radius	> 50 mm

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Coolant System and Hydraulic Design

Cooling 020	*Should*	Hoses: Preferred minimum hose bend radius, measured on inner radius	> 75 mm
Cooling 021	**Shall**	Hoses: Minimum distance hoses and hoses fittings shall be either above or below the magnet's midplane	50 mm
Cooling 022	**Shall**	Hoses shall be supported, e.g. by a bracket, or ties which are mounted to magnet assembly. Ties shall be made of either metal or a radiation resistant polymer. The reference design includes and example hanger bracket.	N/A
Cooling 023	*Should*	Hoses should be bundled by fireproof polymer split loom	N/A
Cooling 024	*Should*	Hoses length should be as short as practical while meeting minimum bend requirement	N/A
Cooling 025	**Shall**	Water Manifolds shall be mounted to the upper magnet half and not the lower magnet half	N/A
Cooling 026	*Should*	Water Manifold: Mounting between the water manifold and yoke should allow electrical continuity to the assembly's single point ground.	N/A
Cooling 027	**Shall**	Water Manifold material	300 Series Stainless Steel
Cooling 028	**Shall**	Water Manifold materials and geometry, as well as their mounting, shall minimize thermal conduction between the inlet and outlet distribution manifolds, to maintain uniform temperature operation of each coolant flow path.	N/A
Cooling 029	**Shall**	Fittings: Hose fittings type and size	Swagelok SS-TP6-AS6
Cooling 030	**Shall**	Fittings: The inlet and outlet connections of the water manifolds to the utility services shall have fittings of the following type and size	Swagelok SS-8-TA-1-8AN
Cooling 031	**Shall**	Fittings: fittings material	300 Series Stainless Steel
Cooling 032	**Shall**	Fittings: JIC fittings shall be made up using "37 Degree Flared Tube Fitting Conical Seals", made of copper, with gold flash plating	Vendor: Seco Seals, or equivalent
Cooling 033	**Shall**	Thermal Switch: There shall be a thermal switch to sense loss of coolant faults for each flow path. A single flow path is taken to be the serial flow from the distribution manifold, through one or more coils and bus, and back to the outlet manifold. Thermal flow switches shall be of the following type:	Vendor: THERMIK Part #: L06-70. 05 0300/0300
Cooling 034	**Shall**	Thermal Switches shall be located on the water cooled bus leads, on the outlet flow side of the last coil in each flow path. *Note: Not all reference design CAD models may meet this requirement. Requirements take precedence over CAD models*	N/A
Cooling 035	*Should*	Thermal Switches should be installed so as to accurately read conductor temperature at the point it egresses from the coil potting. For instance, they should be located as closely as practical to this egress, and mounted with good thermal conductivity.	N/A
Cooling 036	*Should*	Maintenance Access: Minimum spacing between hose fittings to allow wrench access	40 mm
Cooling 039	*Should*	Maintenance Access: Hoses replacement and tightening of fitting should be possible with the minimum amount of hardware removal. This includes the manifold to coil distribution hoses, as well as the connections to the main water supply.	N/A
Cooling 040	**Shall**	Maintenance Access: For each manifold, there shall be an extra fitting fitting for flushing operations, and indicated in the water manifold sheet in the space claim drawings. These flushing fittings shall be located opposite to the supply fitting (on supply manifolds) or the return fitting (on return manifolds). Vendor shall furnish plugs for these fittings.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Coolant System and Hydraulic Design

Cooling 041	*Should*	Maintenance Access: Fittings for supply, return, and flushing should be easily accessible from the maintenace aisleways in the accelerator tunnel, as shown in the "Interface Context" solid models.	N/A
Cooling 042	**Shall**	Maintenance Access: Access to thermal switches must be maintained for periodic tests of functions, preferrably with minimum removal of safety enclosures or other equipment. See "Interface Context Models".	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Assembly Level Requirements

Number	Type	Description	Value Reference
Asm 001	**Shall**	Splitting: The overall mechanical assembly shall be designed such that the highest level assembly can be split into two subassemblies, composed of the upper and lower halves. This splitting shall be achieved with minimum disassembly of other magnet parts. This is necessary to install the magnet around vacuum chambers.	N/A
Asm 002	**Shall**	Precision: When a magnet assembly is split into upper and lower halves, and then reassembled, the magnetic field must remain within the magnetic field specification. Vendor shall demonstrate this.	N/A
Asm 003	**Shall**	Precision: When a magnet assembly is split into upper and lower halves, and then reassembled, the allowed change in the magnetic field harmonics shall be less than 1/2 as much as that harmonic's allowed deviation from nominal. In other words, the repeatability of the magnetic field harmonics after splitting shall be twice as tight as the required accuracy.	N/A
Asm 004	**Shall**	Precision: The accuracy of mechanical components, alignment, assembly, and tolerance stack of the total assembly shall be determined by the vendor such that the final magnet assembly meets the specified magnetic field requirements. This is expected to necessitate tighter tolerances than are specified in the LBNL drawing package, (because the LBNL drawing package tolerances are largely based around)interface requirements.)	N/A
Asm 005	**Shall**	Frequency: Minimum acceptable natural frequency of final magnet assembly, while mounted on 16mm diameter "height levelling adjusters' shown in the "Interface Context" assembly.	> 50 hz
Asm 006	*Should*	Frequency: Minimum desired natural frequency of final magnet assembly, while mounted on 16mm diameter "height levelling adjusters' shown in the "Interface Context" assembly.	> 80 hz
Asm 007	*Should*	Frequency: Mechanical vibration modes of the magnet assembly should avoid harmonics which are multiples of 30 hz	N/A
Asm 008	**Shall**	Mass: The total assembly mass shall be within this percentage of the nominal weight listed on the top level assembly drawing, unless otherwise approved by LBNL.	10 % See master spec list for drawing number
Asm 009	**Shall**	Seismic: Magnet assembly must be seismically qualified according to the following equivalent static accelerations. These loads must be sustained, simultaneously with operational loads, without disruption of magnetic alignment or fiducialization.	1.0g horizontal, 0.2 g vertical
Asm 010	**Shall**	Maintenance Access: The splitting, and then accurate reassembly of magnets into upper and lower halves must be possible in the confined workspace of the accelerator tunnel. This means it must be done without the use of large external tooling or guides, with limited manned access, and within the context of the surrounding equipment shown in "Interface Context" solid models.	N/A
Asm 011	**Shall**	Maintenance Access: The lower magnet half must be removable without disassembling the vacuum chamber which transits through the magnet bore. This will be achieved by lowering and then extracting horizontally.	N/A
Asm 012	**Shall**	Maintenance Access: Features and components mounted on the lower yoke half must not prevent extraction of the lower magnet half into the maintenace access aisle, once it has been lowered below its vacuum chamber. See the "Interface Context Models" for reference.	N/A
Asm 013	**Shall**	Maintenance Access: Bolts which hold the upper and lower magnet halves together must be possible to dissassemble within the context of the surrounding equipment in the accelerator tunnel. See the "Interface Context Models" for reference.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Assembly Level Requirements

Asm 014	*Should*	Maintenance Access: Access to the adjustment studs which interface with the "U" shaped cut outs in the base plate should be maintained as best as possible. These studs must periodically be adjusted to reset precision alignment.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Yoke, Pole, and Magnet Supports

Number	Type	Description	Value Reference
Yoke 001	**Shall**	Poles: The reference nominal pole shape dimensions are provided in the pole and yoke assembly drawing, based on LBNL's magnetic point design. Vendor is responsible for verifying these, modifying them as necessary, to achieve the magnetic requirements. Modifications must remain within the "mechanical tolerances" listed on the drawings.	See master spec list for drawing number
Yoke 002	**Shall**	Poles: The tolerances defining pole shapes on the drawings represent limitations due to mechanical considerations. Vendor shall impose tighter tolerances, as necessary, in order to achieve the magnetic field requirements.	N/A
Yoke 003	**Shall**	Poles: Minimum as built magnetic radius/pole aperture on top level assembly. Note that this minimum is equivalent to nominal (e.g. one sided tolerance band.) This requirement is driven by the vacuum chamber interface.	14.5 mm
Yoke 004	**Shall**	Poles: Maximum as built magnetic radius/pole aperture to be set by vendor as determined by magnetic/electrical requirements.	N/A
Yoke 005	**Shall**	Yoke: If laminated yoke construction is used, special care must be taken in the detailing of tapped holes. Tapped holes into laminate must develop appropriate strength and avoid degradation, e.g., due to layer peeling. This may require special threaded inserts, the use of T-Bar nuts, etc.	N/A
Yoke 006	*Should*	Yoke: Preferred yoke material. Another material may be used, subject to LBNL approval, provided it meets all other requirements.	1006 Mild Steel
Yoke 007	**Shall**	Yoke: The yoke assembly shall be designed such that it is comprised of two major subunits - the upper magnet half and the lower magnet half, which join at the horizontal plane. The joining of individual quadrants into halves, and the attachment of other yoke mounted components, shall be done at a lower sub-assembly level.	N/A
Yoke 008	**Shall**	Yoke: Vendor shall specify appropriate details of mating surfaces at yoke split line, including dimensional tolerance, flatness, surface finish, etc. to achieve magnetic performance, splitting repeatability, and other requirements.	N/A
Yoke 009	**Shall**	Yoke: Vendor shall ensure the size of all fasteners and welds on the yoke, and on items mounted on the yoke, are adequate to meet seismic, vibrational, any magnetic forces, and safe transport. This is especially true for the support leg and plate connection design. Details may be modified with LBNL approval, for instance, to include shear pins, to improve strength or alignment, if necessary.	N/A
Yoke 010	**Shall**	Supports: Magnet support legs shall be welded to the lower half yoke.	N/A
Yoke 011	**Shall**	Support legs must include a semipermanent shim, so that the effective height of the magnet center with respect to the bottom of the base plate can be changed if necessary. These are shown as a reference feature in the various baseplate drawings.	See master spec list for drawing number
Yoke 012	**Shall**	Maintenance Access: The vertical dimension between the lower surface of the magnet baseplate and the midplane of the magnet must be as shown in the drawings, unless otherwise approved by LBNL, in order to facilitate removing a lower magnet half without breaking vacuum.	N/A
Yoke 013	**Shall**	Support plate includes 3x "U" shaped cut outs (24mm dia), which interface with 16mm dia "height levelling" studs. While these height levelling studs are not part of the magnet assembly, the magnet must allow the full range of diametral planar adjustment, without any interferences, by providing adequate clearance around the spherical washer. See "Interface Context" models for reference.	8mm, diametral planar adjustment

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Yoke, Pole, and Magnet Supports

Yoke 014	**Shall**	Supports: The true position of the "U" shaped cut outs for "height levelling studs" must be located within this tolerance of the geometric pole center on the final, as built assembly. This is necessary to preserve the range of motion of adjustments.	+/- 0.5 mm
Yoke 015	**Shall**	Supports: Note the flatness, surface finish, and parallelism requirements shown on the Base Plate Drawings. These requirement are to facilitate sliding adjustments, with minimum stick slip, for precision alignment in the accelerator tunnel.	See master spec list for drawing number
Yoke 016	**Shall**	Maintenance Access: The positions of components, and especially their fasteners shall be compatible with access and disassembly in the confined space environment of the tunnel. Subassemblies which are defined by "spaceclaim" volumes, (e.g., the bus safety enclosure, terminal blocks, manifolds, etc.), may have their mounting holes in the yoke modified or moved - provided disassembly in the tunnel is maintained. Vendor shall review accessibility using the "Interface Context" models provided by LBNL.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Alignment, Fiducial Features

Number	Type	Description	Value Reference
Align 001	**Shall**	Fiducials: Nests for laser tracker retroreflectors shall be located in the positions shown in the pole and yoke assembly drawing. They shall be permanently attached by welding. The amount of weld shall be minimized to prevent distortion from limiting the repeatability of seating a retroreflector in the nest.	See master spec list for drawing number
Align 002	**Shall**	Fiducials: SMR nests shall be of the following type. LBNL will provide the SMR nest components for the vendor to integrate into the assembly.	Vendor: Metrology Works Part Number: BTN-A-Z-BPSM-Y-E-17-4SS
Align 003	**Shall**	Fiducials: Nests contain a small permanent magnet which must be removed during welding to avoid demagnetization. Vendor shall confirm magnet remains magnetized after welding.	N/A
Align 004	*Should*	Fiducials: For yoke quadrants subcomponents that do not have permanently attached SMR nests, vendor should add tooling features to allow easily repeatable measurement. These may include, for instance, reamed holes, reference flats, or spotfaces. Small countersinks which allow a 0.5" SMR to seat are especially preferred.	N/A
Align 005	**Shall**	Yoke Splitting, Maintenance: Alignment features used for the splitting of magnets into upper and lower halves shall be of a type which self indexes or self aligns during assembly. In other words, when the upper half is lowered onto the bottom half by crane, it shall seat in the appropriate position without further manipulation or shifting. See the reference design shown in yoke drawings.	See master spec list for drawing number
Align 006	**Shall**	Yoke Splitting: Alignment features used for the splitting of each magnet half into quadrants and adjustment of coil location can be assumed to occur in a controlled environment in a shop workspace, with good working access. Tooling, alignment guides, or fine manipulation after mating can be allowed. *Note: General disassembly of magnet components must be possible in the accelerator tunnel, as stated elsewhere. Only precision alignment can be assumed to happen on a shop bench.*	N/A
Align 007	**Shall**	Yoke Splitting: Procedures for magnet splitting shall include some provision to facilitate separation without pins binding. This may include the use of additional tooling features incorporated into the yoke design by the vendor, such as jacking screws, etc.	N/A
Align 008	**Shall**	Maintenance Access: Although concept details may change, the alignment pin locations shall remain in the same locations as shown in the reference design, unless otherwise approved by LBNL, to ensure appropriate access for splitting magnets in the accelerator tunnel	N/A
Align 009	**Shall**	Alignment Pins: The pin concept shown in the "Reference Design" CAD models and yoke drawing has not been validated. Vendor may make changes to this concept as necessary, and shall be responsible for validating that the final alignment feature works well in practice, and achieves the vendor determined repeatability which meets magnetic field requirements.	See master spec list for drawing number
Align 010	*Should*	Alignment Pins: Pin concept shown in the "Reference Design" CAD models is a preferred concept. These details, or similar designs are preferred, provided they work in practice to meet the vendor defined repeatability determined to achieve magnetic requirements.	See master spec list for drawing number
Align 011	**Shall**	Alignment Pins: If used, removable precision alignment features such as pins shall be marked such that their orientation is repeatable, and their placement is clear. For instance, taper pin A and tapered hole A will have 1 scribe line, while taper pin B and tapered hole B will have 2 scribe lines.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Alignment, Fiducial Features

Align 012	**Shall**	Alignment Pins: If used, any alignment pins which require seating by force shall be sufficiently long, and also either tapered or chamfered, such that mushrooming or local deformation of these pins due to impact will not impede disassembly or reduce accuracy.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Hardware

Number	Type	Description	Value Reference
HDWE 001	**Shall**	Standards: Unless otherwise specifically approved, all hardware and tapped holes should be metric.	N/A
HDWE 002	**Shall**	Standards: If imperial hardware is approved for use, it shall be conspicuously marked. Imperial hardware may be used where it will present significant cost savings, after approval from LBNL.	N/A
HDWE 003	**Shall**	Thread lubricants, Maintenance: Vendor shall specify appropriate lubricants and/or coatings to ensure galling and seizing are not a problem for disassembly after many years of operation. Because the magnet will be in the vicinity of ultra-high vacuum systems, lubricants require approval of LBNL.	N/A
HDWE 004	*Should*	Thread lubricants: Hydrocarbon based lubricants, lubricants with high vapor pressure, and fluorinated (PTFE) coatings are discouraged. Silver plating, molybdenum disulfide based coatings, molybdenum disulfide dry powder, or other inert dry lubricants, and dissimilar material pairs are preferred.	N/A
HDWE 005	**Shall**	Tapped holes: All tapped holes shall have threaded inserts. Threaded insert materials shall be selected to avoid galling and seizing with fasteners, considering the restrictions on lubrication.	N/A
HDWE 006	*Should*	Tapped holes: For general tapped holes in metal, without high load bearing requirements, phosphor bronze helical threaded inserts are preferred.	N/A
HDWE 007	*Should*	Tapped holes: For tapped holes in metal, with high load bearing requirements, stainless steel key locking inserts, coated with a molybdenum sulfide dry lubricant, are preferred. Examples of high load bearing joints include lift attachment points, and structural connections between the magnet and its support/base plate. Threaded inserts at lift attachment points must be subflush with the yoke surface to ensure swivel hoist rings will seat properly.	N/A
HDWE 008	*Should*	Tapped holes: For tapped holes in G10, brass or bronze materials are preferred. Vendor may suggest insert style.	N/A
HDWE 009	*Should*	Fasteners: Non high strength hardware is preferred, unless high strength hardware is nessecary for strength reasons. High strength refers to fasteners with ultimate tensile strength of 100 KSI or greater.	N/A
HDWE 010	**Shall**	Fasteners: If high strength, or graded hardware is used, hardware must have suitable markings, and be supplied with Certified Material Test Reports and Certificates of Conformance. Graded hardware must not have markings disallowed by the DOE Suspect and Counterfeit Bolt Headmark list.	N/A
HDWE 011	*Should*	Fasteners: Hardware should be standardized as much as practical, both within a single magnet assembly, and among multiple magnet assemblies.	N/A
HDWE 012	*Should*	Fasteners: For highly torqued fasteners, where rounding of heads may occur: Where space allows, hex head cap screws are preferred to socket head cap screws	N/A
HDWE 013	**Shall**	Fasteners: 316 stainless steel fasteners shall be used near the vicinity of poles, coils, or other areas where permeability of materials may affect magnetic field quality.	N/A
HDWE 014	May	Fasteners: Where not specifically required to be stainless steel, fastener material choices are flexible, and may include, for instance mild or alloy steel as appropriate.	N/A
HDWE 015	**Shall**	Fasteners: Special requirements for fasteners of electrical bus leads are included in the Bus Lead requirements section.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Lifting, Handling, Shipping

Number	Type	Description	Value Reference
Lift 001	**Shall**	Rigging: Lift connection points shall be provided for rigging the entire magnet assembly, the upper magnet half, and the lower magnet half.	N/A
Lift 002	May	Rigging: Preferred lift attachment points are marked on drawings yoke drawing. Vendor may modify these points, or add additional assembly/lifting tooling holes, to the yoke, as necessary, pending LBNL approval. If lifting attachment points are modified, they must remain compatible with the surrounding equipment shown in the "Interface Context Models"	See master spec list for drawing number
Lift 003	**Shall**	Rigging: Magnet assembly shall be compatible with specified vendor and product line of lifting hardware, following vendor specified guidelines for SWL and other use.	Crosby, HR-125M, Metric Swivel Hoist Rings
Lift 004	**Shall**	Rigging: When lifting, swivel hoist rings shall be free to rotate over the necessary range without the bail or attached slings contacting other components.	N/A
Lift 005	*Should*	Safety: Rigging for lifting of full assembly, upper magnet half, and lower magnet half should use three points of attachment for best load control. Connections used only for balancing may be substantially smaller than the main load bearing connections.	N/A
Lift 006	**Shall**	Safety: Vendor shall ensure, that specified lifting procedures are safe for both personnel and equipment.	N/A
Lift 007	**Shall**	Safety: If necessary for personnel safety, to protect equipment, or to prevent inadvertent misalignment due to lifting loads, vendor shall design, fabricate, and furnish to LBNL lifting fixtures or tooling which interface with the yoke lifting points.	N/A
Lift 008	**Shall**	Safety: If custom lifting fixtures are necessary, they must be load tested to 1.5x the qualified SWL.	N/A
Lift 009	**Shall**	Maintenance Access: If custom lifting fixtures are necessary, they must not extend outside the footprint of the magnet space reservations.	N/A
Lift 010	*Should*	Maintenance Access: Lift connection points should be useable for manipulating individual quadrants, or other subassemblies which weight more than 50 lbs., during disassembly/reassemble. Rigging of assemblies smaller than a half magnet may be single point picks.	N/A
Lift 011	**Shall**	Shipping: Release for shipping must be authorized by LBNL prior to shipment.	N/A
Lift 012	**Shall**	Shipping crates and packing shall be designed so that magnetic alignment and fiducialization is preserved despite any vibration, shock locking, or other environmental effects of transportation.	N/A
Lift 013	**Shall**	Shipping crates and packing shall be approved by LBNL.	N/A
Lift 014	**Shall**	Shipping crate shall contain an accelerometer of a type to be provided by LBNL.	N/A
Lift 015	**Shall**	Shipping crates shall be design to be adequate for temporary storage of up to 1 year after receipt, including protection from moisture and including desiccant.	N/A
Lift 016	**Shall**	Shipping crates shall be marked on the outside with PO number and total weight in pounds with the unit "pounds" marked. Additionally, for each contained magnet assembly, shipping crates shall be marked with LBNL specification number, vendor top level drawing number, magnet unique identifier with serial number, magnet family, magnet common name, and the assembly's QR code.	N/A
Lift 017	**Shall**	Shipping: Shipments will be DAP to LBNL's on site receiving department.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Documentation, Procedures

Number	Type	Description	Value Reference
Docs 001	**Shall**	General: Vendor documentation shall be provided electronically via upload to LBNL's Product Lifecycle Management Documentation Portal. LBNL uses the following software:	PTC Windchill 11
Docs 002	**Shall**	General: Each vendor solid model, drawing, and document shall have a unique identifier consistent with LBNL's naming nomenclature. LBNL will assign a block of numbers to the vendor for use. Vendor may use their own internal nomenclature in addition to LBNL nomenclature, but file naming and references to documents shall be based on LBNL nomenclature. Nomenclature is of the form: AL-XXXX-XXXX-YYYY, where "X"s are unique identifiers for a given item, and 'Y" is a serial number.	N/A
Docs 003		General: The unique identifier for the highest level assembly of each magnet must match those already assigned by LBNL. These can be found in the "ITEM NUMBER" box in title box of the "master assemblies" provided by LBNL.	N/A
Docs 004	**Shall**	General: Part naming shall follow the applicable sections of LBNL's ALS-U Naming Convention Standard	AL-1119-4345
Docs 005	**Shall**	Solid Models/ Drawings: Vendor solid models and electronic drawings shall be of a kind which can be imported into LBNL's preferred software. The preferred software is:	PTC Creo Parametric 6
Docs 006	*Should*	Solid Models/ Drawings: LBNL prefers solid models and electronic drawings to be natively generated in our preferred CAD software, but this is not required. Vendor shall use start parts and formats provided by LBNL.	PTC Creo Parametric 6
Docs 007	**Shall**	Solid Models/ Drawings: Vendor shall provide electronic copies of solid models, including COTS parts and hardware, in their native format and as AP242 step files. Drawings shall be provided in their native electronic format, dxf files, as well as pdf files.	N/A
Docs 008	**Shall**	Solid Models Vendor shall develop and provide a complete set of solid model for each magnet assembly, subassembly, and component. Solid models shall use metric dimensions.	N/A
Docs 009	**Shall**	Solid Models shall include an assigned material with appropriate density, for automatic calculation of mass and center of gravity.	N/A
Docs 010	**Shall**	Solid Models shall not have threads modelled in tapped holes or hardware.	N/A
Docs 011	**Shall**	Drawings: Vendor shall develop and provide a full set of fabrication approved engineering drawings for each magnet assembly, subassembly, and component. These shall fully define the assembly, including, mechanical, electrical wiring, magnetic pole direction, plumbing, etc. Drawings shall be either metric or dual dimensioned. Drawings shall adhere to ASME Y14.5, 2009 or later.	N/A
Docs 012	**Shall**	Procedures: Vendor shall furnish procedures for splitting and then reassembling a magnet into two halves, while achieving the desired repeatability	N/A
Docs 013	**Shall**	Procedures: Vendor shall furnish procedures for removing and replacing a coil	N/A
Docs 014	**Shall**	Procedures: Vendor shall indicate the appropriate torque, lubrication, and other installation information for each bolted joint.	N/A
Docs 015	**Shall**	Procedures: Vendor shall provide procedures for lifting, including proper use of any tooling, if it is needed.	N/A
Docs 016	**Shall**	Design Basis: Vendor shall document the calculations used to support the magnetic design, including the assigned mechanical tolerances and assembly repeatability.	N/A
Docs 017	**Shall**	Design Basis: Vendor shall document the design basis for safe lifting operations, and if required, lifting fixtures.	N/A

ALS-U BTA Quadrupole Magnet Generic Design Requirements:
Documentation, Procedures

Docs 018	**Shall**	Design Basis: Vendor shall document the design basis for surviving earthquake and shipping loads.	N/A
Docs 019	**Shall**	Design Basis: Vendor shall document engineering calculations to qualify meeting any requirements which are not otherwise validated by inspection, measurement, or test.	N/A
Docs 020	**Shall**	Documentation: For all custom fabricated metal components: Certified Material Test Reports of the base material shall be provided with chemical composition and mechanicals.	N/A
Docs 021	**Shall**	Documentation: For all custom fabricated non-metal components: Certificates of Conformance of the base materials shall be furnished.	N/A
Docs 022	**Shall**	Documentation: For all commercial off the shelf items: **Either** a reference to a recognized standard industry specification **or** a copy of the manufacturer's data sheet shall be provided.	N/A
Docs 023	**Shall**	Documentation: Vendor shall provide nonconformance reports for as built deviations from approved for fabrication models. NCRs must be approved by LBNL.	N/A
Docs 024	**Shall**	Documentation: Nonconformances which substantially affect the magnet's form, fit, function or interfaces shall be incorporated into either a revision or as built version of the solid model and drawings.	N/A

(end section)

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Labels, Marking, Serialization, and Paint

Number	Type	Description	Value Reference
Marking 001	**Shall**	General: Labels required by this section shall be engraved, unless otherwise specified. Engraving may either be directly on components themselves when appropriate, or on G10 or aluminum tags which are then securely fastened to the assembly. An alternative method may be requested by vendor, subject to LBNL approval.	N/A
Marking 002	**Shall**	General: Marking shall be placed conspicuously in regions where they will not interfere with desired functions.	N/A
Marking 003	**Shall**	General: Permanent markings or labels not specified here, such as vendor tags, require approval by LBNL.	N/A
Marking 004	**Shall**	Main Coil Windings: Each coil bus lead shall be marked + and - at the point of egress from the coil according to the electrical schematic.	See master spec list for drawing number
Marking 005	**Shall**	Main Coil Windings: Each coil shall have a label with either the letter "N" or "S", to indicate the pole polarity. The label shall also contain an arrow pointing in the pole's field direction. These labelled magnetic polarities shall correspond to the coil energization when the electrical current flows in the direction marked by the +/- signs on the corresponding bus lead. These polarities and naming shall also be consistent with the electrical schematic. These coil labels shall be on the same side of the coil as the main coil winding bus egress.	See master spec list for drawing number
Marking 006	**Shall**	Corrector Coils Windings: Each coil bus lead shall be labelled either By+, By-, Bx+, or Bx- at the point of egress from the coil, according to which circuit it belongs to, and the electrical schematic .	See master spec list for drawing number
Marking 007	**Shall**	Corrector Coil Windings: Each quadrupole coil shall have two sets of labels, one for each corrector winding. One set of labels shall include the text "By", an arrow, and then the text "BEAM +X". The arrow shall point in the field direction of the vertical field corrector circuit when it is energized by current flowing in the direction specified by the electrical polarity labels of the associated bus lead. Likewise, the second set of labels shall include the text "Bx", an arrow, and then the text "BEAM +Y". This arrow shall point in the field direction of the horizontal field corrector circuit when it is energized by current flowing in the direction specified by the electrical polarity labels of its associated bus lead. These polarities and naming shall be consistent with the electrical schematic. These coil labels shall be on the same side of the coil as the corrector coil bus egress.	See master spec list for drawing number
Marking 008	**Shall**	Water: Water manifolds shall be labelled either "In" or "Out", according to flow direction specified in the plumbing diagram located in the "spaceclaim" drawings.	See master spec list for drawing number
Marking 009	**Shall**	Water: Water manifolds shall be labelled to indicate whether they contain 4x parallel flow paths or 2x parallel flow paths.	See master spec list for drawing number
Marking 010	**Shall**	Water: Each water cooled bus shall be labelled, near the appropriate hose connection fitting, to indicate the flow direction of water, according to the flow direction specified on the plumbing diagram located in the "spaceclaim" drawings.	See master spec list for drawing number
Marking 011	**Shall**	Water: Each hose shall be labelled with arrows indicating the direction of flow. At minimum, one arrow shall be located near each fitting.	See master spec list for drawing number
Marking 012	**Shall**	Electrical: Each bus lead flag shall be marked either + or - at the interface point with main circuit power cable, in accordance to the polarity specified by the electrical wiring schematic.	See master spec list for drawing number

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Labels, Marking, Serialization, and Paint

Marking 013	**Shall**	Electrical: Terminal blocks connection points shall be labelled per the designators shown on electrical schematic. The same designator shall be used for both the label on the terminal and the label on the end of the connecting cable. These markings do not have to be engraved.	See master spec list for drawing number
Marking 014	**Shall**	Electrical: Each wire, corrector coil bus lead, or jumper which connects to a terminal block shall be labelled near the point of connection, per the designators shown on the electrical schematic. The same designator shall be used for both the label on the terminal and the label on the end of the connecting cable. These markings do not have to be engraved.	See master spec list for drawing number
Marking 015	**Shall**	Electrical: Grounding points shall be designated with a grounding symbol, the word "Ground", or the letter 'G'.	N/A
Marking 016	**Shall**	Assembly: The highest level magnet assembly shall be labelled with the print number for the vendor's highest level assembly drawing, if there is a vendor nomenclature being used in parallel with LBNL numbering.	N/A
Marking 017	**Shall**	Assembly: The highest level magnet assembly label shall include a QR code, to be specified in the future by LBNL.	N/A
Marking 018	**Shall**	Assembly: The highest level magnet assembly shall be marked with the total assembly weight. The weight shall be in pounds, and the unit shall also be clearly marked. This weight shall including all components and hardware, including the base plate.	N/A
Marking 019	**Shall**	Yoke Quadrants: Each magnet quadrant yoke shall be labelled with the magnet assembly unique identifier, the magnet assembly serial number, as well as a label with the word "Quadrant" and the quadrant number. The quadrant numbering shall match the coil numbering show on the electrical schematic.	See master spec list for drawing number
Marking 020	**Shall**	Coils: Each coil shall be labelled with the unique identifier for coil type, as well as its serial number. *Note: Coils which have different lead bends, but are otherwise identical, may be considered to be instances of the same part number*	N/A
Marking 021	*Should*	Serialization: Other major components or subassemblies, not already explicitly required to be serialized, shall be serialized when necessary in order to track production or quality information.	N/A
Marking 022	**Shall**	Serialization: For each as built assembly, vendor will provide documentation indicating which serial number of each part is installed in each place. For instance, Coil Part #XYZ with serial #ABC is installed in Quadrant #1.	N/A
Marking 023	**Shall**	Steel Treatment: Steel components shall be coated with an anticorrosive paint, coating or treatment, per the vendor's choice, and subject to LBNL approval. These treatments must be compatible with the UHV restrictions on volatiles described in the "General Requirements".	N/A
Marking 024	**Shall**	Steel Treatment: Quadrupole yoke quadrants shall be this color	Dahlia yellow (RAL 1033 or equiv.)
Marking 025	**Shall**	Steel Treatment: If coloring is applied to steel components other than the yoke quadrant themselves, one of the following colors shall be used	Light Gray (RAL 9022 or equiv.) White (RAL 9010 or equiv.) Black (RAL 9005 or equiv.) Blue (RAL 5007 or equiv.)

ALS-U BTA Quadrupole Magnet Generic Design Requirements: Labels, Marking, Serialization, and Paint

Marking 026	**Shall**	Steel Treatment: Anti corrosive coatings or treatments must not impede high precision geometric inspection of magnetically critical surfaces, for instance, by adding any thickness of the same order as the pole geometry tolerance. If necessary, magnetically critical surfaces may be protected with a temporary corrosion inhibitor, which can be removed for inspection at LBNL, and then reapplied. This includes both the pole tips, as well as flats on the adjacent pole faces, as shown in the top level assembly drawings. If used, a temporary corrosion inhibitor must be compatible with the UHV restrictions on volatiles described in the "General Requirements"	See master spec list for drawing number
Marking 027	**Shall**	Steel Treatment: Anti corrosive coatings or treatments shall not be applied to precision sliding surfaces, mating surfaces, contact areas for electrical grounding, fiducial or tooling marks, or other places where they would interfere with function.	See master spec list for drawing number

(end section)