Lawrence Berkeley National Laboratory Engineering Specification	Cat Code LC0114	LBNL Document # LC-1003-0087	Rev E	Page 1 of 103
Author(s) Katherine Ray		Collaborating Institution		
Reviewed By MLEITNER,AJDEMELLO,DLEITNER		Reviewed Date **Mar 7 2019 8:09:52** AM PST		
Approved / Concurred By MLEITNER,AJDEMELLO,DLEITNER		DCC Release Date **Mar 7 2019 8:09:52** AM PST		
Title **LCLS-II / LCLS-II - UNDULATORS VERTICALLY POLARIZING UNDULATOR ASSEMBLY FULL ASSEMBLY HGVPU-WI-29H929**				

HGVPU Full Assembly Work Instructions (WI)

Windchill Unique ID: **LC-1003-0087**

Rev: **E**

Issued: **Mar 7 2019 8:09:52** AM PST

Prepared by	Checked by
Katherine Ray Work Instructions Originator	Daniela Leitner QA Manager
Approved by	**Concurred**
Allan DeMello Technical Lead	Matthaeus Leitner CAM

Contents

Revision History

Revision	Issued	Changes
A	08-25-2016	Original Issue.
B	09-15-2017	Update based on experience building pre-production unit and design changes
C	11-13-2017	Add section 6, clarify section 11 & 13, other changes based on feedback
D	11-05-2018	Modifications reflect design changes due to flexible strongback
E	02-20-2019	Add VP 13, update Fagor Encoder parts in VSS, add load cell serial numbers to VSS, add press plate serial numbers, update Fagor Encoder figures, torque spec on encoder backing plate, specify tape over shims, add motor firmware update, ask for photo of strongback-magnet module gap

Purpose

The purpose of this Working Instruction is to describe the process of assembling the top level assemblies of the HGVPU.

Scope

These work instructions cover the assembly of the HGVPU and subsequent Gap Acceptance Testing. The magnet module assembly and spring cage assembly & calibration are covered in separate work instructions, and performed prior to completing this work instruction. The SLAC control system checkout is covered in a separate document and required to complete this work instruction.

Definitions

HGVPU: Horizontal Gap Vertical Polarizing Undulator. The device that will take an electron beam use it to create coherent x-rays. The beam flows from the "upstream" side of the undulator to "downstream" side of the undulator, and then through the interspace for refocusing.

Interspace: The assembly that will be placed on the small platform at the downstream end of the undulator. (Includes quadrupole magnet, phase shifter, beam diagnostics, etc.)

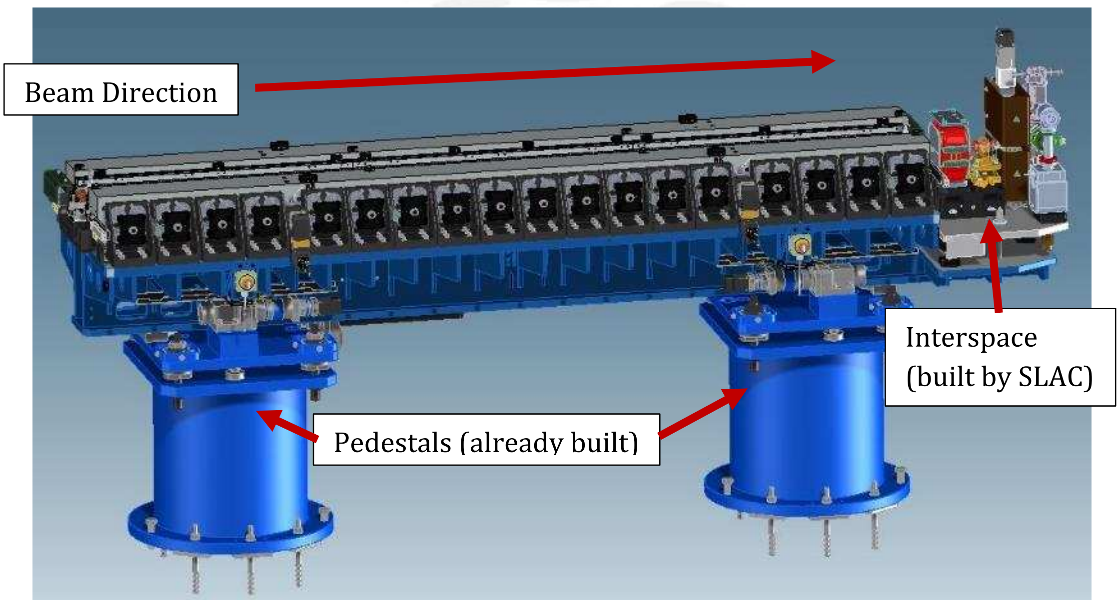


Figure 1: Full HGVPU

Upstream/Downstream: These terms refer to the electron beam direction. The beam starts upstream, the opposite end to where the interspace platform is, and goes to the downstream side of the undulator before going through the interspace (see Figure 2).

Left/Right (Aisle/Wall): Left/right are defined from the point of view of standing at the upstream end, looking down the undulator (see Figure 2). The left side will be towards the aisle in the final installation, and the right side will be towards the wall.

X, Y, Z: The Z-axis is the beam direction, Y-axis is up and X-axis is the direction that makes the coordinate system right-handed, i.e. to the left (see Figure 2).

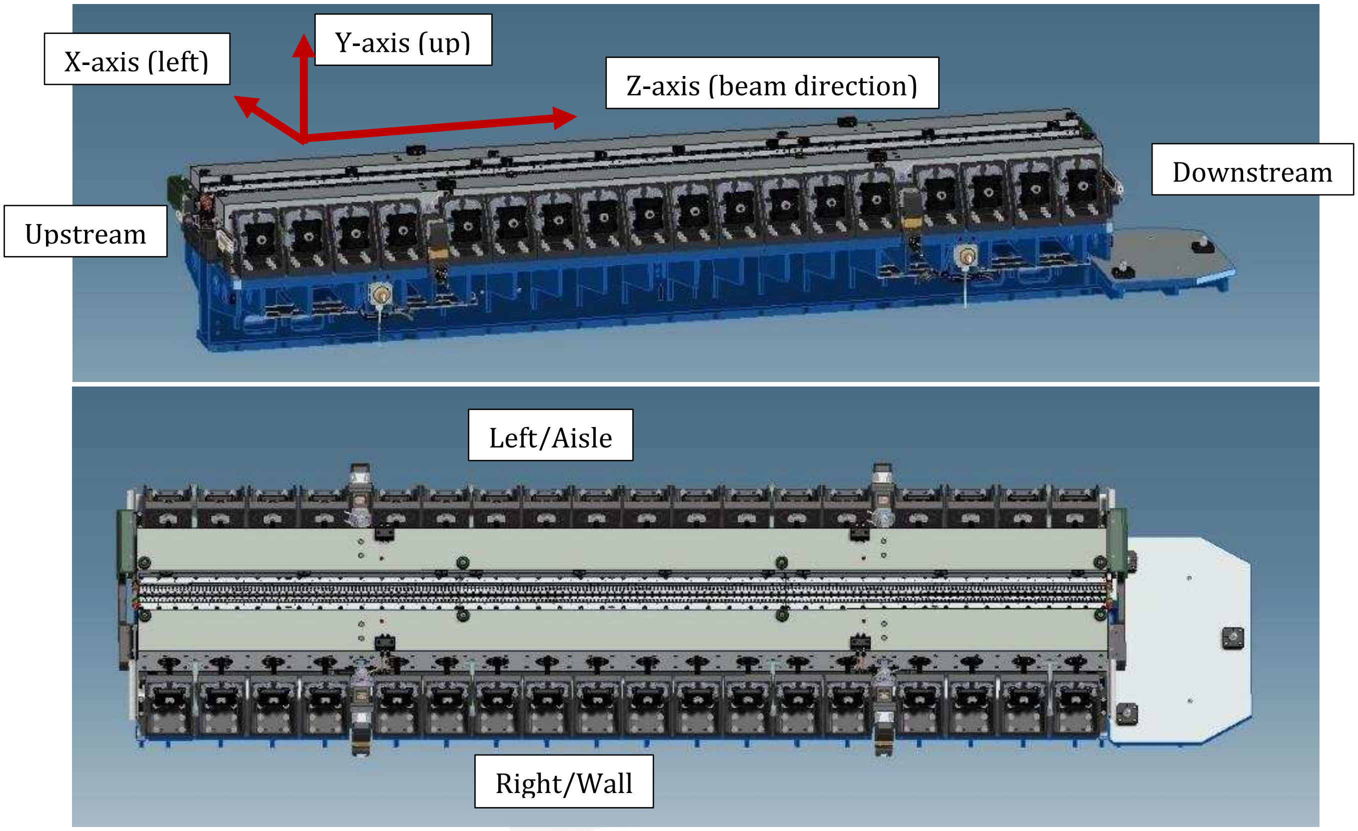


Figure 2: Deliverable portion of HGVPU

Reference Documents

- HGVPU-ACL-29H929 – Full Assembly ACL
- HGVPU-ACL-29H881 – Magnetic Module ACL
- HGVPU-WI-29H881 – Magnetic Assembly Work Instructions
- LC-1002-9204 – Spring Calibration Work Instructions
- EN LC-1000-5688 – Undulator Control System
- LCLSII-2.7-PP-00855 – LCLS-II HGVPU Undulator Motion Controls Checkout Procedure
- LCLSII-3.2-PR-0038-R2 – Physics Requirements Document,
- Engineering Note 11220 – HGVPU BOM
- Drawing 29H929 – HGVPU Top Assembly
- Drawing 29L130 – Cable Management
- Drawing 29K457 – Mechanical Assembly
- Drawing 29H948 – Strongback-Girder Assembly
- Drawing 29H947 – Mechanical System, Girder Slides Assy
- Drawing 29K387 – Hardstop Assembly Lower Left
- Drawing 29H953 – Hardstop Assembly Lower Right
- Drawing 29H896 – Strongback Left Assembly
- Drawing 29H897 – Strongback Right Assembly
- Drawing 29H934 – Motor and Gear Assembly
- Drawing 29H907 – Gap Encoder Assy 1
- Drawing 29H908 – Gap Encoder Assy 2

Tools Required

Calibrated Tools:

- Torque wrenches, large and small, with calibration certificates
- CMM

Non Calibrated Tools:

- Feeler gauges
- Ground ceramic block
- Gauge blocks
- Strongback centering fixture (29K027)
- Strongback position plate fixture (29L036)
- Loadcell readout chassis
- GT2-H50 Keyence sensors with fixtures to attach to spring cages
- Clamps
- 1" thick, long pieces of foam padding
- Non-ferromagnetic Allen wrenches
- Cleaning fluid & wipes (alcohol)
- Lubrication for screws
- Lubrication for drive system
- Girder support during assembly
- Strongback support during assembly
- Push plate fixtures
- Spring cage positioning fixture
- Gloves (latex/nitrile)
- Control system chassis with SLAC provided software
- Extension cables between control chassis, motors, encoders, sensors

Software:

- Spring cage positioning & adjustment
- HGVPU control system software
- Magnet module shim adjustment

Hardware Required

Fabricated Parts & Hardware:

Part #	Description	Req'd
29H866	GIRDER WELDMENT	1
29K386	HARDSTOP BRKT, LONG L, ASM, VPU	2
29H942	HARDSTOP BRKT, LONG R, ASM, VPU	2
29H945	HARDSTOP BRKT, SHORT, VPU	4
29H990	VERTICAL POTENTIOMETER INTERFACE BRACKET	1
29H991	UPSTREAM WEDGE BLOCK (FLAT)	1
29H992	VERTICAL POTENTIOMETER POSITION BRACKET	1
29L222	STRONGBACK FLEXURE	4
29K388	UPSTREAM WEDGE BLOCK (DOUBLE CAM)	1
29K389	DOWNSTREAM WEDGE BLOCK (42.8 DEG)	1
29K390	DOWNSTREAM WEDGE BLOCK (25.6 DEG)	1
29L034	CARRIAGE BRACKET 1	2
29L035	SPRING CUP BRACKET	4
29L036	SPRING GUARD WELDMENT 1	4
29L037	SPRING GUARD WELDMENT 2	4
29L038	SPRING GUIDE ROD	4
29L039	CARRIAGE BRACKET 2	2
29L051	GREASE FITTING SPACER	16
29H952	HARDSTOP BRACKET UPPER LEFT	2
29H950	HARDSTOP BRACKET UPPER RIGHT	2
29L046	GREASE FITTING MANIFOLD	4
29H902	TILT ENCODER BRACKET TALL	2
29H903	TILT ENCODER BRACKET SHORT	2
29H904	TILT ENCODER PLATE	4
29H860	SPRING CAGE CUT	16
29H913	SPRING CAGE UNCUT	20
29L289	COVER – END PANDUIT	4
29L288	END PANDUIT	4
29L219	PANDUIT ADAPTER	4
29L204	LEFT MOUNTING - MOTOR GUARD	4
29L196	FACE PLATE - MOTOR GUARD	4
29L195	RIGHT MOUNTING - MOTOR GUARD	4
29L198	SPACER - MOTOR GUARD	8
29L199	STRAIN RELIEF BODY	4
29L206	CLAMP - STRAIN RELIEF	4
29L067	E-STOP SWITCH ASSY	3
29L053	E-STOP BRACKET SHORT	1
29L290	COVER-CENTER PANDUIT	1
29L291	CENTER PANDUIT	1
29L054	WELDMENT-BRACKET E-STOP-CONN-BOX	2
29L270	SPACER PLATE	2

Part #	Description	Req'd
29L269	ENCODER CONNECTOR PLATE	1
29L041	LIMIT SWITCH ADJUST ASSY	8
29H778	VAC CHAMBER LIMIT SWITCH BKT	4
29K271	KINEMATIC BALL MOUNT ASSY	3

Strongback Left Assembly (29H896):

Part #	Description	REQ'D (per system)
29H914	STRONGBACK ASSEMBLY	1
29H881	ENTRANCE MODULE LEFT	1
29H872	CENTER MODULE LEFT	1
29H882	EXIT MODULE LEFT	1
29L300	MODULE END CLAMP ASSEMBLY	1
29L301	KEEPER POSITION PLATE ASSY	1
29L294/ 29L295 /29L063	SHIMS	A/R
29L045	MAGNET SHIM	1
29L287	BOX FLEXURE	96
29L303	HGVPU BALL SCREW MOUNT	2
29K240	FIDUCIAL MOUNT ASSY	4
29L298	SOLID PUSH ROD	18

Strongback Right Assembly (29H897):

Part #	Description	REQ'D (per system)
29H914	STRONGBACK ASSEMBLY	1
29H893	ENTRANCE MODULE RIGHT	1
29H894	CENTER MODULE RIGHT	1
29H895	EXIT MODULE RIGHT	1
29L300	MODULE END CLAMP ASSEMBLY	1
29L301	KEEPER POSITION PLATE ASSY	1
29L294/ 29L295 /29L063	SHIMS	A/R
29L045	MAGNET SHIM	1
29L287	BOX FLEXURE	96
29L303	HGVPU BALL SCREW MOUNT	2
29K240	FIDUCIAL MOUNT ASSY	4
29L298	SOLID PUSH ROD	18

Motor and Gear Assembly (29H934):

Part #	Description	REQ'D (per system)
29L024	GEARBOX ADAPTER	4
29L025	BRACKET – DRIVE MOTOR ASSY	4
29L027	BEARING HOUSING STOP	4
29L026	BEARING MOUNT & COUPLING HOUSING	4
29K445	BALL SCREW AND NUT ASSY	1

Gap Encoder Assembly 1 (29H907):

Part #	Description	REQ'D (per system)
29H890	ACTUATOR ARM 1	1
29H899	ENCODER MOUNT PLATE	1
29H898	READHEAD MOUNT 1	1
29H851	ACTUATOR PLATE	1
29H871	ACTUATOR PLATE CLAMP	1
29H920	ENCODER LEAD COVER 1	1
29H922	ENCODER LEAD INSERT	1
29L307	CUSTOM SHOULDER SCREW FOR AMOSIN SCALE BASE	1
29L305	AMOSIN SCALE MOUNTING BASE MODIFICATION	1
29L306	AMOSIN SCALE CLAMP MOD	2

Gap Encoder Assembly 2 (29H908):

Part #	Description	REQ'D (per system)
29H900	ACTUATOR ARM 2	1
29H899	ENCODER MOUNT PLATE	1
29H901	READHEAD MOUNT 2	1
29H851	ACTUATOR PLATE	1
29H871	ACTUATOR PLATE CLAMP	1
29H921	ENCODER LEAD COVER 2	1
29H922	ENCODER LEAD INSERT	1
29L307	CUSTOM SHOULDER SCREW FOR AMOSIN SCALE BASE	1
29L305	AMOSIN SCALE MOUNTING BASE MODIFICATION	1
29L306	AMOSIN SCALE CLAMP MOD	2

Work Instructions

1 Overview

1. Assign assembly number and attach label per assembly print (29H929).
2. Enter the following information on the Verification Signoff Sheet:
   a. Serial number from step one
   b. Work instructions number and revision
   c. Start date
   d. Ambient temperature at assembly start
   e. Serial numbers of all component parts to be used in the assembly

2 Mounting Girder on CMM or in Working Position

3. When measuring the girder on the CMM, support the girder at the mounting block locations.

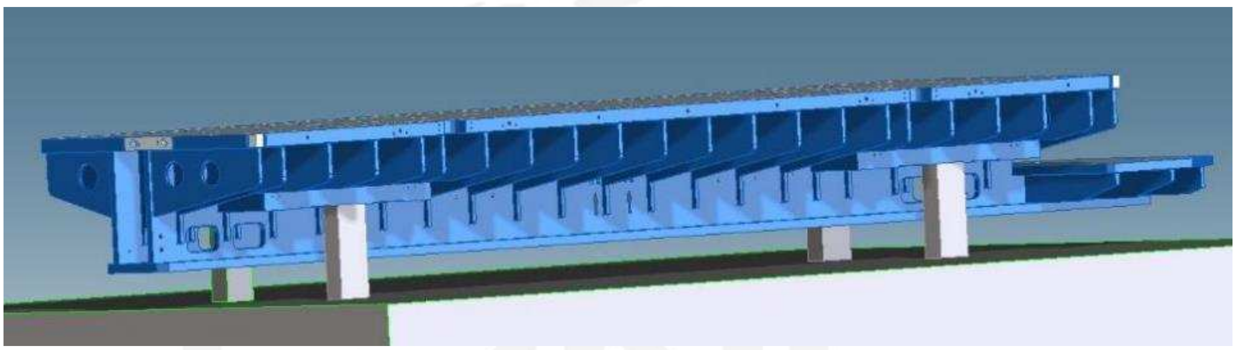


Figure 3: Girder supported at 4 center mounting block locations.

4. When maneuvering the girder on its own, slings can be passed through the rectangular holes.

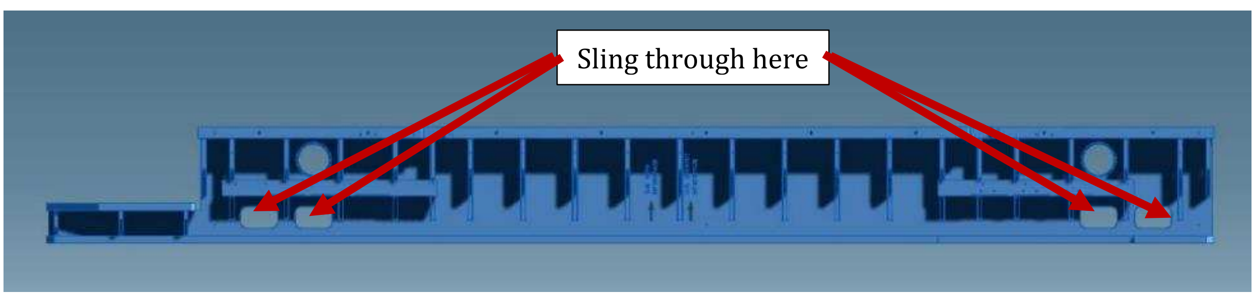


Figure 4: Sling locations

5. Once the HGVPU is fully assembled, it is desirable to use the lifting cradle designed for it, but slings through the rectangular holes, in conjunction with an H-shaped spreader bar to keep the slings away from the spring cages and motors, may also be used. Blocks of wood/plastic may be used to keep the slings away from the wiring, and weighted blocks may be used to keep the assembly level.

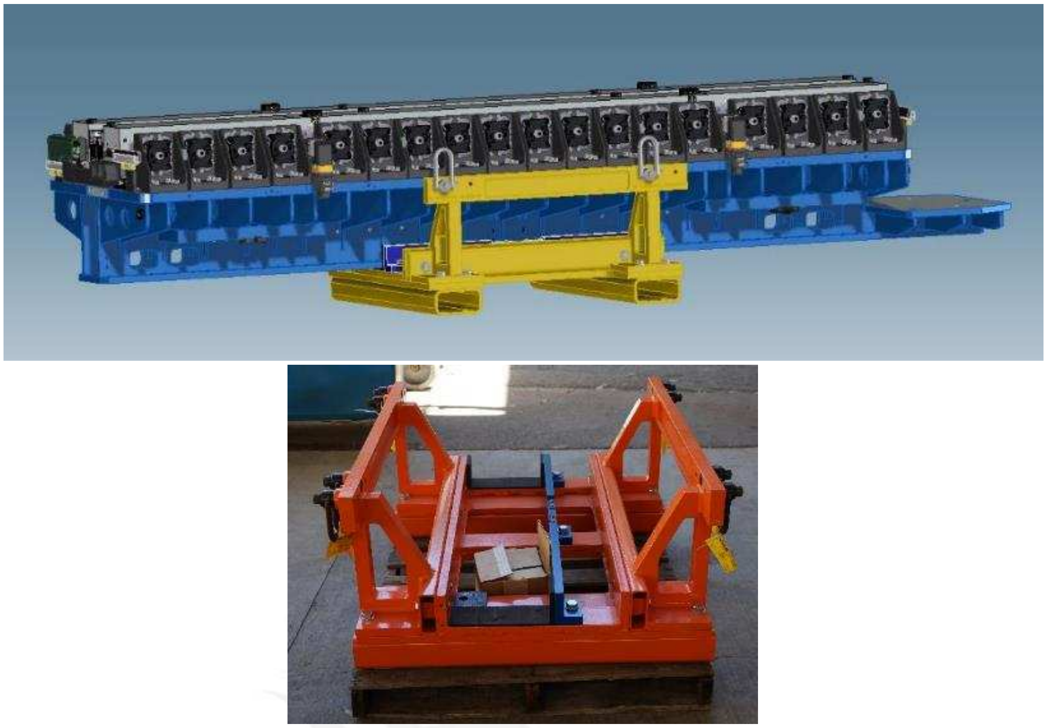


Figure 5: Full HGVPU with cradle (top), cradle alone (bottom)

Figure 6: Lifting with H-shaped spreader bar & slings – including chainfall and lead bricks to keep level.

6. During assembly steps not completed on the CMM, the girder may rest on the beam running the length of the bottom. Clamps, screws and/or jacks may be used to ensure stability as necessary.

NOTE: For good ergonomics, the top of the girder should be at approximately waist height on the primary technicians, and the total height (support + girder + strongbacks) should be below armpit height of technicians to facilitate reaching over the strongbacks. The girder is ~15" (387.15 mm), the strongback assemblies add ~10". Waist height is generally around 35"-40" (890-1000 mm), so recommended support height is 20"-25" (500-635 mm).

Figure 7: Pre-production undulator supported on the beam running the length of the bottom with jacks and clamps (not visible).

7. Install M6 locating pins according to drawing 29H947. Note that the four (4) pins at the outer end of the linear bearing should be sunk deeper due to the counterbore. This allows the carriage to slide on and off for assembly.

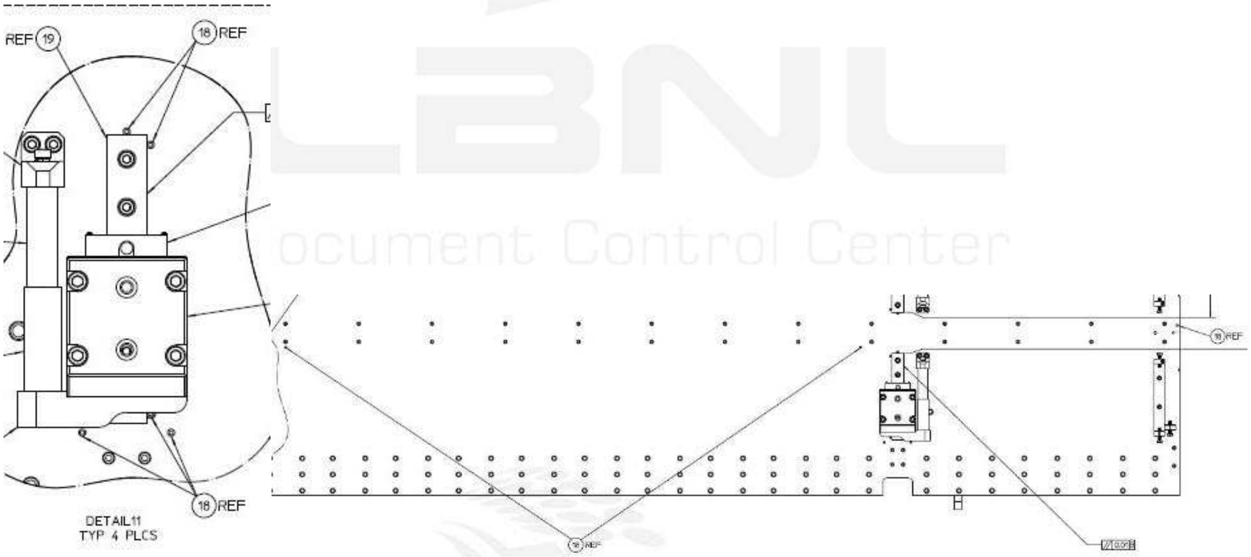


Figure 8: Parts of 29H947 Rev D that show where to place locating pins. Always use most recent revision of drawing.

8. Ensure that the girder has been inspected on a CMM while supported as shown in Figure 3 and the report has been provided to LBNL.

VERIFICATION POINT 1

3 Install Linear Bearings (Dwg 29H947)

9. There will be four linear bearings in the locations shown.

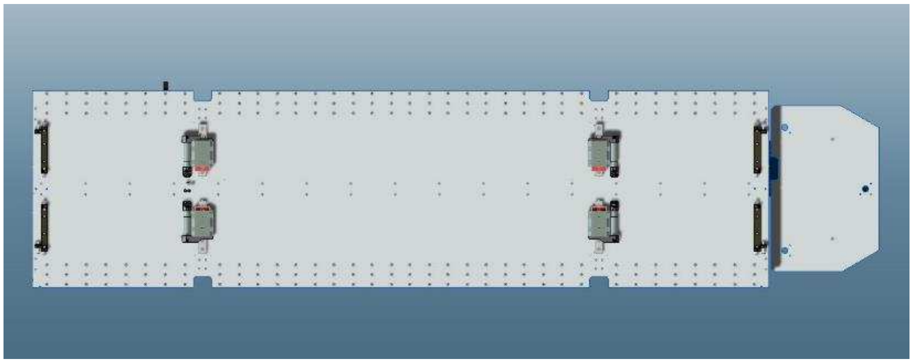


Figure 9: Linear bearing with constant force springs on girder.

10. It is absolutely critical that the linear slides are parallel within the system, otherwise the strongback assemblies will bind. The drawing calls for the position to be within ±0.05mm and parallelism to be within 0.01 mm. We recommend assembling on the CMM (supported as in step 3).

11. The Schneeberger rails are delivered with the carriage already on the rail. Carriages can be removed to allow easier access to all bolts using plastic rail extension shipped with rail and carriage.

    <u>Note:</u> If the carriages are removed from the rails be certain that they are reassembled to the same rail they were removed from.

    If carriages are not removed, ensure that you place rail-carriage assembly in correct orientation, see below.

12. The carriages were provided with wipers that add too much friction. Remove the wiper and replace with the endcap that does not touch the rail.

13. Attach the rail segment to the girder using six M8 screws per rail segment. Do not torque all the way yet.

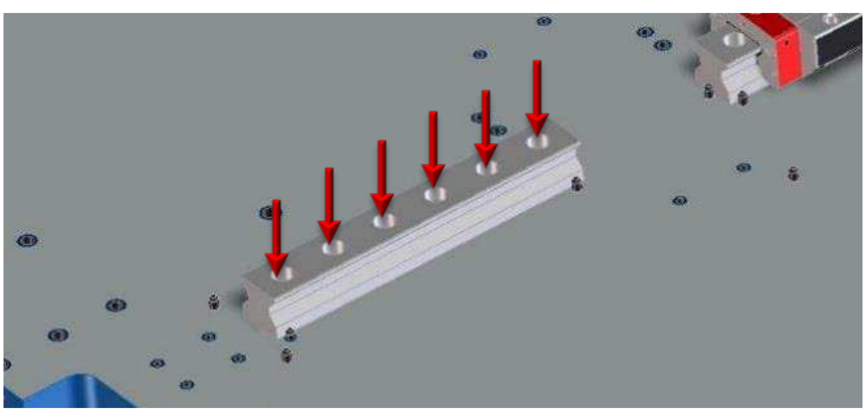


Figure 10: Attach Schneeberger rail to girder

14. Measure the location and parallelism of the linear bearing rails on the CMM, using at least 2 points per rail.
15. Adjust rails according to CMM measurements. Shim at the pins to maintain new location.
16. Re-measure & re-shim as necessary
17. When rail position is in tolerance according to drawing 29H947, torque screws to 36.6 Nm (27ft-lbs).

VERIFICATION POINT 2

18. Re-measure, and create report to send to LBNL verifying position and parallelism of rails.

VERIFICATION POINT 3

19. Once the rail section is in place, the carriage can be replaced if it was removed (the carriage needs to be paired with the same rail it came with, see note in step 11). Orient the carriage such that the precision ground side of the carriage faces upstream.

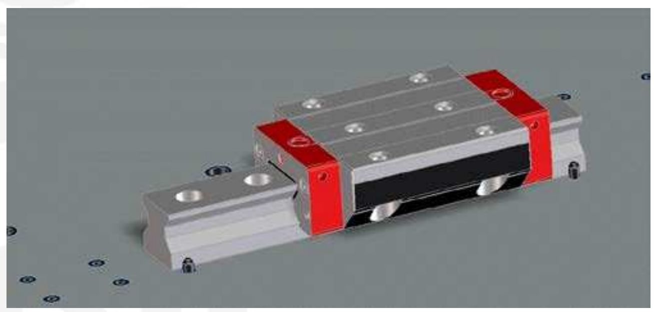


Figure 11: Downstream side (left) and upstream side with precision ground portion of carriage (right).

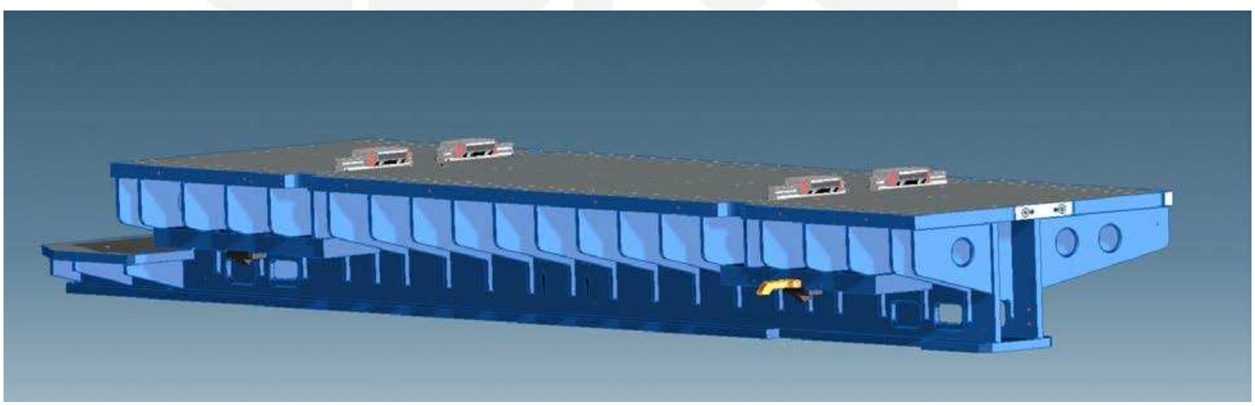


Figure 12: Precision ground side of carriages pointing upstream

20. Use Mobil XHP 222 grease (may be either blue or gray in color) to grease the carriage and rails. Slide the carriage back and forth to ensure full rail is greased.

Figure 13: Grease for the rails

21. With the carriage in place, the strongback flexure (29L222) can be installed with four M10 screws 36.6 Nm (27 ft-lbs). Align the precision ground edge of the carriage with the side of the flexure. Orient so the holes on the end face outward. Repeat for all 4.

VERIFICATION POINT 4

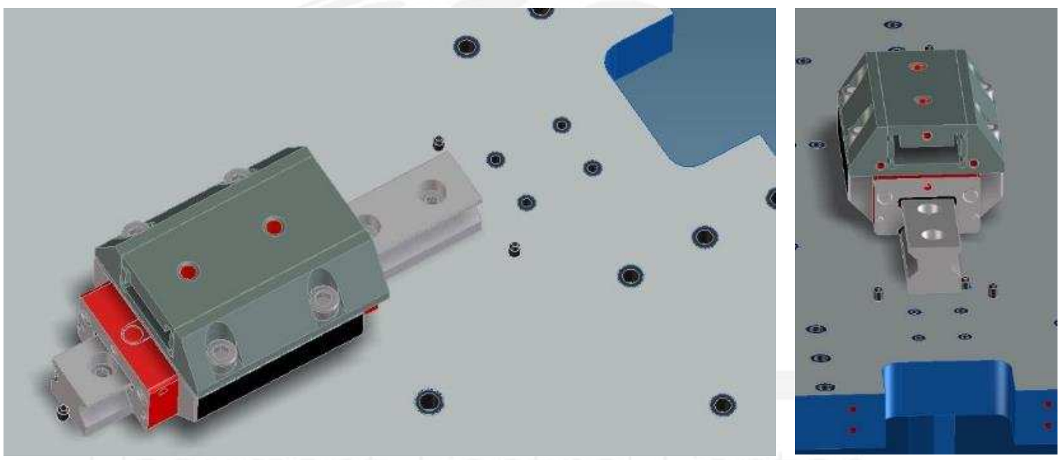


Figure 14: Attach strongback flexure to the Schneeberger carriage.

22. Assemble the constant force spring according to drawing 29H947. Lubricate the Spring Guide Rod (29L038) and screw it into the larger Spring Guard Weldment (29L036). Torque to 21.2 Nm, 15.6 ft-lbs, use thread locker.

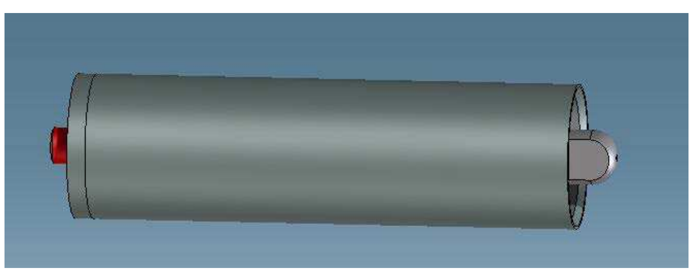


Figure 15: Spring guide rod in spring guard weldment

23. Screw smaller Spring Guard Weldment (29L037) to the Spring Cup Bracket (29L035) (torque spec 21.2 Nm)

24. Coat the spring liberally with grease and slip the lubricated spring over the spring guide rod.
25. Lubricate the outside of the smaller spring guard weldment and slide it over the spring.
26. Fit the corresponding Carriage Bracket (29L034 or 29L039) over the spring guard weldment.
27. With Spring Cup Bracket loosely mounted with screws, use clamp or fixture to compress spring assembly at least halfway, and attach the Spring Cup Bracket to the Girder with 2 screws. (torque spec 21.2 Nm – lock washers used)
28. Fit the Carriage Bracket up against the linear bearing flexure and fully actuate the spring assembly to ensure smooth motion and no surface friction, binding, or scratching between the weldment tubes.

VERIFICATION POINT 5

29. Do not attach the Carriage Bracket yet. Spring will be attached to linear bearing flexure after motors are mounted.

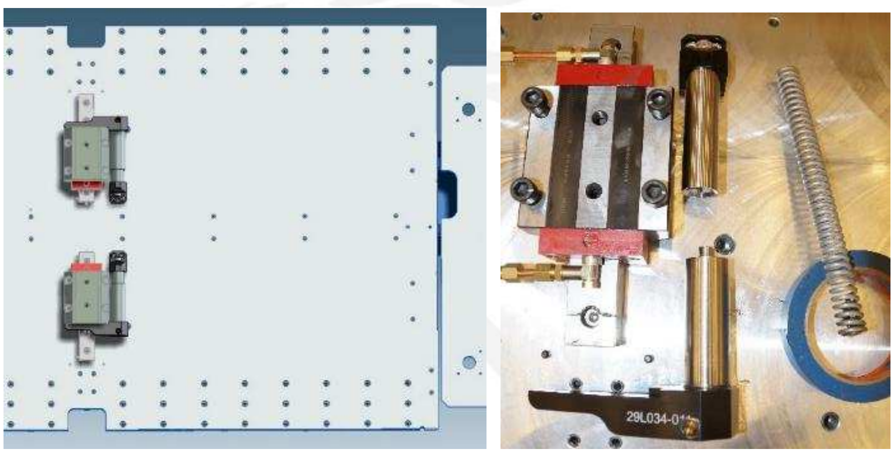


Figure 16: Constant force springs assembled next to carriages (left) constant force spring parts (right)

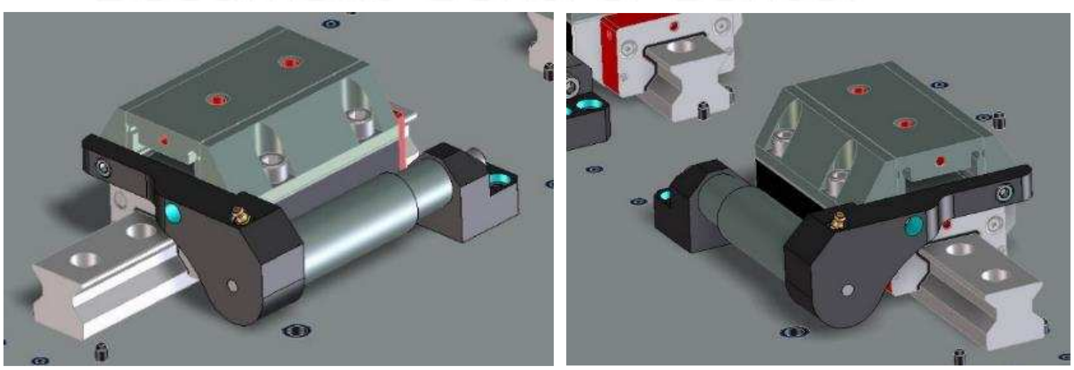


Figure 17: Carriage bracket 1, 29L034 (left) and carriage bracket 2, 29L039 (right)

30. Install grease system fittings to carriages and carriage spring brackets per drawing 29H948 (parts #4-10 on 29H948). Do not connect grease manifold and upper half of grease system assembly. Those will be connected during Strongback installation.

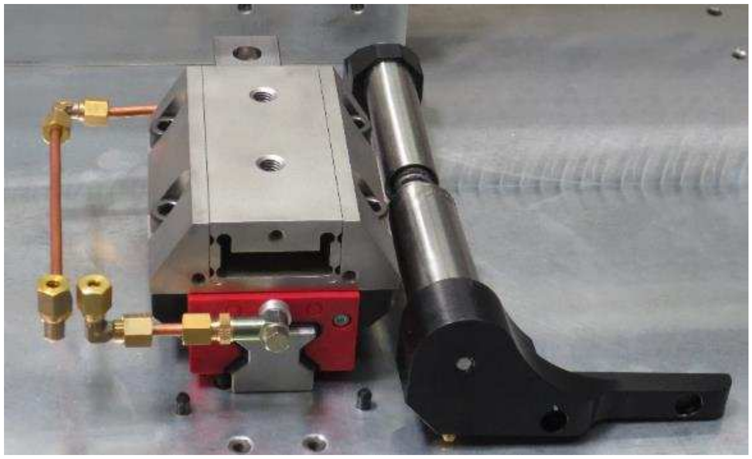


Figure 18: Grease system fittings attached, spring assembled and detached.

4 Install Hard Stop Bases (Dwg 29H947)

31. Install hardstop bases (29K387 and 29H953) in the four locations as shown on 29H947. Torque to 15 Nm.

32. Ensure the bolts do not protrude too far over the hardstop base, so that there is sufficient room to place the strongbacks.

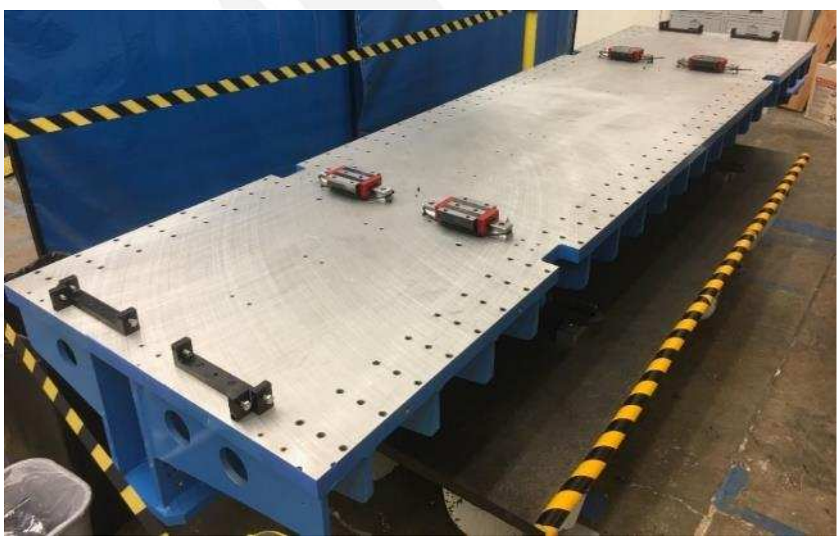


Figure 19: Four hard stop bases installed on pre-production girder.

5 Install Magnetic Modules and Other Attachments to Strongbacks (Dwg 29H896 and 29H897)

5.1 Set Up

CAUTION: STRONG PERMANENT MAGNETS.

When magnets are installed in modules, the two largest risks are 1) that the magnetic field will interfere with an implanted medical device or 2) that a tool will be attracted to the magnets and strike with enough force to shatter the magnets, which are brittle. The secondary risk is scratching, denting, or chipping the magnets enough to change their performance.

Avoid the use of ferromagnetic tools. Remove all objects from your person which might have ferromagnetic material (i.e. watches, keys) or might be affected by the magnets (i.e. credit cards, phones) before working. Tie glasses on securely. Wear safety glasses. Cover magnets with 1" thick foam and protective covering whenever possible. Stay away from magnets if you have an implanted medical device.

33. Ensure that 2 strongback inspection reports have been uploaded to Windchill.

VERIFICATION POINT 6

34. Ensure that one complete set of 6 magnet modules is available and has not been damaged during shipping. Check that all magnet-pole shims are present. Check that in the modules ending in a magnet, the magnet is proud of the keeper (or at least not recessed).

VERIFICATION POINT 7

35. Identify which module goes in which position.

The following are the drawing numbers and drawing titles.

29H881 – Entrance Module Left	**29H893 – Entrance Module Right**
29H872 – Center Module Left	**29H894 – Center Module Right**
29H882 – Exit Module Left	**29H895 – Exit Module Right**

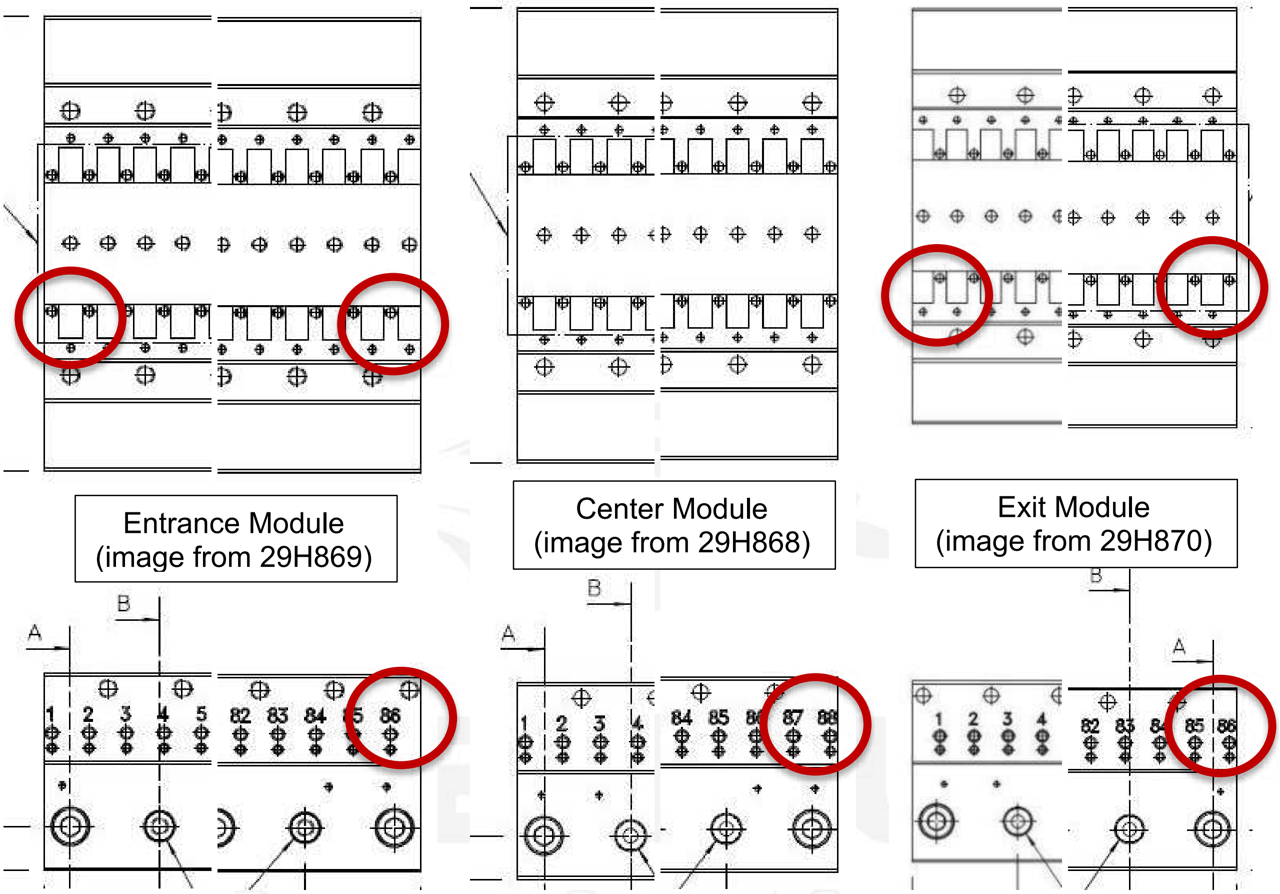
NOTE: Due to an issue with final measurements at SLAC, the raised final magnet module label cannot be on top. Previous versions of the drawings had "left" and "right" switched. Refer to Revision D (or later) for correct left/right designation.

Differences between Entrance Module Keeper, Center Module Keeper, Exit Module Keeper

Entrance Module Keeper starts with a pole, ends with a magnet, and has 86 poles

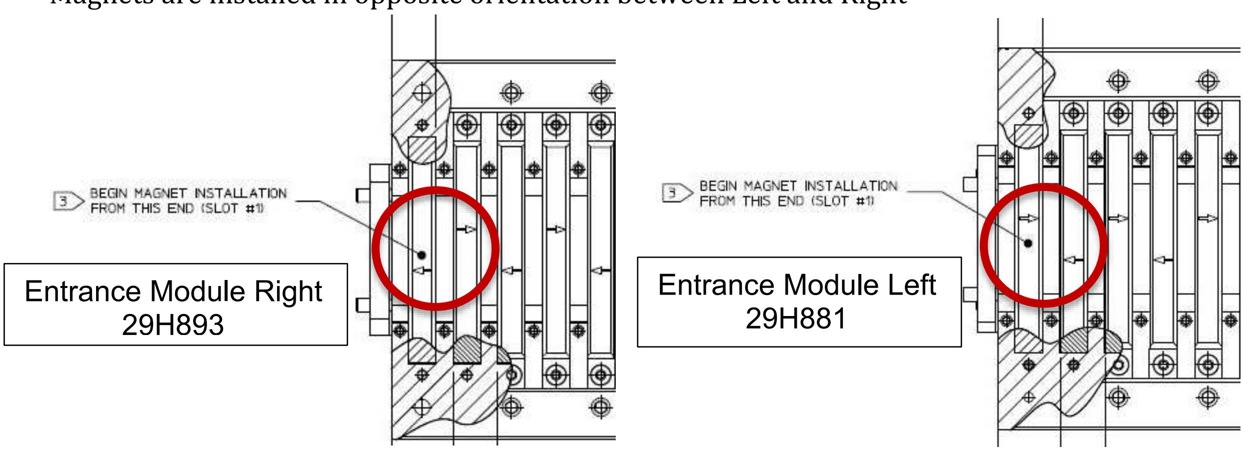
Center Module Keeper starts with a pole, ends with a pole, and has 88 poles

Exit Module Keeper starts with a magnet, ends with a pole, and has 86 poles



Difference between Entrance Module Left and Entrance Module Right (applies to center and exit modules as well, consult drawings)

Magnets are installed in opposite orientation between Left and Right



36. Sit the strongback upright such that the magnet modules will rest on the tabs due to gravity.

Figure 20: Strongback in upright position, resting on blocks

37. Ensure that the eight M6 pins, four M8 inserts and eight M6 inserts have been installed according to the strongback drawing 29H914.
38. Clean the module mating surface on the strongback.
39. Install 96 box flexures (29L287) into the pockets. They should flex in the Z-direction, so the openings should be at the top and bottom. They should only fit in the correct orientation.
40. Once all modules are installed, you should be able to fit a 0.002" feeler gauge into the gap between module and strongback. The box flexures should protrude by 0.005" at this stage to achieve this.

Figure 21: Check parallelism of box flexures

41. Check the parallelism of each box flexure to the strongback mounting surface (use a gauge block). Replace any box flexure that is not parallel with another one.

VERIFICATION POINT 8

42. Prep each bolt (part #17 on 29H896 and 29H897) with a washer (part #19 on 29H896 and 29H897), and lubrication.

43. Insert all 96 lubricated M6 bolts into the counterbores on the back of the strongback.
44. Install all 18 nested springs (part #11 on 29H896 and 29H897) into the counterbores on the mating side of the strongback.

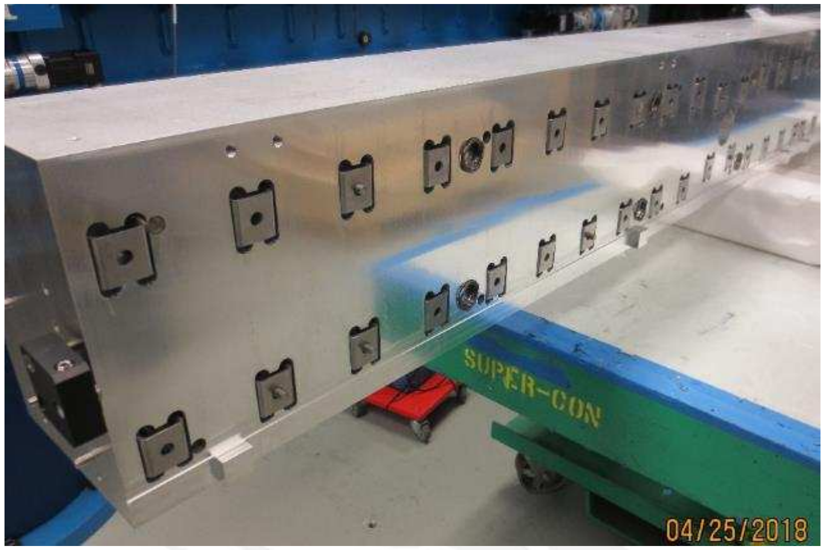


Figure 22: Box flexures, nested springs and bolts inserted.

45. Both strongbacks are identical (29H914), but the entrance module is placed in a different position depending on whether the strongback is the left or the right strongback (see figure below). Each module has an arrow indicating the beam direction (Z-axis). It is recommended that you draw the beam direction on the strongbacks to ensure correct orientation and placement of the modules.

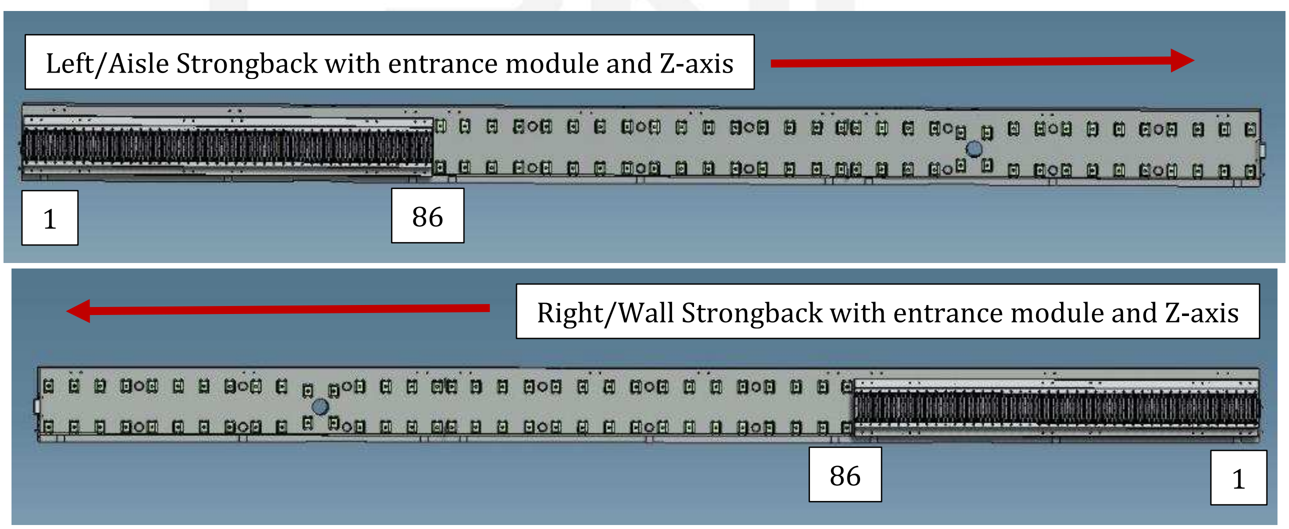


Figure 23: Entrance module is placed where the beam enters the undulator, which is different based on right or left strongback. Draw beam direction for clarity. Pole 1 of the entrance module is at the end of the strongback.

5.2 Entrance Module

46. Get the correct entrance module for the strongback currently being built (refer to section 5.1, and remember the serial number label should point down). Check the Entrance Module bottom mating surface for cleanliness.

47. Put fixture at end of strongback to maintain the 4.98 mm distance from the front face of the strongback within in a tolerance of +/- 0.05mm.

48. Place Entrance Module onto the Strongback, and secure by engaging the M6 bolts through the back of the strongback. Use assembly drawings 29H896 or 29H897 depending on left or right assembly (Strongback orientation will flip for each assembly).

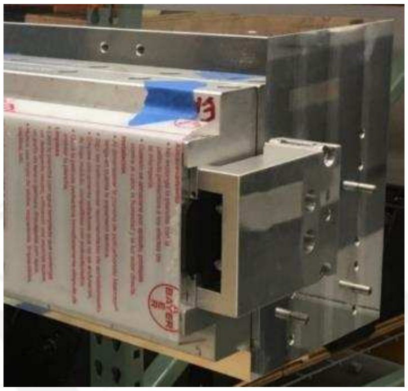


Figure 24: Fixture for maintaining 4.98mm offset.

49. Push the Entrance modules up against the fixture that controls its Z-position.

50. Tighten the M6 bolts to finger-tightness.

51. Verify the 4.98mm gap has been maintained, then torque the bolts to 50 in-lbs. The torque should be applied starting at pole #44 and working outwards. (See Figure 25).

52. When finished with torqueing from the center, re-torque all module bolts again from one end.

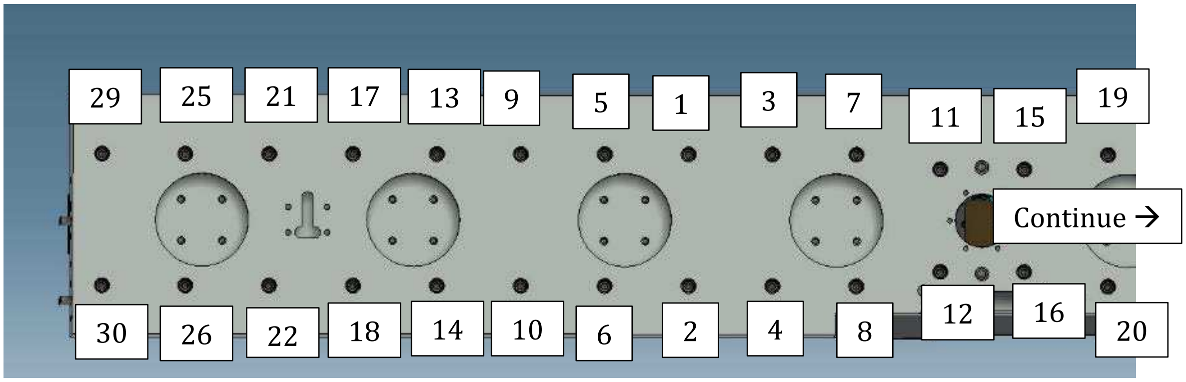


Figure 25: Torque from the center outwards.

VERIFICATION POINT 9

5.3 Center Module

53. Check the Strongback surface again for cleanliness and ensure none of the box flexures or springs has fallen out.

54. Pick the correct center module for the strongback currently being assembled. The magnet pattern should continue across module junctions.

55. Check Center Module bottom mating surface for cleanliness.

56. Remove keeper end plate (29H874) from the ends of the entrance and center module which will be touching.

57. Place Center Module onto Strongback about an inch away from the Entrance Module making sure not to bump them into each other. Pole 1 of the center module should be next to pole 86 of the entrance module and the arrows on the module should match each other.

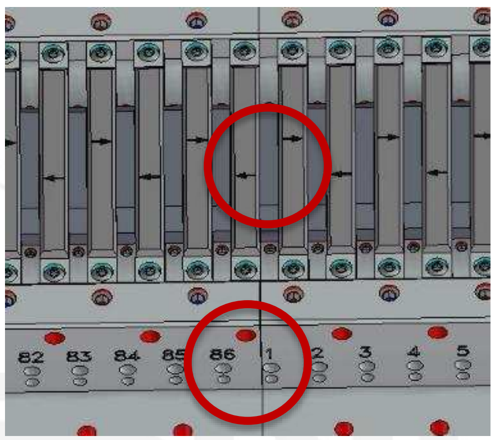


Figure 26: Entrance module to center module interface

58. Once Center Module is on the Strongback, use soft rubberized clamps or loosely engaged M6 bolts to temporarily keep module from falling off.

Figure 27: Non-ferrous, soft, rubberized clamps used to keep module on strongback (Exit module pictured).

59. Before pushing the Center Module towards the Entrance Module, place two 0.006” hardened brass shims in between the two modules towards the outer edges. As the Center Module slowly approaches the Entrance Module, temporarily place a 0.001” shim in between the mating pole and magnet from each module. While gently sliding the shim back and forth between the pole and magnet, keep pushing the Center Module closer until the shim has a nice amount of “drag.” Use fixture to push on the module.

Figure 28: Example fixture to push the module into place.

60. If the two 0.006” shims between modules are loose add appropriate shim thickness to ensure a snug fit. Note down the actual shims used (it is okay to mark the junction itself with sharpie or similar). (This shimming prevents the modules from becoming so tight that the pole is squeezed, preventing it from being adjustable during tuning).

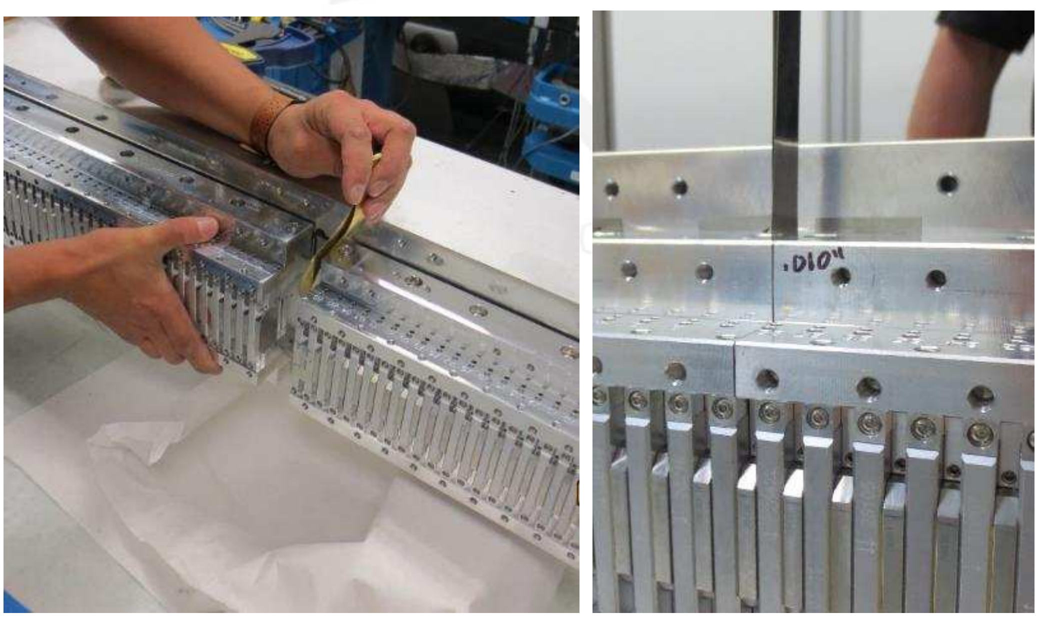


Figure 29: Push new module towards already attached module with both keeper and magnet shims in place. Note actual shims used.

61. Once the junctions between modules has been established and maintained, tighten the M6 bolts until they are “finger-tight.”

62. Check that a 0.002" shim does not fit between the pole and magnet between the 2 modules.
63. Torque the bolts to 50 in-lbs. The torque should be applied starting at pole #44 and working outwards.
64. When finished with torqueing from the center, re-torque all module bolts again from one end.
65. This concludes the Center Module installation. Note that both the 0.001" and 0.006" shims will be removed for all CMM measurements and re-inserted for all adjustments.

VERIFICATION POINT 10

5.4 Exit Module

Repeat the procedure for the exit module.

66. Check the Strongback surface again for cleanliness.
67. Ensure none of the box flexures or springs has fallen out.
68. Pick the correct exit module for the strongback currently being assembled. The magnet pattern should continue across module junctions.
69. Check Exit Module bottom mating surface for cleanliness.
70. Remove keeper end plate (29H874) from the ends of the center and exit module which will be touching.
71. Place Exit Module onto Strongback about an inch away from the Center Module making sure not to bump them into each other. Pole 1 of the exit module should be next to pole 88 of the center module and the arrows on the module should match each other.

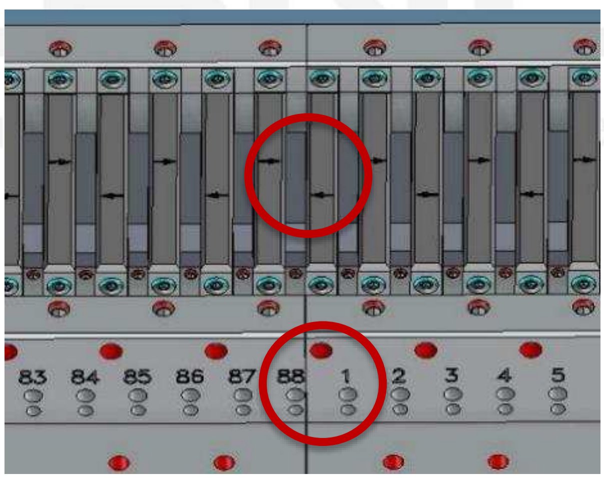


Figure 30: Center module to exit module interface.

72. Use soft rubberized clamps to keep module from falling off.
73. Place two 0.006" hardened brass shims in between the two modules towards the outer edges. As the Exit Module slowly approaches the Center Module, place a 0.002" brass shim (29L045) in between the mating pole and magnet from each module.

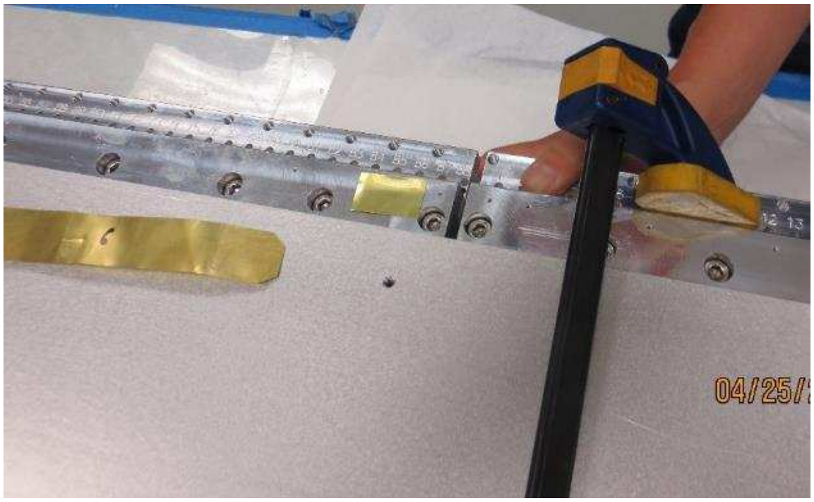


Figure 31: 0.002" and 0.006" shims ready to be placed into gap

74. Gently slide the shim back and forth between the pole and magnet, while pushing the Exit Module closer until the shim has a nice amount of "drag." If the two 0.006" shims between modules are loose add appropriate shim thickness to ensure a snug fit. Record the actual shim thickness used.
75. Make sure M6 bolts are "finger-tight."
76. Check that a 0.004" shim fits between pole and magnet and a 0.005" shim does not. Ensure the final 0.002" brass shim is in place.
77. Torque the bolts to 50 in-lbs. The torque should be applied starting at pole #44 and working outwards. Re-check the center bolt torques after getting to the ends.
78. This concludes the Exit Module installation. Note that the 0.006" shims will be removed for all CMM measurements and re-inserted for all adjustments.

VERIFICATION POINT 11

5.5 Other Attachments

79. Check that magnet orientation pattern continues over module gaps, all orientation arrows point in the same direction, correct modules are installed as per section 5.1, entrance module is in correct position per Figure 23, and you can get a 0.002" feeler gauge between modules and strongbacks.
    a. Photograph the 0.002" feeler gauge going between modules and strongbacks and attach it to the verification sheet

VERIFICATION POINT 12

80. Record the junction shim values in the verification sign off sheet.

VERIFICATION POINT 13

Because tightening screws can deform the strongback at the micron level, all parts that screw in to the strongback must be attached prior to making CMM measurements. This includes 1) the load cells and ball screw mounting plate for the motors, 2) the fiducial nests and 3) the spring cage plungers.

81. Attach loadcells to loadcell reader and check that all the loadcells are functioning.

Figure 32: Array of loadcell readers

82. Attach 8 loadcells (2x motor location) to the strongbacks and tighten until the loadcells are snug against the strongback and read 4-5 N. Use Loctite 242 and paint mark.

83. Record the load values (excel, photograph ok).

VERIFICATION POINT 14

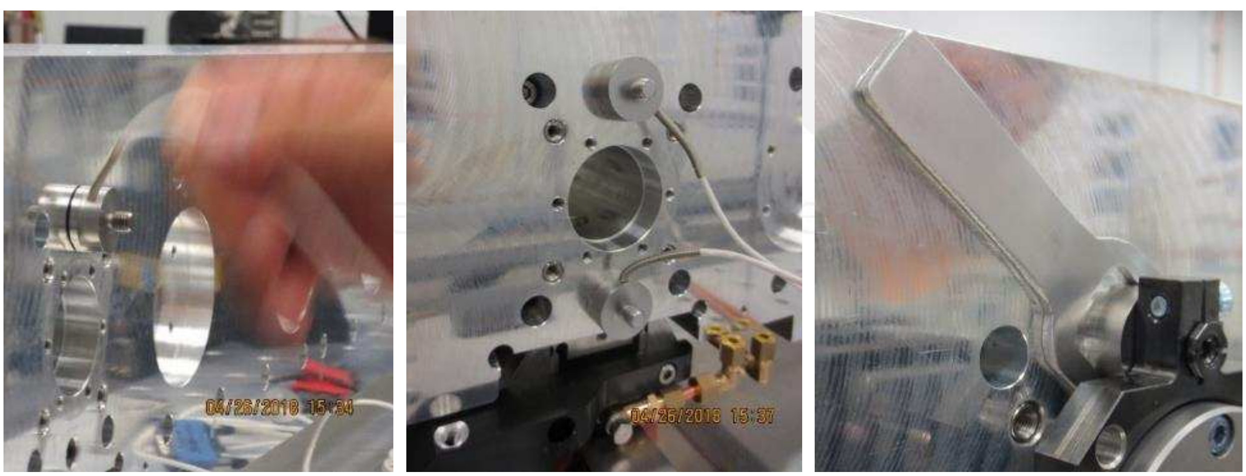


Figure 33: Attaching load cells (left) load cells attached (center) use flat wrench (right).

84. Attach the ball screw mount (29H924) to the strongback with 6 shoulder screws. Use Loctite 242 and torque to 10 in-lbs. Paint mark. **Note:** these are not meant to rigidly mount the ball screw mount to the strongback, they should allow ~0.5 mm of motion.

85. Loosely attach the 2 loadcell clamp posts (29H979), the set screw and the clamping M6 screws and washers. These will be tightened when the motors are attached.

Figure 34: Ball screw mount attached to strongback and loadcells.

Fiducial Nests

86. Attach 8 Brunson 1.5THD-B drift nests to girder according to drawing 29H948, using a bolt and epoxy.
87. Attach 4 Brunson 1.5THD-B drift nests to each strongback with bolt and epoxy, according to drawing 29H948.
88. Attach 4 fiducial drift nest mount post with welded on 0.5THW drift nests (29K240) to the back side of each strongback. Torque to 40 in-lbs. Use Loctite 242.
89. Label all fiducial nests. See Figure 92.

Spring Cage Plungers

90. Attach 18 spring cage plungers without the spring cage to the back of the strongback. Use 4 bolts with Belleville washers (400 lb flat load). Torque to 40 in-lbs. Use Loctite 242 and paint mark.

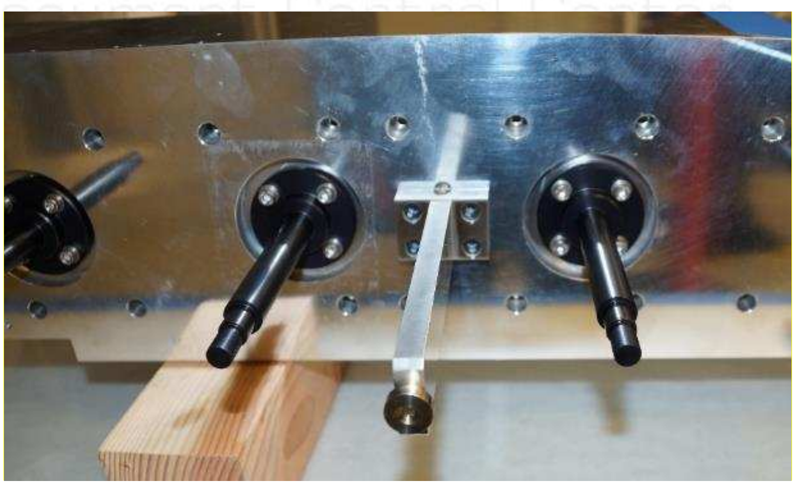


Figure 35: Fiducial posts and spring cage plungers mounted on strongback.

The Strongback assembly is now ready to be measured and adjusted.

6 Take CMM Measurements of the Strongbacks

91. All poles must be coplanar with each other within ±10 μm, and the magnets should be recessed compared to the poles by 140±70 μm.

92. Support the strongback as it will be on the girder. **IMPORTANT: The strongback must be oriented to the CMM the same way as it will be when it is measured on the girder. Flipping 180° amplifies CMM errors.**

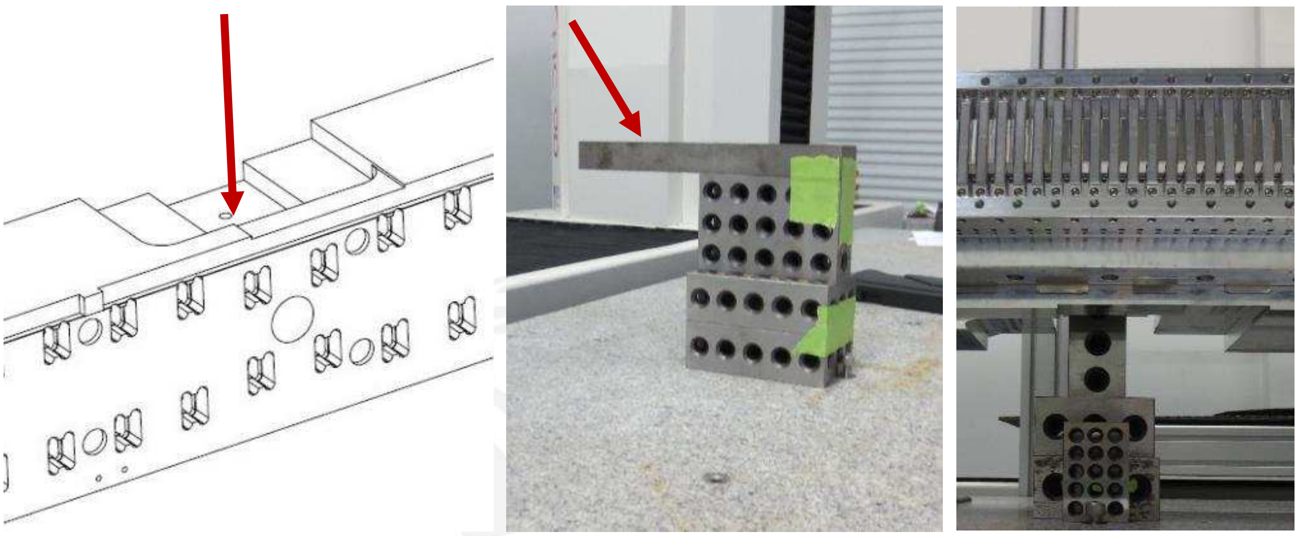


Figure 36: Primary Datum – take at least 3 points on each of the 2 surfaces that mate with the flexure (or the precision block supporting those surfaces)

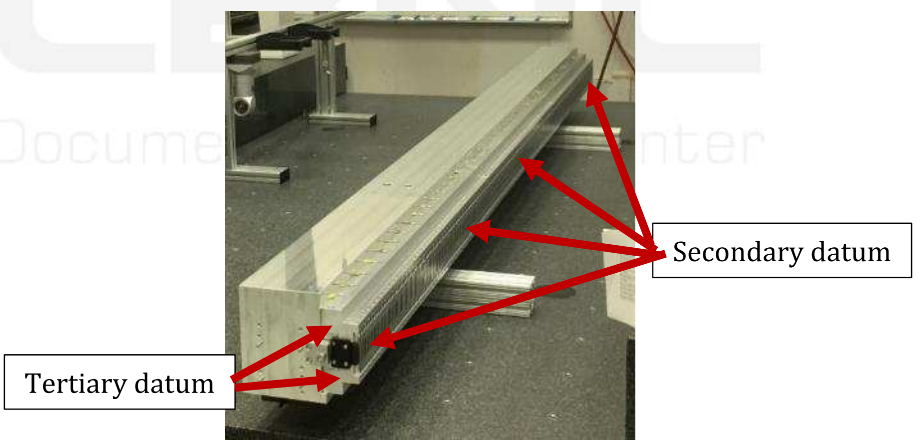


Figure 37: Strongback on CMM.

93. Set up the coordinate system as follows:

    a. Primary datum feature: Take several points (at least 3) on each of the 2 surfaces that mate with the flexure, and make a best fit plane. This feature sets the vertical axis

b. Secondary datum feature: A best fit of the "top" (the exposed side) of the poles. Take 2 points on 10% of the poles and take a best fit line parallel to the primary datum. See figure. This feature MUST NOT set the vertical axis.

c. Tertiary datum feature: The end of the keeper

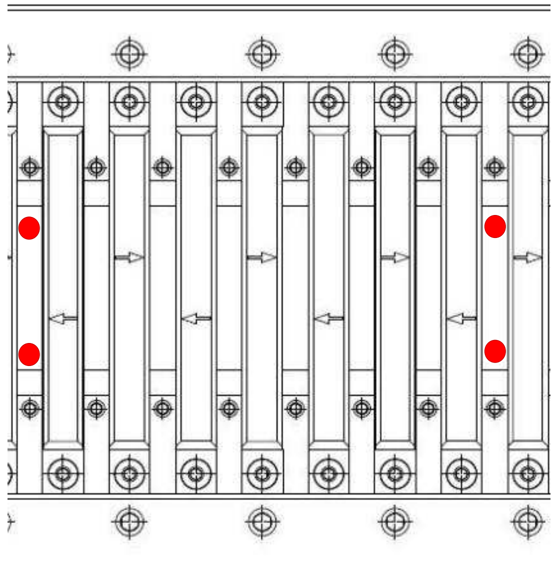


Figure 38: Take 2 points per pole.

94. The axes should be set up as follows:

a. Z-axis is the beam direction (same direction as the arrows on the side of the keepers)

b. X-axis is pointing from strongback to modules so that pulling a pole out of the module is moving the pole in the positive X direction.

c. Y-axis is the direction that makes the coordinate system right-handed, i.e. up for the right/wall strongback and down for the left/aisle strongback.

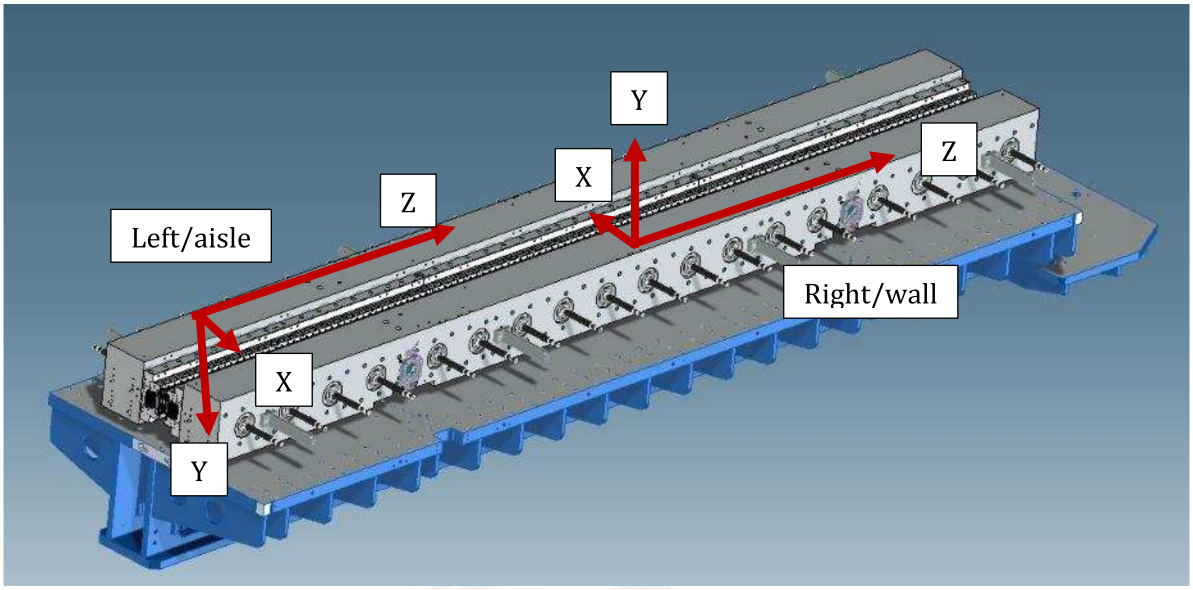


Figure 39: Coordinate system for individual strongbacks.

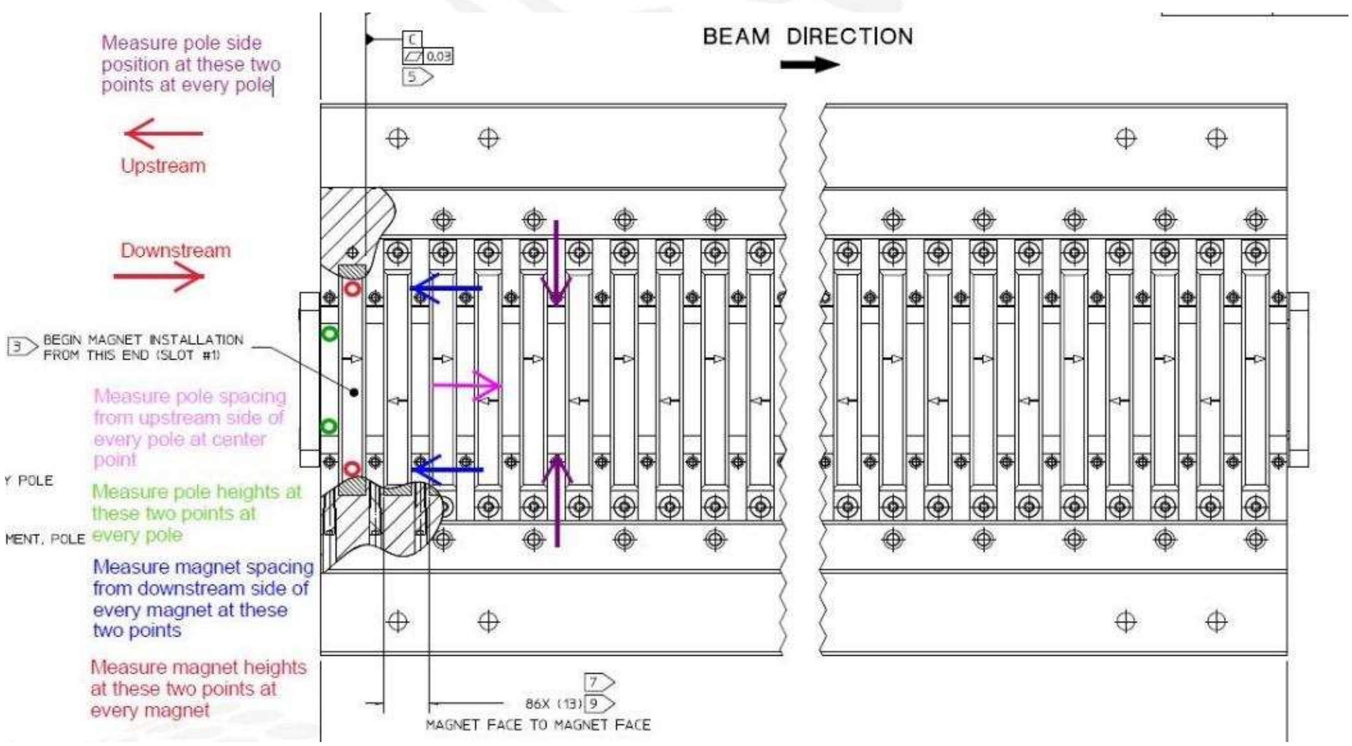


Figure 40: Where to measure the pole height, magnet height, and pole side.

95. Measure the following (initial and final measurement only, intermediate measurements have an abbreviated CMM program, see step 100):
    a. The X-dimension of each pole, measured at 2 points (green dots, see figure above).
    b. The X-dimension of each magnet, measured at 2 points. (red dots, see figure above)

c. Pole side distance from the primary datum, measured on the top side of the pole, at shim locations (see table) – the poles should all be within 300 µm of each other. The average of each module should not be offset from the average of the other 2 modules by more than 200 µm. (purple arrow, top side only)

d. The longitudinal (Z-dimension) of the magnet measured from the downstream side, at shim locations, measured at 2 points (blue arrows). Each should be within ±50 µm of their position compared to the 1st magnet (i.e. number of magnets away times 13 mm period).

96. Record the initial measurements in excel (.xlsx) format and put the file on Windchill.

VERIFICATION POINT 15

97. Inspect the data. Use the shimming software ("Shim_Map_Analysis_v17" or most up-to-date version) to create a shim map.
    a. Open the program.
    b. Select a folder to save the output files
    c. Set "File Format" to correct company's CMM output file format.
    d. Press "Load Individual Strongback Data" & follow in-program instructions for left/right & iteration #
    e. Press "Create Shim Map"
    f. Press "Output Shim Map"
    g. The output files are "shim_data_L/R##" and "shim_map_L/R##". The "shim_map" file is your shim map. Do a sanity check on the signs: +/- should be add/remove, check that this makes sense based on your data.

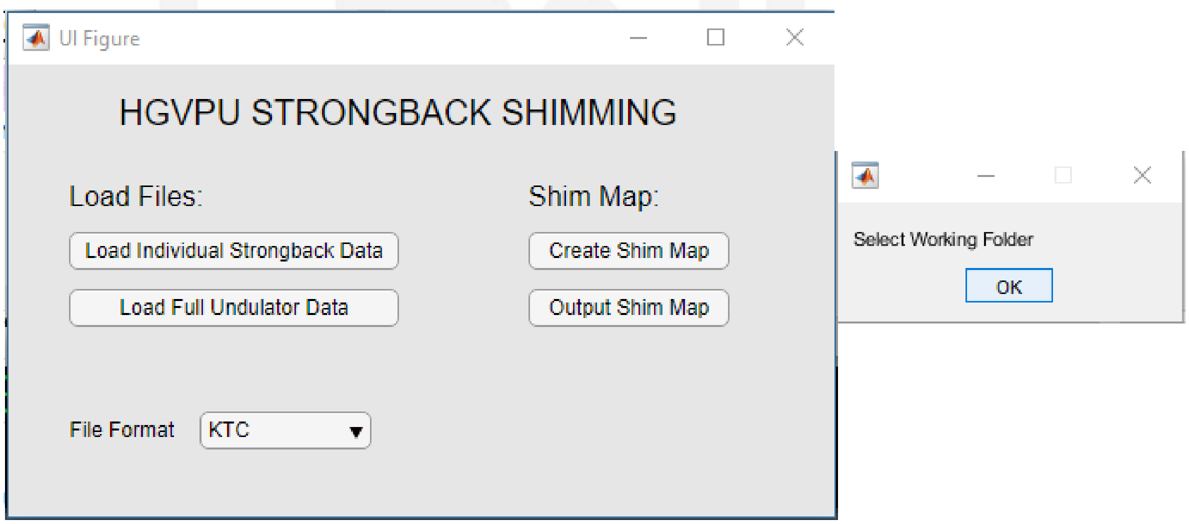


Figure 41: "Shim_Map_Analysis" opening window

98. Inspect the pole side distance and longitudinal measurements and determine what needs to change to be brought into tolerance. (Shims between the tabs the modules rest on and the modules, different junction shims). Make these changes during the shimming steps below.

99. Shim between the strongback and magnet modules to adjust pole and magnet heights and bring them into tolerance.
    a. Insert the junction shims in all the module junctions, and install the end fixtures to keep the Z-position of the modules.
    b. Loosen the entire module, or all 3 modules.
    c. Perform the shim adjustments
    d. Use part 29H926 to push the modules against the keeper position plate.
    e. Torque the center module from the center towards the edges, then torque the exit and entrance module, starting at the center and working towards the edges.
    f. Remove the junction shims between entrance and center keepers, and between center and exit keepers, remove the end fixtures, and check that there are no 0.001" magnet/pole shims between the entrance and center magnet modules.

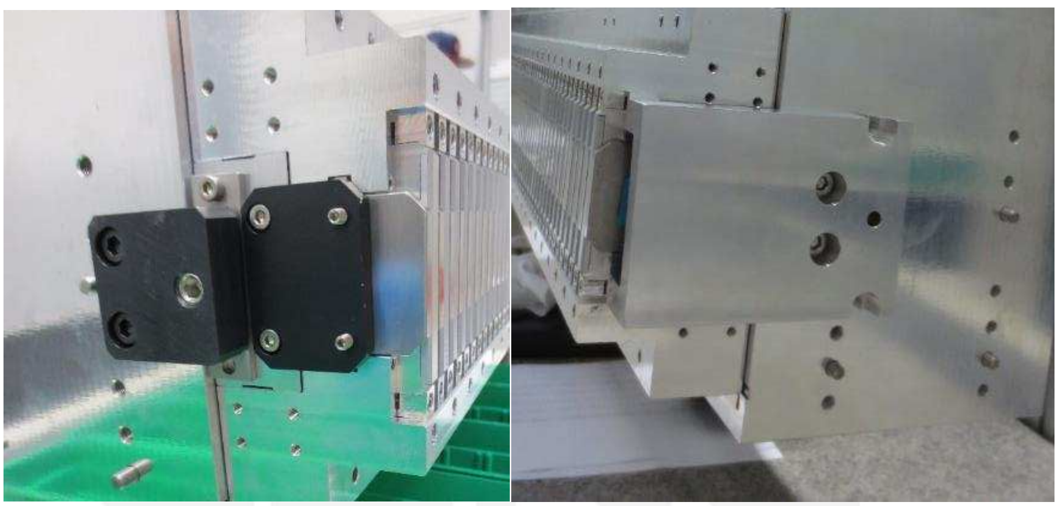


Figure 42: Install end fixtures to keep the Z-position every time modules are loosened.

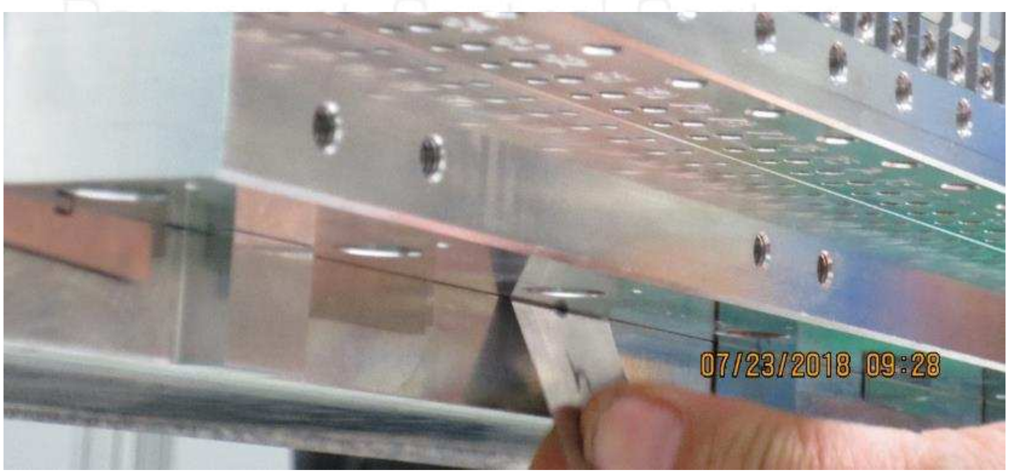


Figure 43: Perform shim adjustments

100. For subsequent iterations, just measure 2 points per pole at shim locations. See table for pole numbers corresponding to the shim locations. Measure pole side distance and longitudinal dimension of the magnet only if previous measurement was not in tolerance.

Pole Number Corresponding to Shim Location			
	Entrance Module Pole Number	Center Module Pole Number	Exit Module Pole Number
1	2	2	2
2	8	8	7
3	13	13	13
4	19	19	18
5	25	25	24
6	30	30	29
7	36	36	35
8	41	42	40
9	47	47	46
10	52	53	51
11	58	59	57
12	63	64	63
13	69	70	68
14	74	76	74
15	80	81	79
16	85	87	85

101. Adjust any individual poles that still do not meet the requirements after shimming, refer to the Magnetic Assembly Work Instructions (HGVPU-WI-29H881).

102. Continue making adjustments until the following tolerances are met (**Note: If this takes more than 3 iterations, contact LBNL to discuss**):
   a. Verify that no magnets are sticking out further than the poles.
   b. Ensure that the 140 µm difference between pole heights and average magnet height is maintained, and there are no abrupt jumps in magnet height.
   c. Verify that the Y-position of the poles is within 300 µm of each other.
   d. Ensure that the poles are within ±10 µm co-planarity
   e. Ensure the poles are within ±10 µm perpendicularity to the primary datum feature. (Minimize roll)

103. Steps (d) and (e) above will be checked by the "Shim_Map_Analysis" program, which will put a slight "W" or "M" shape into the strongback to compensate for magnetic forces.

104. Ensure the junction shims and end fixtures have been removed before performing any CMM measurements. If they are present, the CMM data is not valid and must be repeated.

105. When all the poles are coplanar, re-measure everything, record the final measurements in excel (.xlsx) format and put the file on Windchill.

VERIFICATION POINT 16

7 Install Strongbacks to Girder-Slide Assembly (Dwg 29H948)

Figure 44: Gap centering fixture and one strongback on girder.

106. Put gap centering fixture in the middle of the girder on the vacuum chamber alignment pins.

Figure 45: Strongback position plate fixture at end of girder.

107. Put the strongback position plate fixture (29L036) (or equivalent) at the upstream end of the girder. If strongback pole spacing positions did not match, add appropriate shims to this fixture.

108. Install hard stop upper component on strongback according to drawing 29H948 (M6 screws torque to 8.7 Nm).

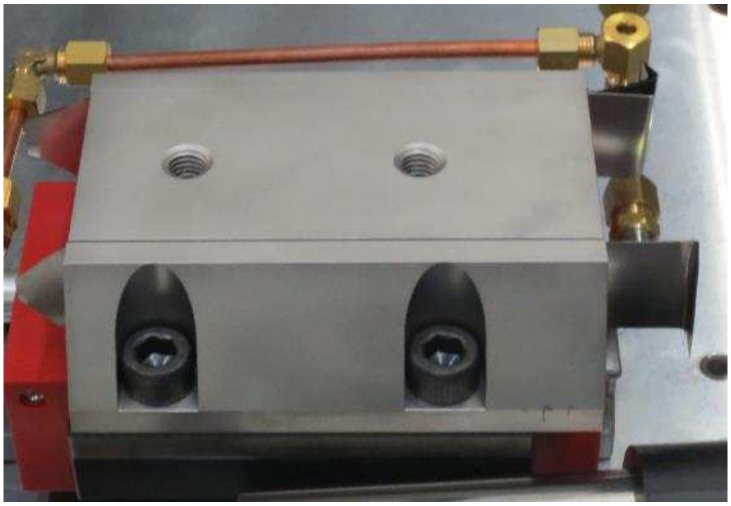


Figure 46: Long, thin, 0.009" thick shims inserted in flexure.

109. Insert sufficiently thick shims into the slots in each linear bearing flexure to prevent it from flexing during strongback installation. (Should be close to 0.009" per slot).

110. Using an overhead crane, attach a sling to the hoist rings on the strongback, and move the first strongback assembly into position over the girder assembly.

Figure 47: Crane hoist points on strongback

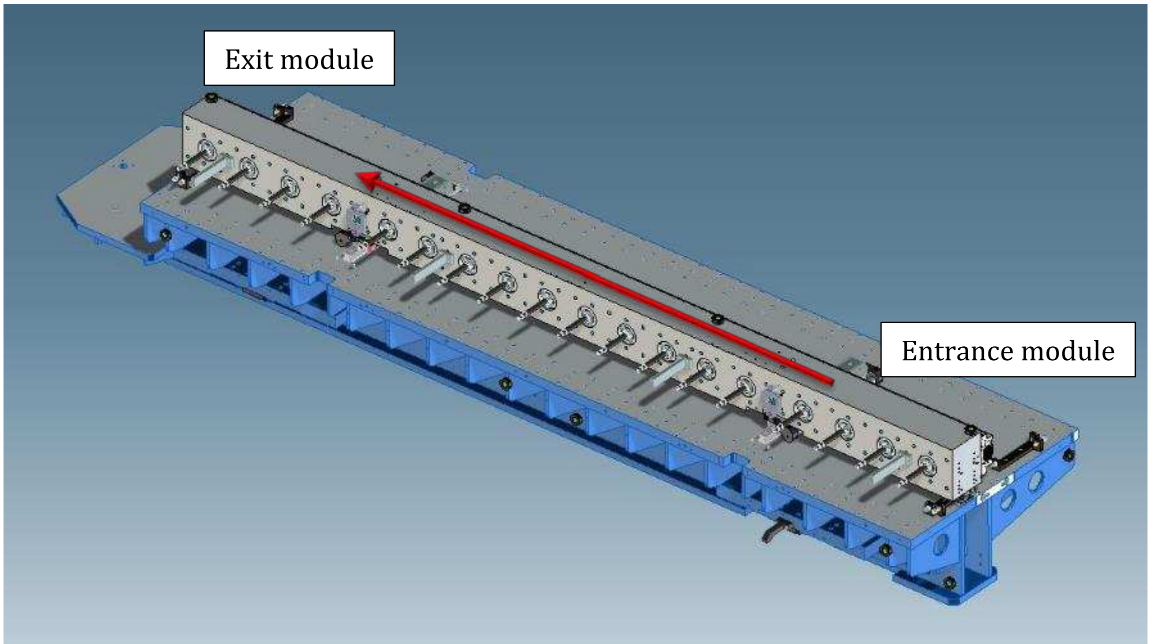


Figure 48: Left strongback mounted. Exit module goes near interspace platform. All arrows on magnet modules point in direction of red arrow. Pole numbers increase from entrance to exit.

111. Position the strongback over the linear bearing carriages. Set gently on the flexures, making sure the end of the strongback touches the strongback position plate fixture. Keep tension on lifting straps until strongback is fully positioned.

Figure 49: Strongback touching strongback position plate fixture.

112. Ensure that the hard stop bases and uppers are interfacing correctly.

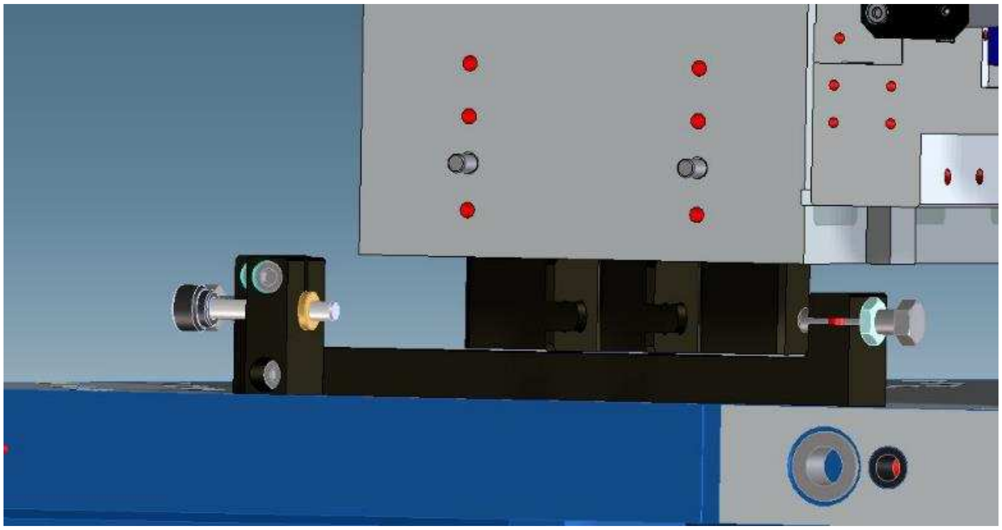


Figure 50: Hard stop base and upper.

113. Put anti-seize (Permatex Aluminum Anti-Seize #80078 or equivalent) on the threads of the M10 screws, and put M10 screws into the counterbores in the top of the strongback into the tapped holes of the flexures and get them finger tight.

VERIFICATION POINT 17

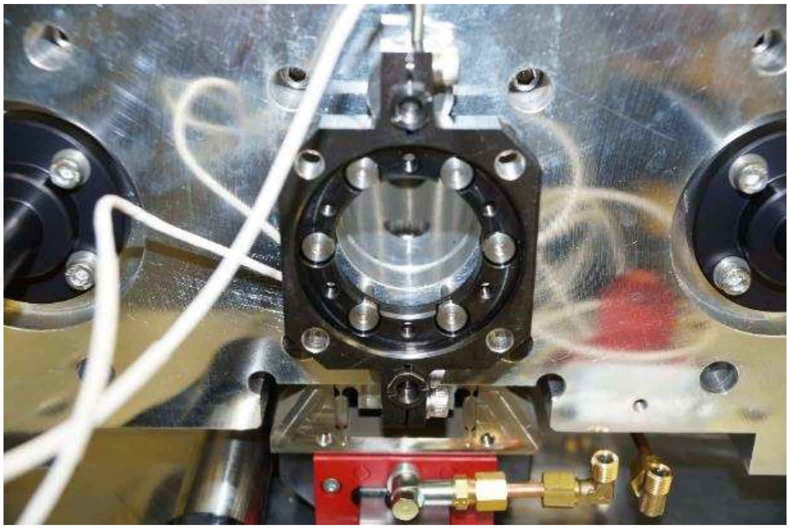


Figure 51: Screw locations between strongback and linear bearing

114. Check the distance between the strongback and the flexures in 4 places. The measurements should be within 50 thousandths (1.25 mm) of each other. Lifting straps can be completely removed now.

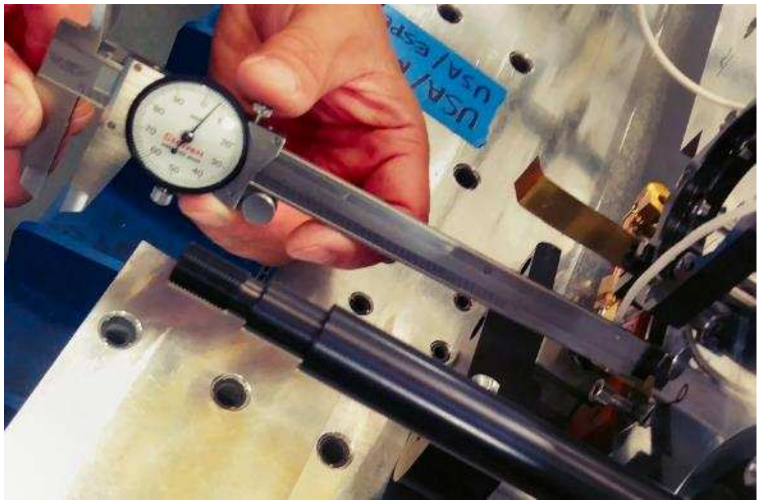


Figure 52: Measure distance between strongback and flexure.

115. Push the strongback (by hand) towards the center until it touches the gap centering fixture.

Figure 53: Strongback against gap centering fixture.

116. Torque the M10 screws to 31 ft-lbs.

VERIFICATION POINT 18

117. Put blocks in the hardstops and use them to lock the strongback in place.

Figure 54: Blocks in the hardstop keeping strongback towards center.

118. Repeat steps 107-117 for the second strongback. Put foam at the ends of strongbacks to protect during crane operations.

Figure 55: Foam to protect during crane operation of second strongback.

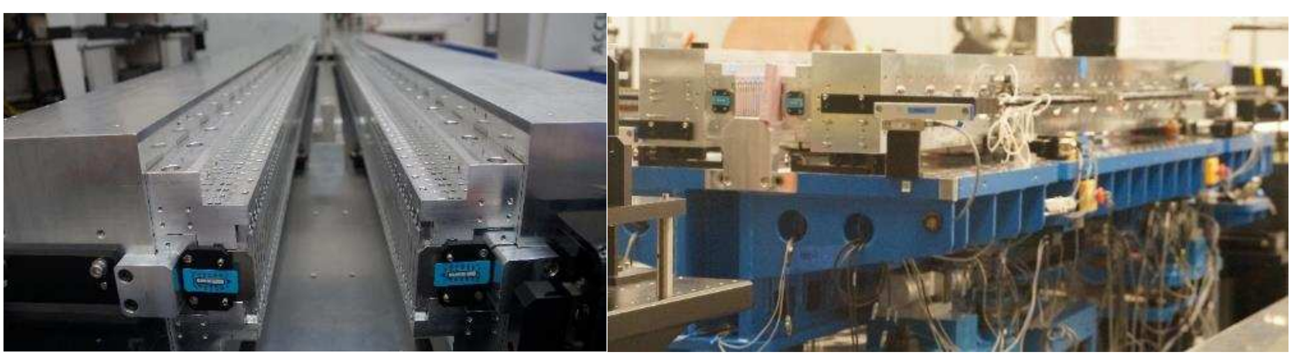


Figure 56: Second strongback installed.

119. Connect grease manifold fittings on strongbacks to grease system from carriages according to 29H948 (parts #4-6, 23, 25, 27-28 on 29H948). Connect grease fitting manifold to strongback using Loctite 242, torque screws to 10 in-lbs.

120. Ensure that the grease fitting spacer (part #4, 29L051) is properly centered, or grease will leak. The top for the spacer should be close to the edge of the chamfer.

Figure 57: Ensure grease fitting spacer is centered.

121. Add 15 pumps from grease gun to each of the 8 grease entry points.

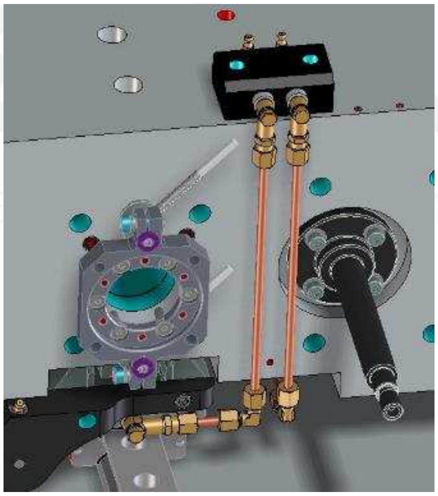


Figure 58: Grease fittings

8 Install Tilt Encoders (Dwg 29H948)

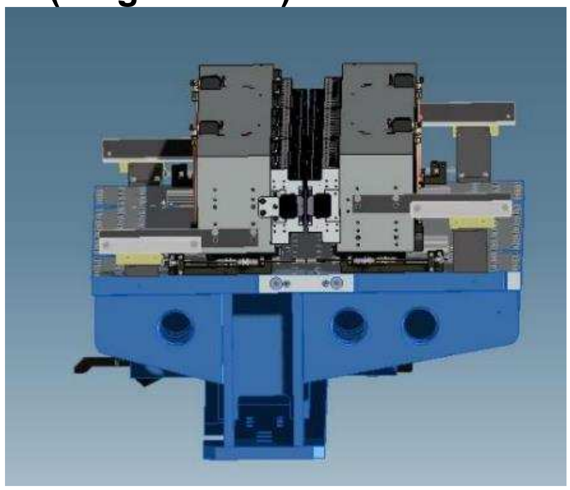


Figure 59: Tilt encoders attached to strongbacks.

122. Remove the blue wipers from the Fagor Encoders:
    a. Remove one of the blue "dogbone" pieces
    b. Remove the corresponding blue end cap
    c. Scrape off the clear silicone
    d. Remove the wipers by sliding it out the end using needle nose pliers
    e. Replace the end cap and dogbone piece

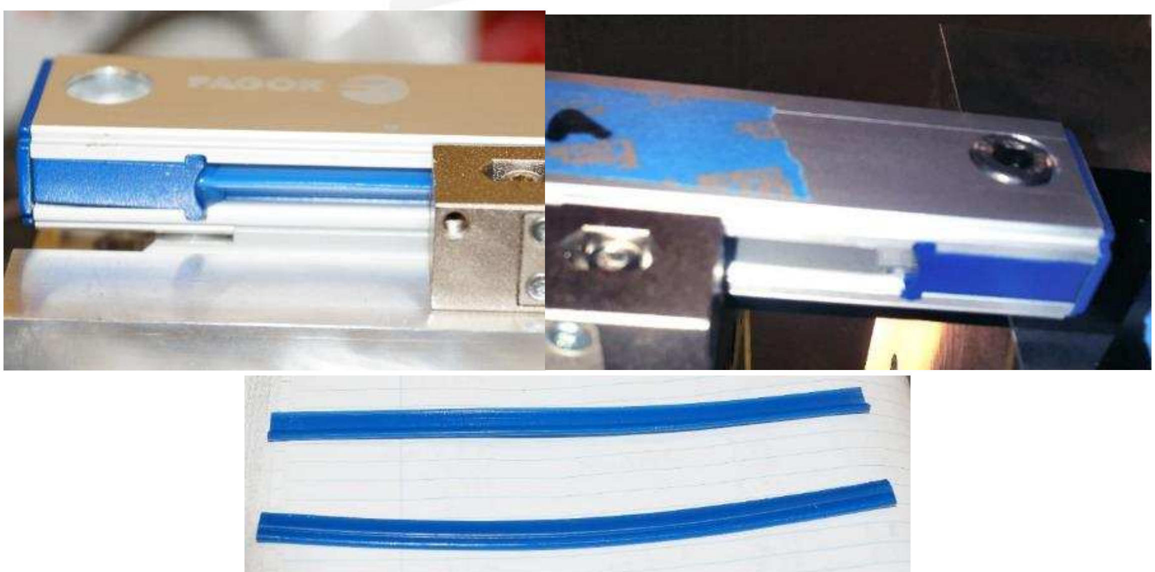


Figure 60: Before removing wipers (top left), after removing wipers (top right), the removed wipers (bottom).

123. Modify the Fagor B2-70 bracket (according to drawings 29L331 & 29L332)
    a. Remove and reinsert the bushings (DO NOT force the bushing out the backside of the bracket or over-compress the wave spring.

b. Modify ONLY ONE of the spring clips per bracket by filing the corners and edge to prevent the clip from digging into the encoder housing. The clip closest to the gap is the one modified. Check drawings 29L331 & 29L332

c. Mark the parts with the serial number as indicated in the drawings.

124. Attach the Fagor backing plate to the scale bracket (29L317 or 29L318). Ensure backing plate is registered against aligning surface. Torque M5 screw to 40 in-lbs. Ensure gaps indicated by flags #3 and #4 in drawing 29L333 and 29L334 are kept.

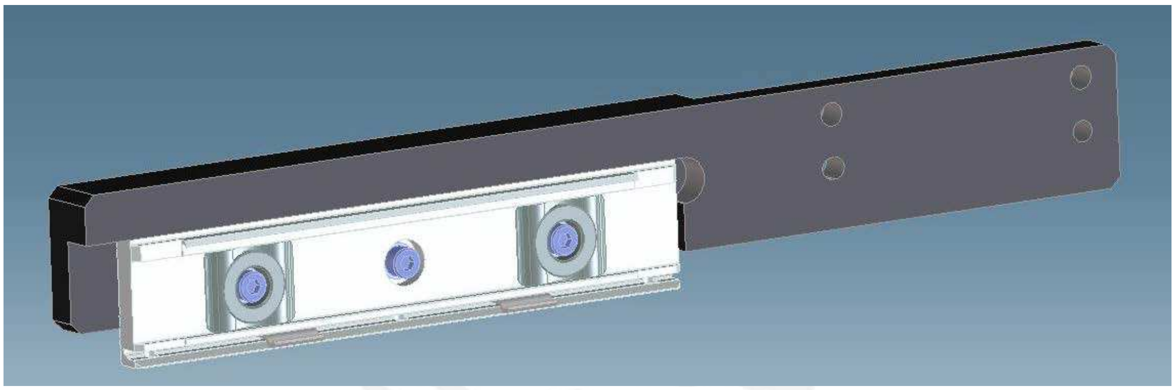


Figure 61: Backing plate attached to scale bracket

125. Slide the encoder into the v-groove of the Fagor backing plate. Keep the red tabs in place. Ensure readhead connector points outward. With the red tab attached, you cannot see the connector, but it takes up space, so the screw hole on the connector side is further from the end.

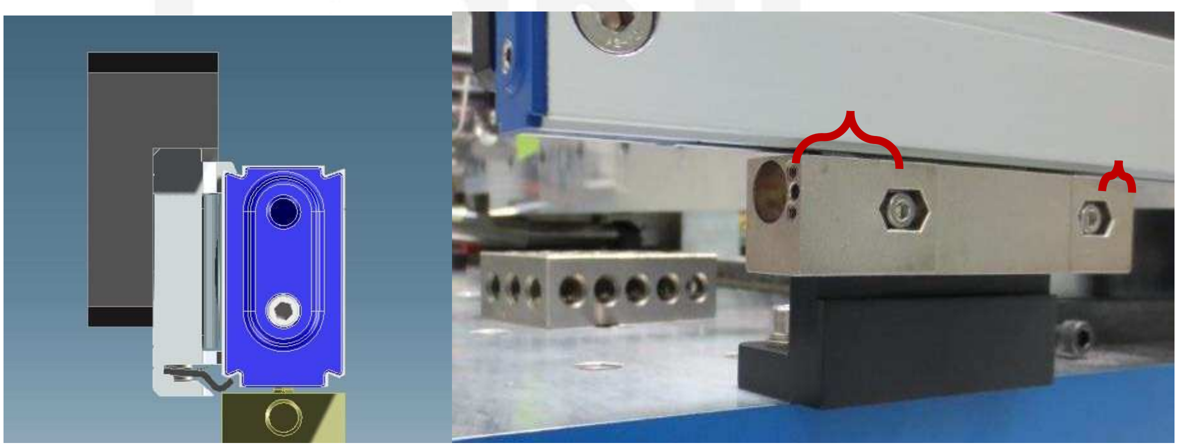


Figure 62: Encoder mounted on backing plate (left) Connector faces out, connector is side with screw further from edge (right).

126. Tighten the spring clamps (screws are on the bottom). Torque to 1 Nm.

127. Check drawing 29H948 and make sure the short and tall brackets (29H903 and 29H902) and subassemblies 29L333 & 29L334 are in the correct locations.

128. Attach the assembly to the strongback. Use the pins for alignment. Push downwards on the bracket while tightening the screws to ensure any play in the pin/pinhole fit is biased in the same direction. Torque the M6 screws to 50 in-lbs

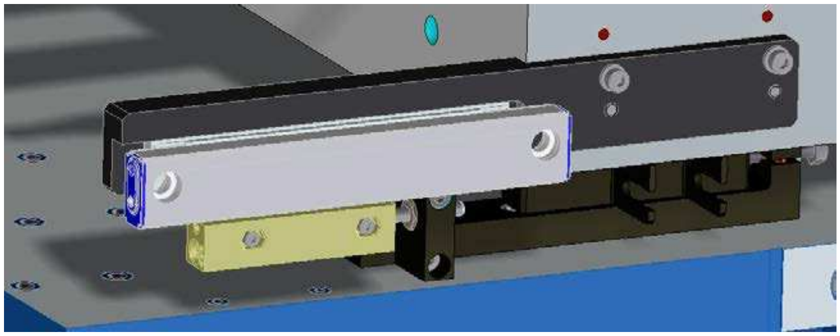


Figure 63: Scale bracket and encoder attached to strongback.

129. Attach the read head to the short or tall bracket using the nut plate. Torque to 11 in-lbs.

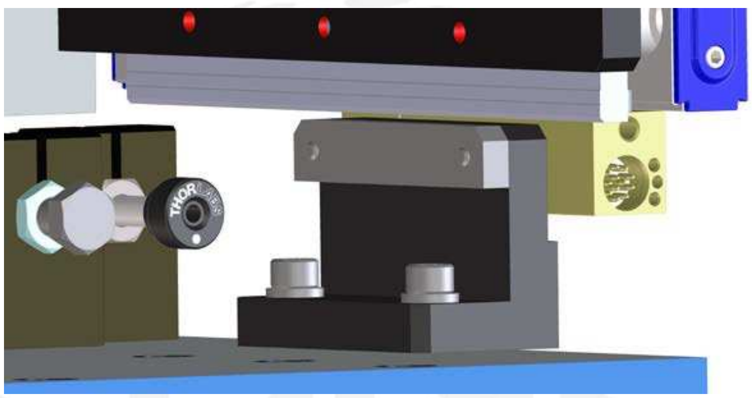


Figure 64: Nut plate.

130. Attach the short or tall bracket to the girder. Ensure the encoder and readhead remain aligned. Torque M6 screws to 50 in-lbs.

Figure 65: Keep readhead and encoder aligned while torqueing.

131. Remove the red tabs (requires a 2mm Allen wrench).

9 Install Motor Assemblies (Dwg 29H934)

132. The strongbacks should be pressed against the gap fixture to keep them aligned.

133. Attach the loadcells to the loadcell readers.

134. Check that the loadcell readers have the following settings
    a. INPt: +/- 50M
    b. deC.P: FFFF
    c. Rd.S.0
        i. In 1: 0
        ii. RD 1: 0
        iii. In 2: 1120
        iv. RD 2: 500

135. Pre-assemble the ball screw, ball screw support (SYK FK15-C5), and the Bearing Mount & Coupling Housing (29L026).
    a. Fasten the nut portion of the ball screw support to the ball screw and tighten set screws.
    b. Use 4 M5 screws to attach ball screw support to bearing mount and coupling housing. Torque to 5.1 Nm (45.1 in-lb). Paint mark.

136. Use 6 screws to attach the ball screw to the ball screw mount. Orient the attachment flange such that the grease hole is near the top. Torque the M5 screws to 8.7 Nm (77 in-lbs) and paint mark.

VERIFICATION POINT 19

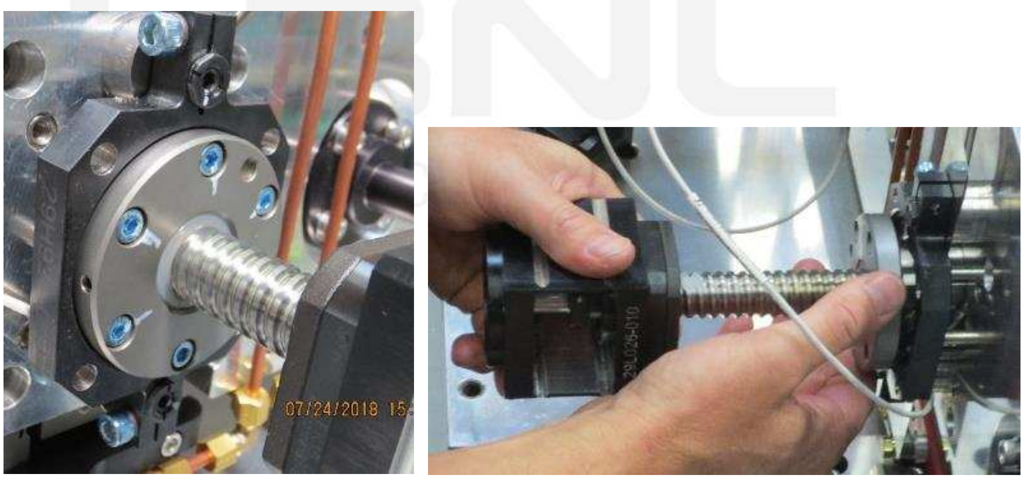


Figure 66: Attach ball screw to ball screw mount. Orient grease hole towards the top.

137. Use a vertically adjustable stage and a smooth block to get the ball screw parallel. Watch the load cells and try to balance them and keep them both under 30 N (positive or negative okay).

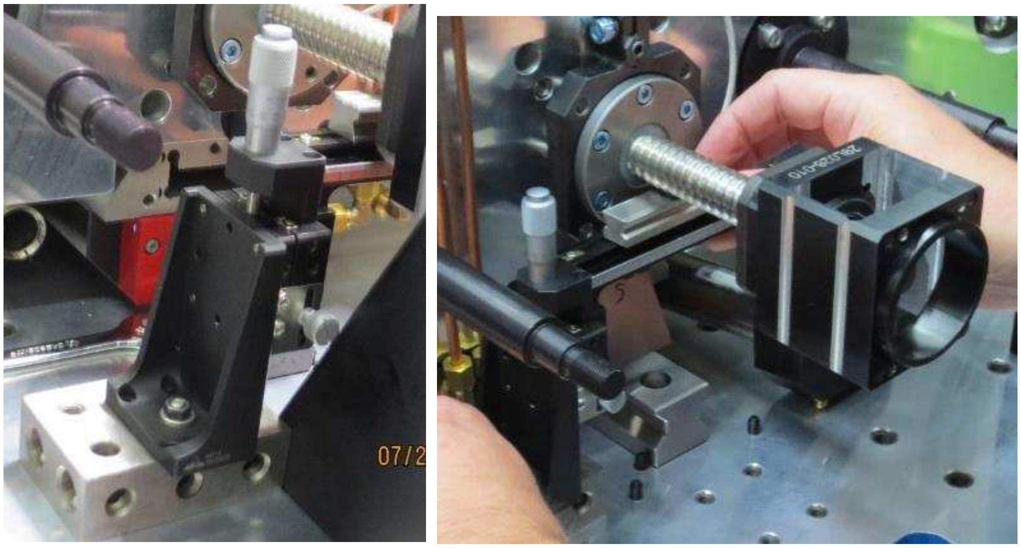


Figure 67: Using a vertically adjustable stage to ensure ball screw is parallel.

138. Ensure at least a 250 µm (0.010”) gap between the load cell and ball screw mounting plate.

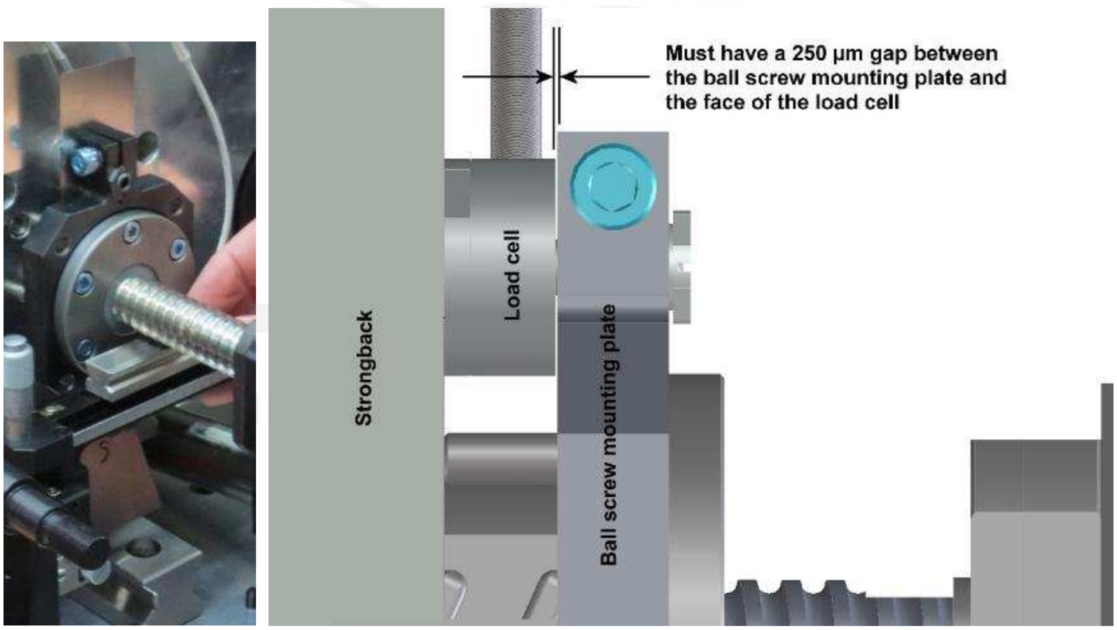


Figure 68: Ensure a minimum 250 µm (0.010”) gap between load cell and ball screw mounting plate.

139. Slide the drive motor assembly bracket (29L025) over the coupling housing and set the bearing housing stop (29L027) to the correct height for a parallel ball screw. (Use 2 screws, see drawing 29H934).

140. When:

a. The ball screw is parallel
b. The load cells are balanced
c. The gap between load cells and ball screw mounting plate is maintained,

Lock the loadcell clamp posts in place by torqueing the clamping screws to 15 Nm (11 ft-lbs) and the set screws to 10 Nm (90 in-lbs). Paint mark both the clamping and set screws.

VERIFICATION POINT 20

141. Rotate the ball screw until the drive motor assembly bracket can touch both the coupling housing and the pins on the girder.

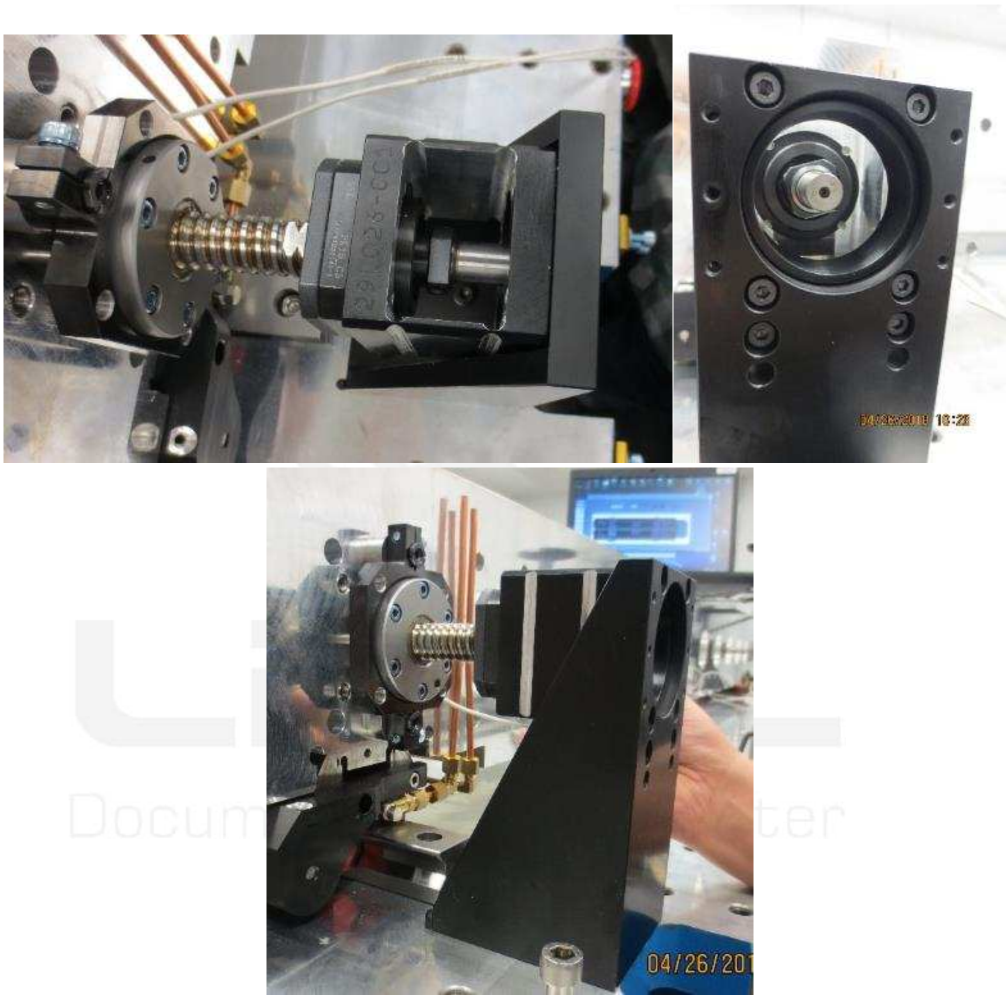


Figure 69: Ball Screw attached to the Ball Screw Support attached to the Coupling Housing, attached to the Mount Bracket. Bearing Housing Stop is installed, but only the bolts are visible.

142. Bolt the bracket to the girder. Torque to 15 Nm (11 ft-lbs). Paint mark. (Note: standard torque wrench will not fit. Use extension.)

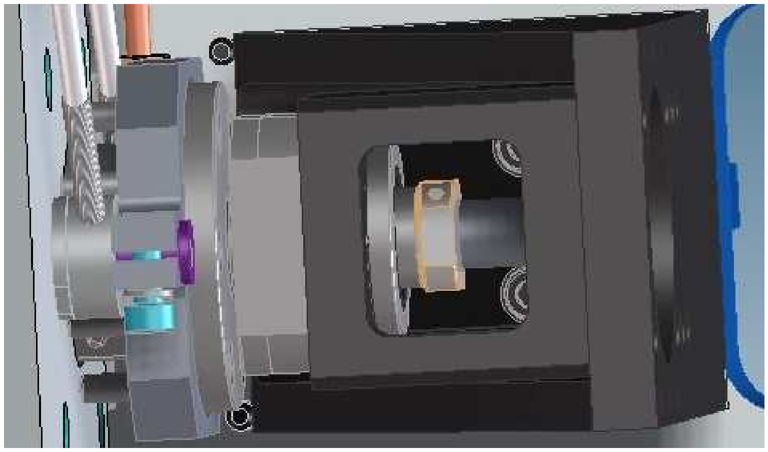


Figure 70: Bracket against positioning pins.

143. Torque the coupling housing to bracket screws to 5.1 Nm (45.1 in-lbs) and paint mark.

144. Attach the gearbox adapter (29L024). The position should be determined by the coupling housing, though the 6 screws attach to the bracket. Torque screws to 2.6 Nm (23 in-lbs) and paint mark.

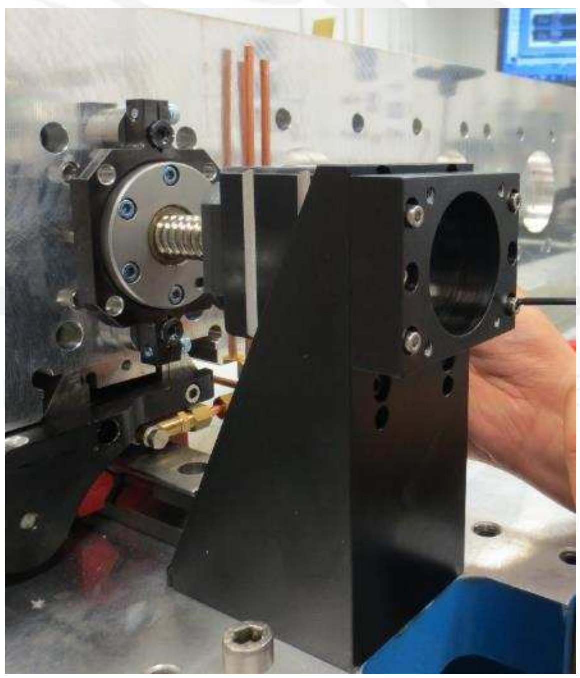


Figure 71: Gearbox Adapter attached.

145. Attach gearbox to motor according to gearbox manufacturer's instructions. Torque to 3.5 Nm, 31 in-lbs and paint mark.

146. Attach coupling to gearbox. Leave 1.2 mm gap between coupling and gearbox. Torque to 3.5 Nm (31 in-lbs) and paint mark. Ensure the set screw is pointing up for ease of assembly later.

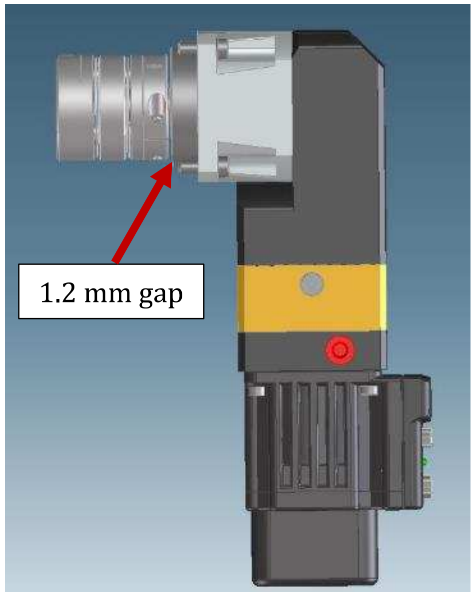


Figure 72: Motor, gearbox and coupling. Gearbox to coupling gap is 1.2 mm.

147. Slide coupling over ball screw.

148. Attach gearbox to gearbox adapter with 4 screws. Torque to 5.1 Nm (45.1 in-lbs) and paint mark.

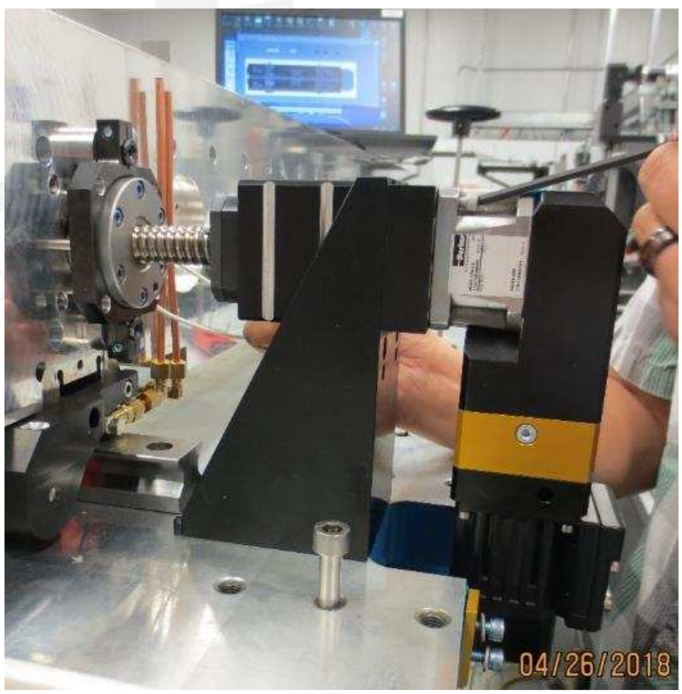


Figure 73: Attach gearbox to gearbox adapter.

Figure 74: Coupling attached to ball screw.

149. Attach coupling to ball screw. Torque to 3.5 Nm (31 in-lbs) and paint mark.

VERIFICATION POINT 21

150. Repeat steps for all 4 motor assemblies.

151. Verify that the difference between top and bottom load cells for all pairs of load cells are less than 50 N, and that the values of the load cells are within ±50 N.

VERIFICATION POINT 22

10 Wire Control System for Assembly

152. Move the assembly onto the CMM. Make sure that the Z-axis of the full assembly is oriented the same way that the strongbacks were measured. (Refer to step 92 for explanation).

153. Reattach the loadcells to the loadcell readers

154. Wire the Fagor encoders, motors and e-stops to the control system. Refer to 29L130 for cable routing and SLAC cabling drawings. Refer to Motion Controls Checkout Procedure (LCLSII-2.7-PP-00855) especially appendices for other control system information.

155. Note that the wall side 90 degree motor cables should be pointing outward and the aisle side 90 degree motor cables should be pointing inwards.

156. Install 29L205, the plate assembly.

157. Install hard stop sensors and dummy vacuum chambers sensors (part #13 on 29H948) at roughly 1" from tab on bracket to nose on switch.

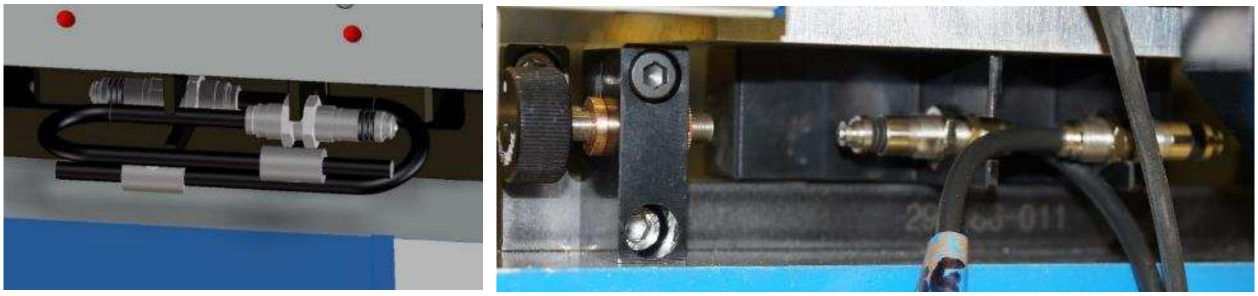


Figure 75: Hard stop sensors

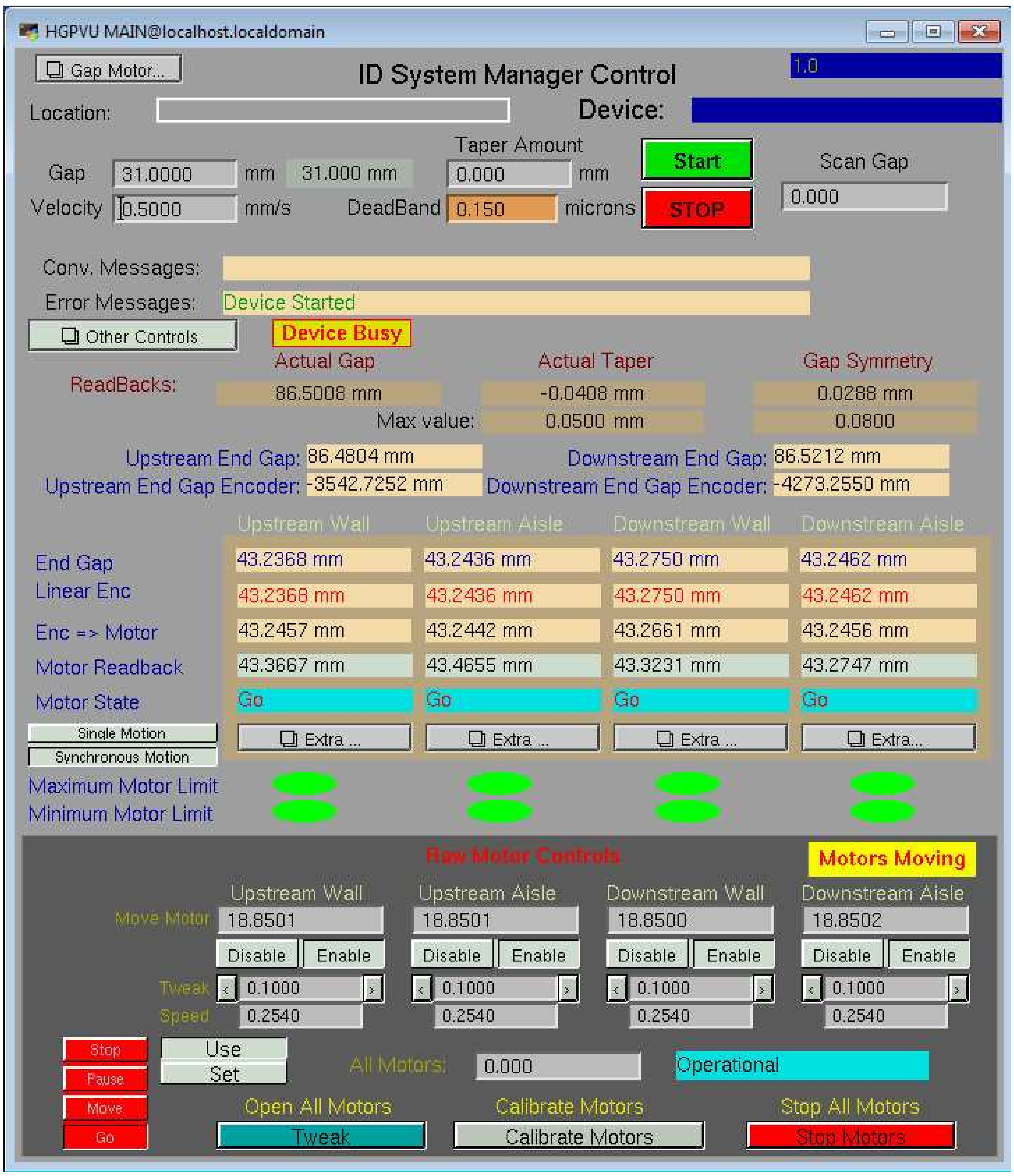


Figure 76: Control system interface

158. Remove the blocks on the hardstops.

159. Make sure strongbacks are touching centering fixture.

160. Adjust the windows labeled “offset” until the windows labeled “value” reads 15.000, record Fagor encoder offset values.

VERIFICATION POINT 23

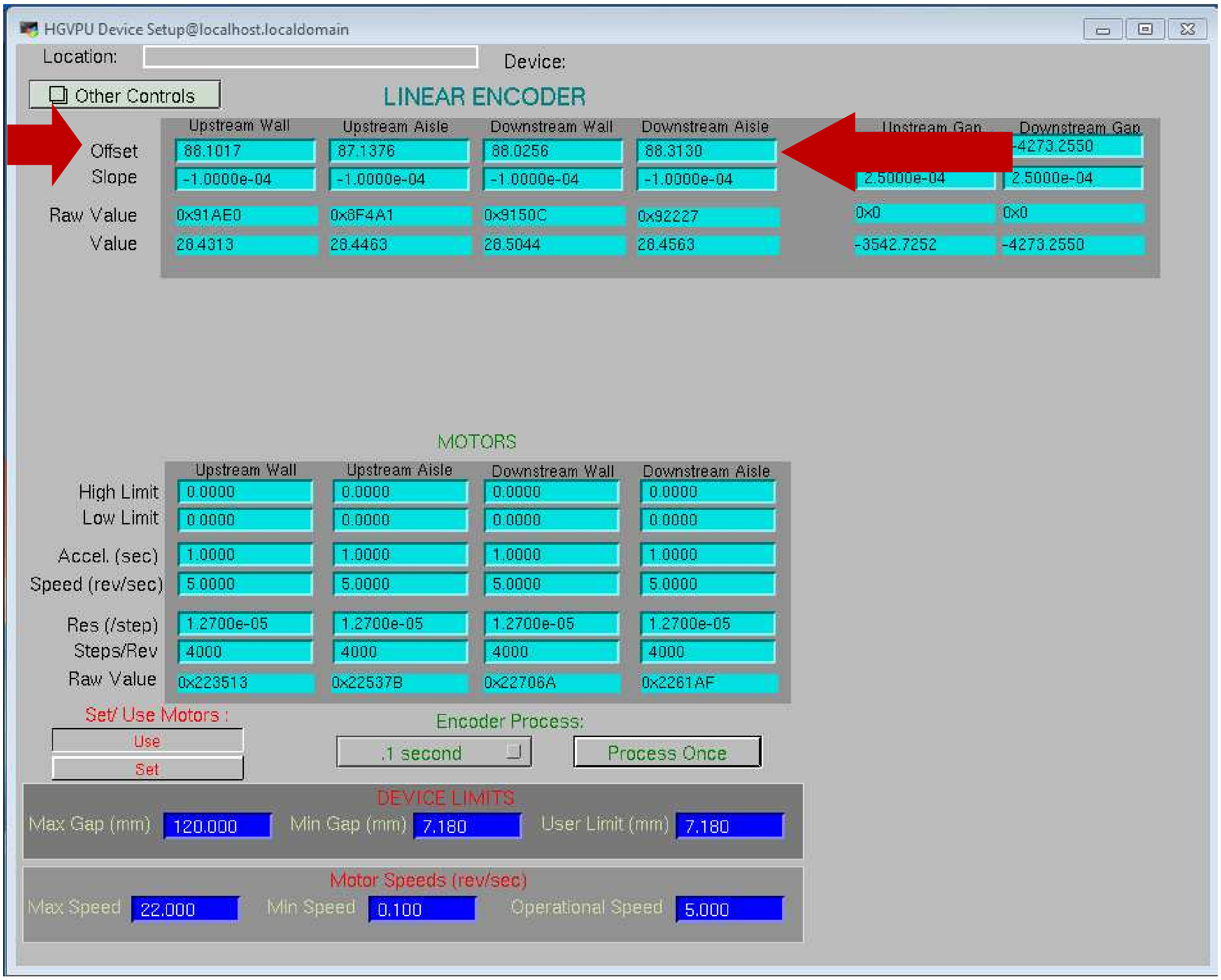


Figure 77: Where to find and edit offset values

161. Use the motors to open the gap to 100mm checking that no hardstops or cables interfere with the gap motion.

VERIFICATION POINT 24

162. Check the balance of the load cells. If they are unbalanced, (reading more than 200N) report to LBNL to decide how to proceed.

VERIFICATION POINT 25

163. At this point the constant force spring should be attached to the linear bearing & flexure.

164. Attach corresponding Carriage Bracket (29L034 or 29L039) to the Strongback Flexure (29L222). (torque spec 8.7 Nm, 6.4 ft-lbs).

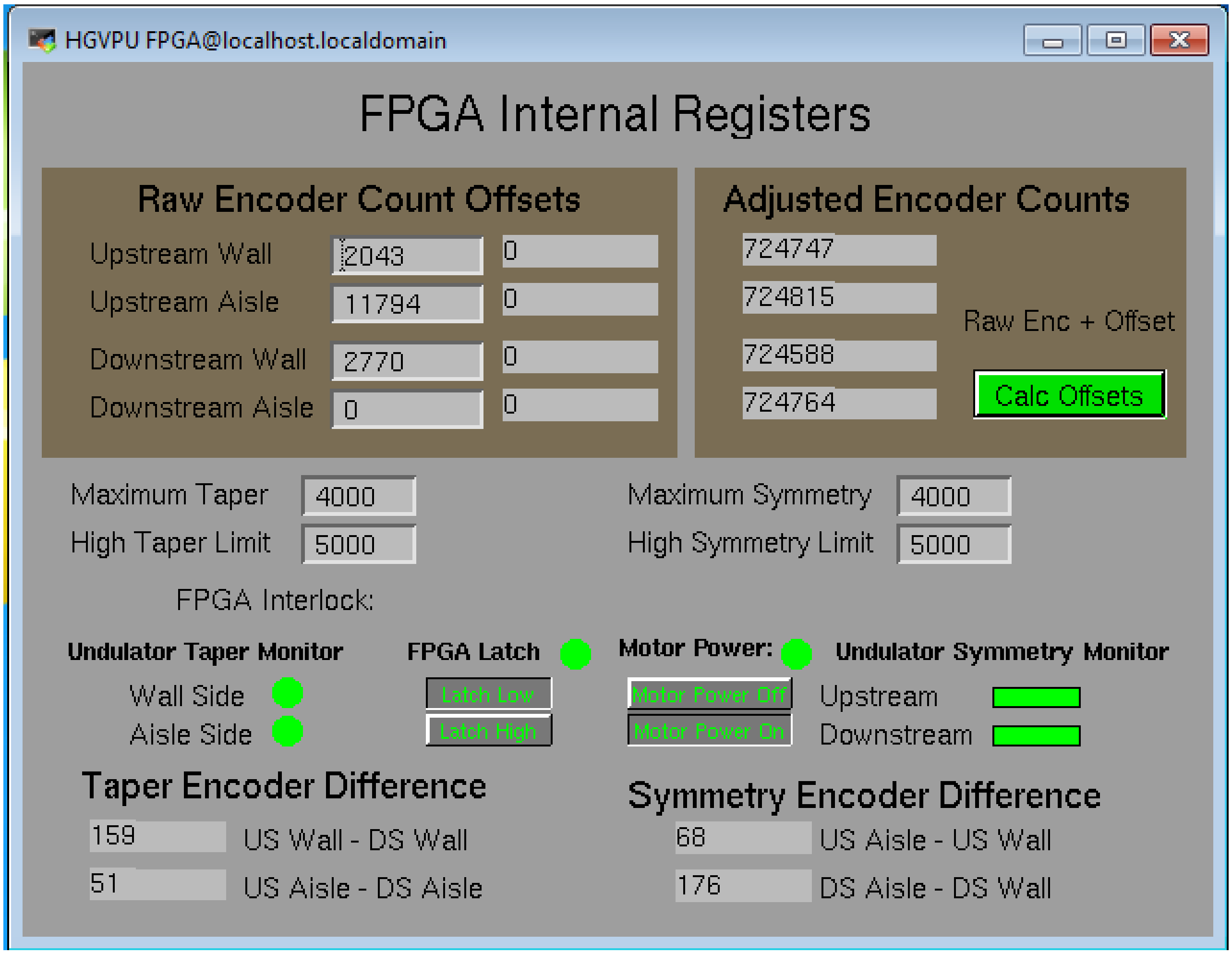


Figure 78: The screen you use when the motors do something wonky.

11 Measure on CMM

165. Measure the gap fixture to start the CMM process. Fixture handles can be temporarily removed for measurement.

166. Set up the coordinate system as follows:

a. Primary datum surface: A best-fit plane down the center of the gap (beam path) using the gap alignment fixture spacers. This will be used to set pole height and gap encoders.

b. Secondary datum feature: The top of the Girder inside vacuum chamber mounting hole pattern.

c. Tertiary datum feature: Girder precision end

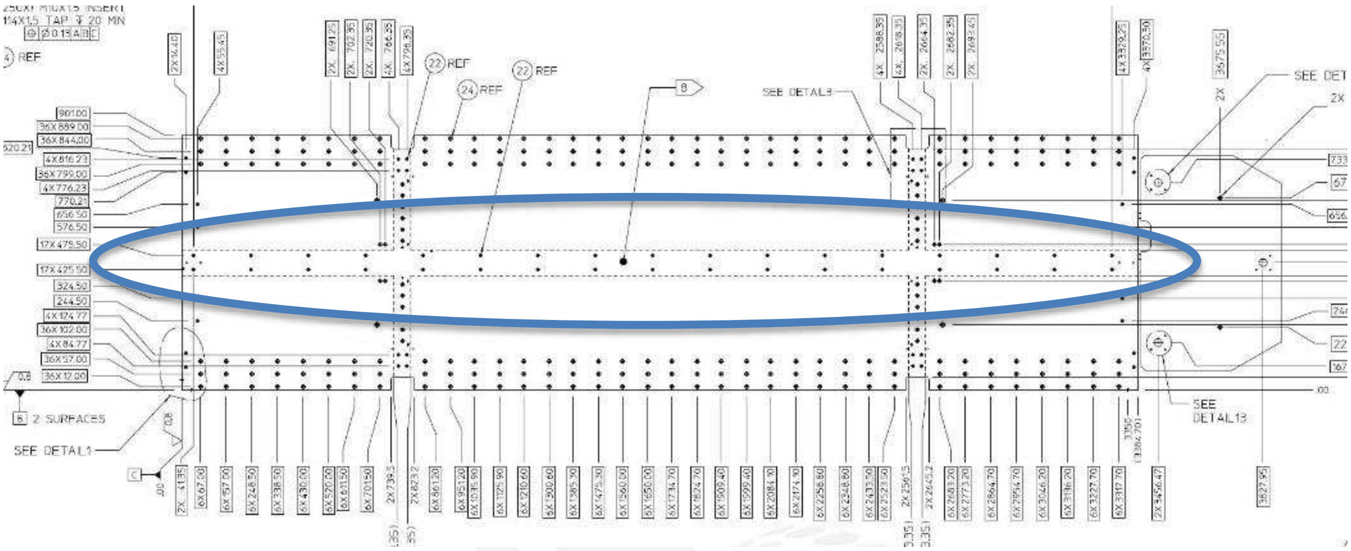


Figure 79: From 29H866, the zone marked by note 8 is the secondary datum feature.

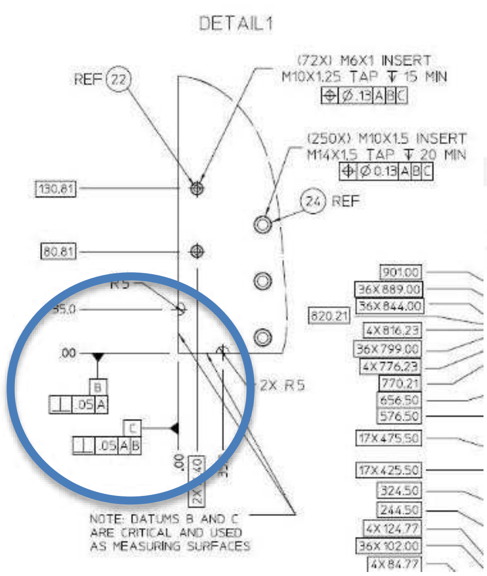
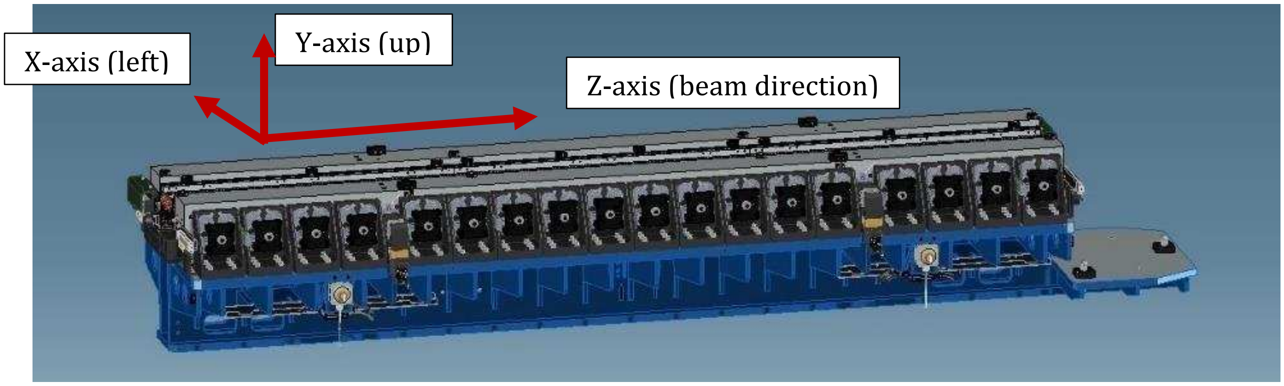


Figure 80: Datum C on drawing 29H866 should be the tertiary datum feature.

167. Coordinate system reminder:



a. Z-axis is in the beam direction – set by sliding the strongback
b. Y-axis is up – could be changed with shims between flexures and strongbacks
c. X-axis makes it right-handed (points left) – set using the motors
d. Roll – rotation about Z – set by relative thickness of top and bottom shims between magnet modules and strongback.
e. "Yaw" in quotes means pitch, rotation about X – could be changed with shims between flexures and strongbacks
f. "Pitch" in quotes means yaw, rotation about Y – set using motors

168. Once coordinate system is established, gap fixture can be removed. Put foam over the magnets and poles before removal.

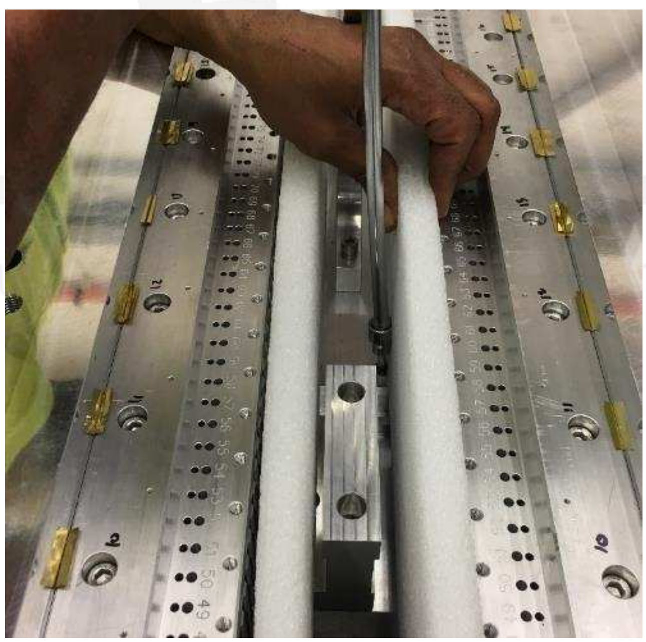


Figure 81: Remove the centering fixture.

169. Use the motors and Fagor encoder readings (offsets as recorded in Verification Point 23) to reset the gap to 30 mm.

170. Measure the pole midpoint heights at the shim locations on both strongbacks.

171. Use this data to correct taper and gap width.
   a. Find a best fit line for each strongback, and find the delta pole height of the line. (ex. Aisle best fit has difference of 30 µm, and upstream is open more than downstream)
   b. Use the delta pole height to determine how much to rotate the strongbacks (ex. Close the upstream end by 15 µm and open the downstream end by 15 µm)
   c. Determine how to change the offset values to get the desired rotation (ex. Tell the aisle upstream encoder it is 15.015 mm so it will close and the aisle downstream it is 14.985 mm so it will open)
   d. Adjust offset values
   e. Go to 30.5 mm gap then go to 30 mm gap
   f. Re-measure pole midpoints

172. Repeat step 171 until the strongbacks are parallel to the gap fixture. Use the same method to ensure the gap is precisely 30 mm when the encoders think it is 30 mm. (Use the best fit lines).

pole shim #		aisle	wall
2		14.950	-15.009
8	6	14.94813	-15.0103
13	12	14.94827	-15.0112
19	18	14.94855	-15.0149
25	24	14.95832	-15.0176
30	30	14.96597	-15.015
36	36	14.97174	-15.0077
41	42	14.97438	-15.0121
47	48	14.97866	-15.0103
52	54	14.9808	-15.0091
58	60	14.98158	-15.0119
63	66	14.98472	-15.0162
69	72	14.9865	-15.0209
74	78	14.98664	-15.0253
80	84	14.97791	-15.023
85	90	14.98356	-15.0239
88	96	15.00746	-15.025
94	102	14.99373	-15.0147
99	108	14.99087	-15.0186
105	114	14.98815	-15.0128
111	120	14.98542	-15.0165
116	126	14.99107	-15.0154
122	132	14.99034	-15.0116
128	138	14.99211	-15.0088
133	144	14.99176	-15.0092
139	150	14.99603	-15.0109

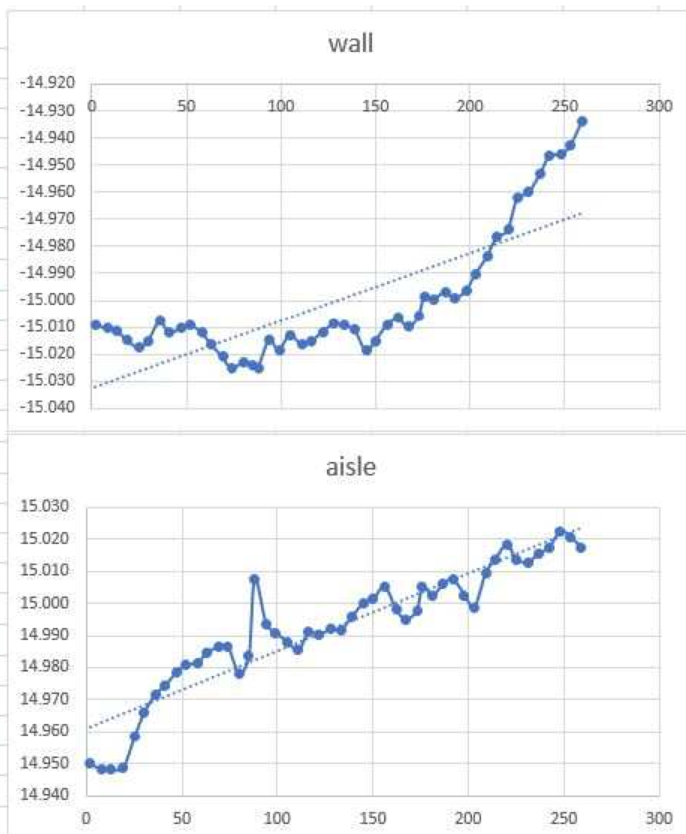


Figure 82: "Before" data to use to correct taper and gap width. Upstream wall needs to close, downstream wall needs to open, upstream aisle needs to open and downstream aisle needs to close. When the best fit lines are horizontal, aisle should be 15.00 mm and wall should be -15.00 mm

173. Record new encoder offset values

VERIFICATION POINT 26

174. Measure the following:
    a. The X-dimension of poles at shim locations, measured at 2 points.
    b. The Y-dimension of the pole side, measured on the top side of the pole, at shim locations
    c. The longitudinal (Z-dimension) of the magnet measured from the downstream side, at shim locations, measured at 2 points.
    d. (Recommended) Proxy points for the primary datum (Datum B on drawing 29H866 and a point near the interspace platform) – if the fixture is removed, want to be able to check coordinate system.
175. Use these to check the following requirements:
    a. Pole heights – All poles must coplanar with each other within ±10 µm (check X-dimensions of poles (there is a "W" or "M" of ~8 µm peak to peak that does not count towards this requirement))
    b. Strongback to strongback "yaw" (pitch) must be within 200 µm of each other. (check an average of Y-dimensions of poles at ends of the strongbacks).
    c. Strongback to strongback Y position must be within 200 µm of each other (check average of Y-dimension of poles)
    d. Strongback roll (based off poles to girder angle) must be within 1 mrad of each other and 1 mrad of the girder – if the top and bottom of the pole is measured 20 mm apart, there should be less than 0.02 mm variation in the X dimension.
    e. Strongback to strongback Z position should be within 100 µm (magnet Z-dimension left vs. right).
    f. Gap parallelism – The gap must be 7.2 mm ±10 µm over all the poles (software adjusts between open gap and 7.2 mm gap)
    g. Gap taper – the strongbacks should be parallel to each other within 3 µm. (The gap should not have an overall taper)

NOTE: Shimming software will check for (a), (d), and (f). Previous steps dealt with (g). Parts (b), (c), and (e) may be performed after spring cages are on, but it is easier to make adjustments at this point.

176. If Y adjustment is needed:
    a. Shim between the strongback tabs where the modules rest and the magnet modules.
177. If Z adjustment is needed:
    a. Put shims between modules, similar to step 99, put an indicator at the end to track position and push to appropriate position (loosen, tighten modules as in step 99).
    b. If only one module is out, shimming between modules can be adjusted to push it into place, but there MUST be AT LEAST 0.001" between keepers.
178. Put the data into the shimming software. It will output a shim map with 0.0005" increments to:
    a. Make left to right strongback roll angle less than 0.25 mrad
    b. Make the gap width constant to ±10 microns.

179. Adjust by shimming entire modules with shims in between modules and strongbacks according to the shim map. **NOTE: Only the top shims can be reached once the strongbacks are mounted on the girder. Most shimming should have been done during Section 6.**
    a. Use the part 29H926 on both ends to ensure that the Z-axis position is maintained during the process. Put the 0.006" shims (or the adjusted value for the individual junction) in between the modules.
    b. Loosen the entire module, or all 3 modules.
    c. Perform the adjustments
    d. Torque the center module from the center towards the edges, then torque the exit and entrance module, starting at the center and working towards the edges.
    e. Remove both parts 29H926.

180. Repeat measurements & adjustments as many times as necessary to get poles co-planar and gap width within tolerance.

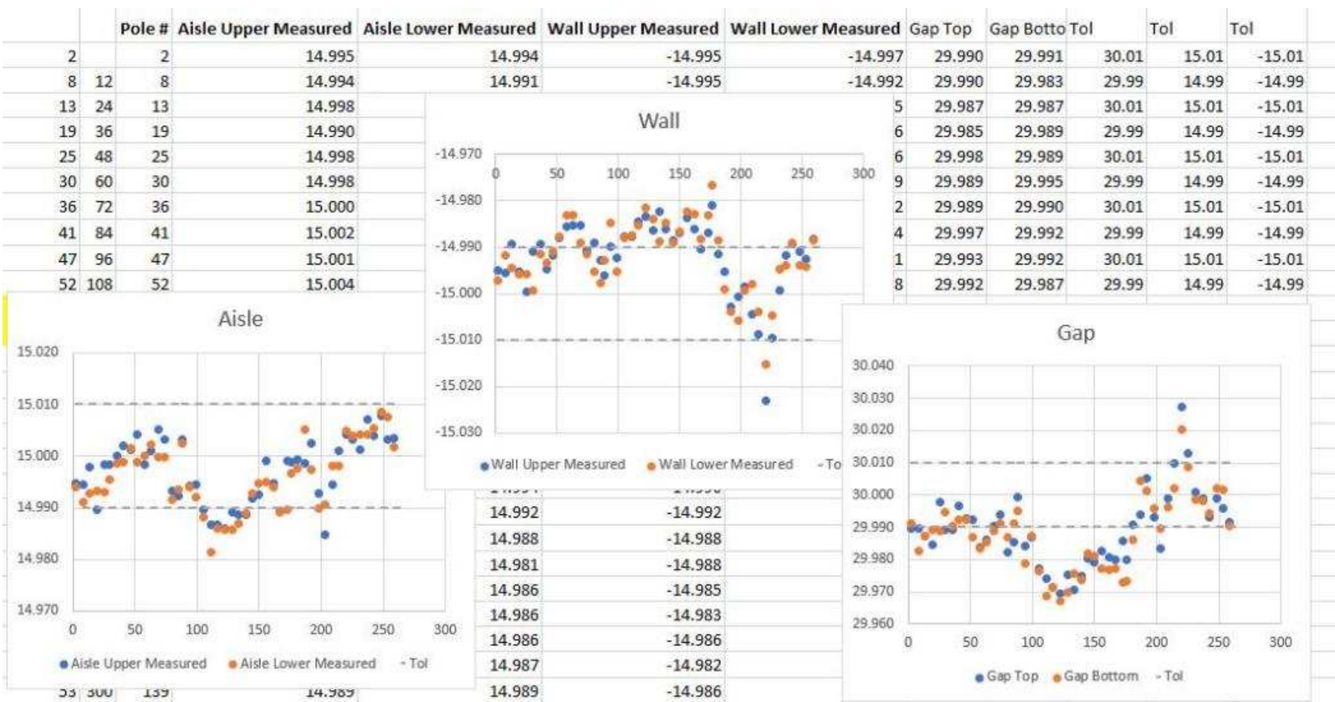


Figure 83: Data in the middle of the process – gray dashed lines are the tolerance we are aiming for. The wall strongback is a little too far into the gap as a whole and the downstream end probably needs shims added. The aisle strongback is well positioned, but the middle may need shims taken away. Both of these issues show up in the gap graph. Top and bottom match very well, so roll is okay.

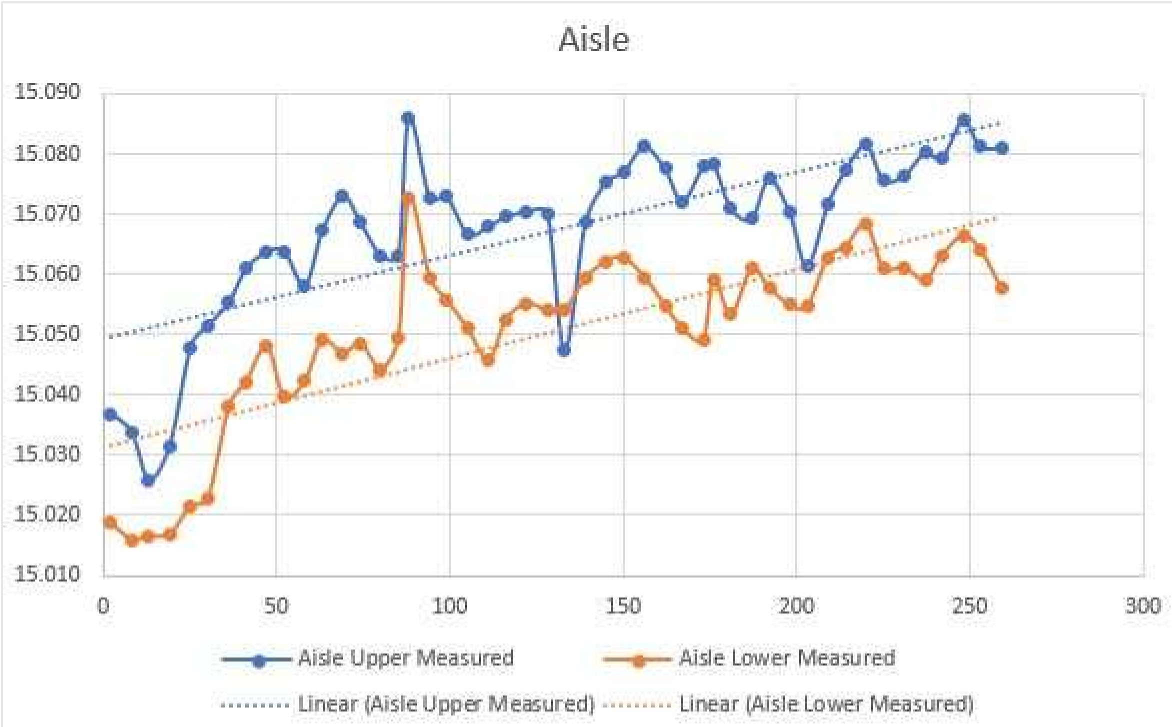


Figure 84: Data from the aisle strongback earlier in the process. Points are measured 24 mm apart. The top and bottom measurements are 15-20 microns apart. Roll is 0.02 mm/24 mm = 0.00083 rad = 0.83 mrad, which is higher than the 0.25 mrad requirement.

181. Once shimming is done, make any necessary adjustments to motors and make sure new encoder off-sets are saved into the control system.

182. Provide a documentation showing:
   a. Final pole heights (at shim locations) after the adjustments compared to primary datum feature (in .xlsx format)
   b. Graph of final gap width (the software output)
   c. Graph of top & bottom pole heights of each individual strongback with linear best fit line (the software output)
   d. Encoder values
   e. Data showing Y, Z, “yaw” requirements are met (from the initial measurements)

VERIFICATION POINT 27

12 Install and Align Spring Cages (Dwg 29K457)

183. Move the strongbacks to 60 mm gap. Verify with ceramic block and encoders.

184. Ensure that you have the spring cage sort map showing each serialized spring cage’s position on the girder.

185. Place the correct spring cage base with assembled springs and associated compression plate over the correct plunger.

186. Assemble all of the flat washers onto the end of the plungers. Ensure that the compression plate is oriented correctly. (180° rotation looks same if not marked. Serial number down is one possible marking.) Mount the compression plates to the plungers.

187. Screw on the locking collar onto the end of the plunger and tighten it until the compression plate is tight against the plunger flat washer.

188. Make sure that the compression plate is aligned to the spring cage base with a square or a level. Tighten the collar's side Allen screw.

Figure 85: Tilt the compression plate so it straightens out as you tighten. Use a square to check alignment.

189. Put 6 bolts through spring cage base into girder and leave loose.

190. Verify that the spring cage bolts are still tight. Check clamping bolts for the spring buttons and that the compression plate is tight to the plunger. Also check that no paint marks have shifted. If any bolts are loose, the spring cage will need to go through calibration again.

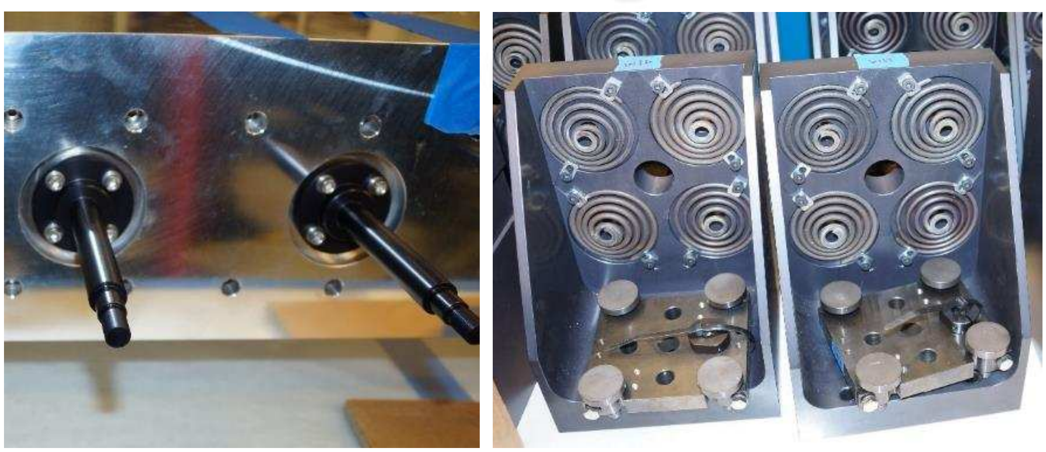


Figure 86: Plunger is attached to strongback. Slide Spring Cage on and attach compression plate.

191. Mount spring cage adjustment tooling to the girder. (See Figure 88)
    a. Bar & push/pull device (29L117 & 29L111)
    b. 2 Keyence sensors and brackets

192. Use gauge blocks to zero Keyence sensors to the plunger plate and double check that it is zeroed correctly.

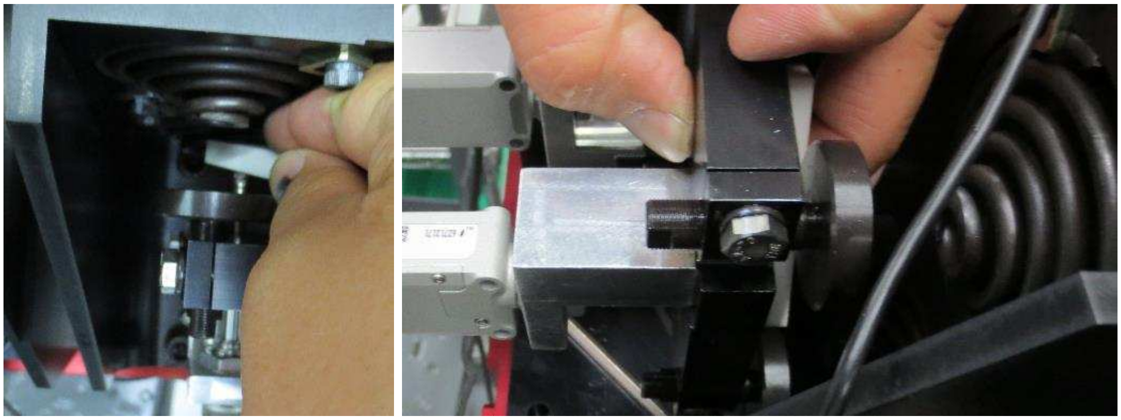


Figure 87: Zero Keyence sensor against the back of the compression plate.

193. Load spring cage file into LabView software
    a. Software will subtract Keyence reading & target value so that you will aim for a “zero” reading. (See Figure 88).

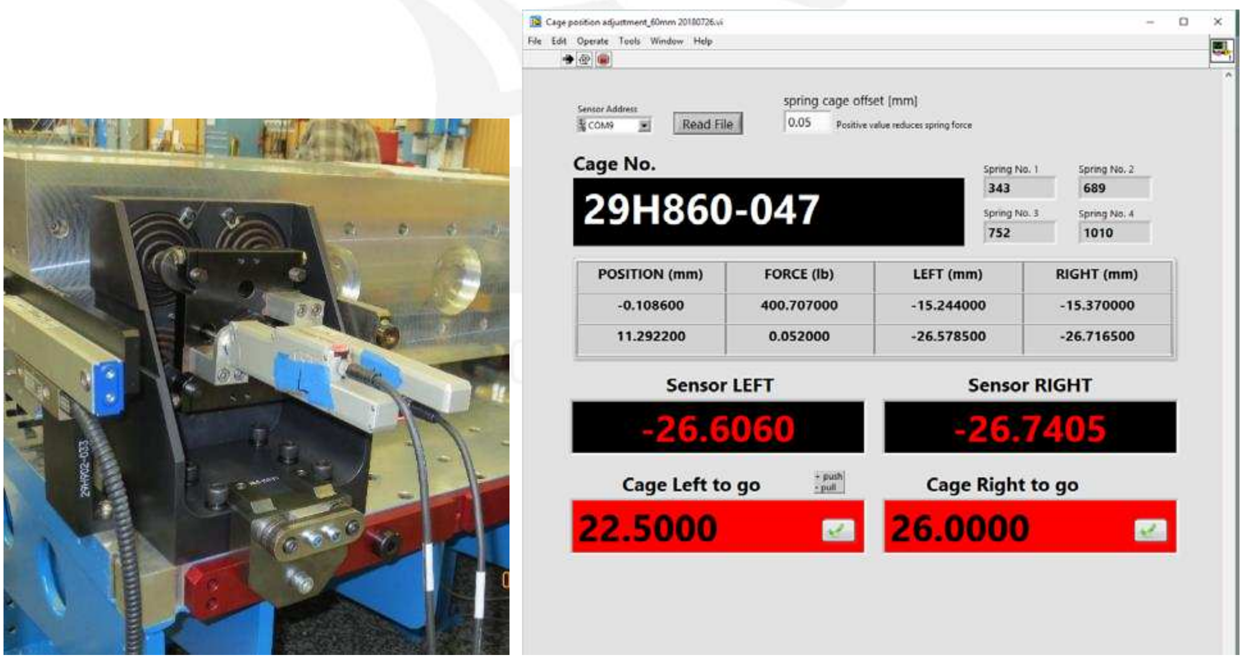


Figure 88: Keyence sensors attached (left) and LabVIEW Cage position adjustment.vi screenshot (right).

194. Get the spring cage in approximately the right location. The bar & push/pull device work better pulling the cage towards the edge, so place cage a little closer to the center than final – “to go” window should show a negative number.

NOTE: Do not bottom out the push-pull device, you can break it. Put it back to center after a few uses.

195. Preload the 6 screws until the split washer is just starting to flatten.

196. Use pusher adjustment tooling to fine position the spring cage.
    a. During pre-production build, aimed for -0.010 mm reading before torqueing to get a zero reading after torqueing. Each cage installation will be different depending on girder surface so drifting during mounting will not be identical.
    b. Adjustment tooling might be needed during torqueing to achieve best result. Tolerance after torqueing is +/- 10 microns.

197. Torque 6 screws starting with 2 back screws, then 2 middle, then 2 front. Torque until split washer is flat.

VERIFICATION POINT 28

198. Check the Fagor encoder values every few cages and correct the gap with the motors if the strongbacks have drifted.
    a. Adjustment needed ~ every 3 cages
    b. Adjustment needed if sum of "Actual Taper" and "Gap Symmetry" is greater than 10 microns.

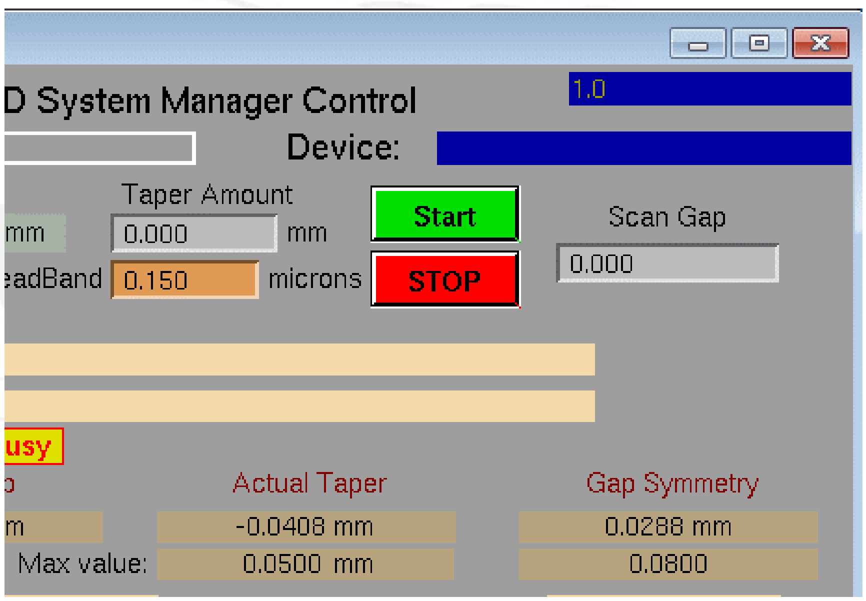


Figure 89: Where to look for "Actual Taper" and "Gap Symmetry"

199. After a spring cage is adjusted, mark it with a piece of masking tape or adhesive dot to indicate it is done. After all of the spring cages are completely adjusted, look at the back edge of the spring cage base where it meets the edge of the girder and look for any gross angle of the two surfaces. If there is one, then there is probably something wrong with the cage calibration. Double check & re-align if necessary.

200. Repeat steps 186-199 until all spring cages have been installed.

13 Fiducialize Entire System on CMM and Adjust Spring Cages

201. Put the entire HGVPU on the CMM, supported at the mounting locations (as in Figure 3).

202. Bring the strongbacks to 101 mm gap, then close to 100 mm gap and zero the loadcells.

203. Remove gap fixture if it is still on the system & return the strongbacks to 30 mm gap.

204. The following are instructions for closing the strongbacks to 7.2mm gap safely and slowly while monitoring load on the motors:
   a. Place two 6mm thick (aluminum/plastic) blocks into gap, just for safety purposes, during small gap approach.
   b. Track loadcell values as you close the gap. Record all 8 values, sum each of the motors, and sum each of the strongbacks, and track the strongback values vs. gap in a graph. The strongback values should be negative with a double hump at small gap. Maximum value of 1300 N (300 lbs) is ideal.
   c. While approaching gaps smaller than 22mm, watch load cells closely and stop gap motion if
      i. Any individual load cell has an absolute value of 500N or greater.
      ii. Any individual load cell is positive by more than 200N (this indicates that the magnets are overpowering the springs).
      iii. The sum of the 4 loadcells on a strongback is greater than 2200 N (500 lbs)
   d. Troubleshooting:
      i. If the loads go too high, that could mean that motors have been mounted under too much pre-load, or spring cage calibration data has been compromised.
      ii. If the load cells show too much positive force, it means the magnets are stronger than the spring cages, and the spring cages should be moved outwards towards the edge.
      iii. If the load cells show too much negative (compressive) force, it means the spring cages are stronger than the magnets and the spring cages should be moved inwards towards the gap center.
      iv. Move back out to 60 mm before making spring cage adjustments.

Here is the scaling factor for how much to move all the cages on a side based on force seen.

Gap (mm)	Amount of force change per micron of spring cage change when moving all 18 cages (Pounds/micron)	Ideal Force (Pounds)
7.2	4.0	-300
8	3.1	
9	2.3	(ask LBNL for these #'s if needed)
10	1.7	
11	1.4	

An example: at 7.2 mm gap, force is -400 lbs on both strongbacks. Ideal force is -300 pounds. The spring cages are 100 lbs too strong. Scaling factor is 4.0 lbs/μm. Therefore all 36 spring cages need to be moved 25 µm inward, or the 18 spring cages on one strongback need to be moved 50 µm and the centerline needs to be shifted 25 µm. Centerline may never be shifted more than 50 µm for any device.

205. Once you can get to 7.2 mm gap safely:
   a. Record load cell values at 30, 20, 15, 10, 8 and 7.2 mm gap.
   b. Once 7.2 mm gap is reached check
      i. Sum of the 2 downstream loadcells is within 100 N of the sum of the 2 upstream loadcells on the left strongback
      ii. Sum of the 2 downstream loadcells is within 100 N of the sum of the 2 upstream loadcells on the right strongback
   c. Record load cell values as you open the gap again at 7.2, 8, 10, 15, 20 and 30 mm gap.

VERIFICATION POINT 29

206. Set up the same coordinate system as the previous CMM measurements:
   a. Primary datum surface: A best-fit plane down the center of the gap (beam path)
   b. Secondary datum feature: The top of the Girder inside vacuum chamber mounting hole pattern.
   c. Tertiary datum feature: Girder precision end

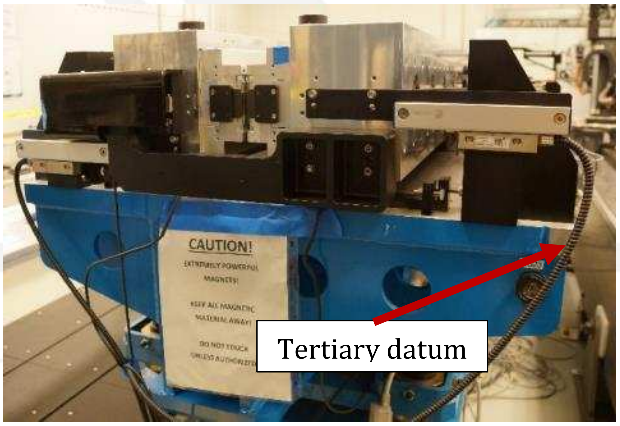


Figure 90: Tertiary datum feature

207. Go back to 7.2 mm gap.

208. Remove safety blocks once gap has been established.

209. Measure pole heights at 7.2mm gap.

210. Move out to 30 mm gap and measure pole heights at 30 mm gap.

211. Put the 7.2 mm gap data, the 30 mm gap data, and the load cell values at 7.2 mm gap into the spring cage sorting software (This step may be done by LBNL). The amount of deflection seen at the ends of the strongback should be equal to the amount of deflection seen at the center of the strongback.

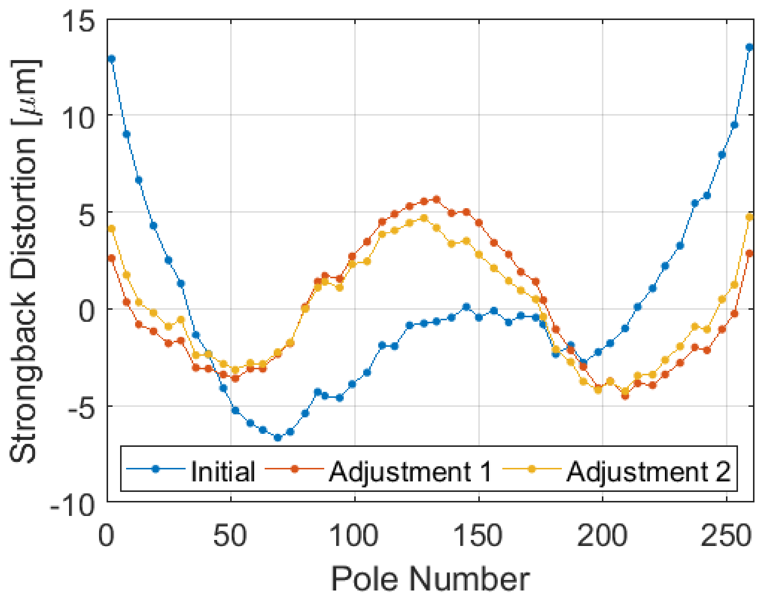


Figure 91: Strongback deflection at 7.2 mm gap vs. 30 mm gap through 2 iterations of spring cage adjustment. Aiming for the center deflection and end deflection to be equal.

212. Adjust the spring cages according to the spring cage sorting software.

213. Re-measure pole heights at 7.2 mm gap, and put the data along with previous 30 mm gap data into spring cage sorting software.

214. Two iterations have generally been needed to bring the gap deflection into tolerance. Continue re-measuring at 7.2 mm and adjusting spring cages according to the software until gap deflection is in tolerance.

215. Record each set of measurements and the output from the program and put the files on Windchill.

VERIFICATION POINT 30

216. Once the spring cages and gap have been qualified, bring the gap to 101 mm and then to 100 mm and re-zero the loadcells.

217. Measure the following:
    a. Pole tops (Y), magnet longitudinal position (Z) and pole heights (X) at shim locations at 100 mm (or wider if necessary) gap.
    b. Distance from the primary datum to poles at shim locations, measured at 1 point at the following gaps:
        i. Measure at 30 mm gap
        ii. Measure at 20 mm gap
        iii. Measure at 15mm gap
        iv. Measure at 10mm gap

v. Measure at 8 mm gap

vi. Measure at 7.2mm gap

c. Load cell values at each of these gaps

d. X, Y, Z coordinates of all fiducial nests at 60 mm gap (the gap the HGVPU is shipped at). (4 1.5” nests per strongback, 4 0.5” nests per strongback, 8 1.5” nests on the girder = 24 fiducial points total, 3 inaccessible = 21 fiducial points expected). (Use tight tolerance stainless steel balls in the drift nests, report center point coordinate of the balls. 1.5” and 0.5” stainless steel balls required. McMaster-Carr parts 9642K73 and 9642K57 work).

NOTE: Fiducial nests HG20, HG 21 and HG22 are inaccessible to CMM probe and can be left out.

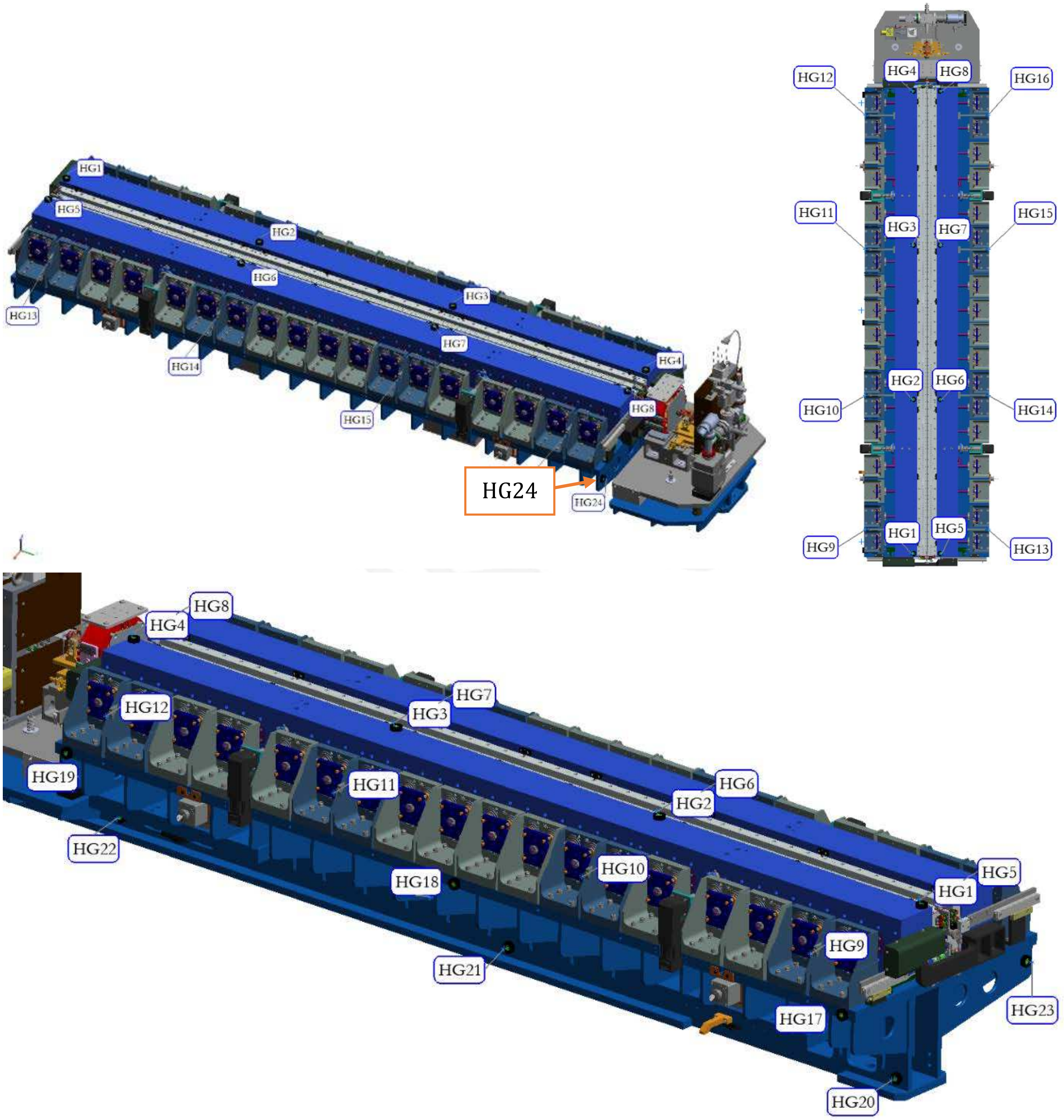


Figure 92: Fiducial numbering – HG1-HG8 are 1.5" nests on the strongbacks. HG9-HG16 are 0.5" nests on posts on the strongbacks. HG17-HG22 are 1.5" nests on the left/aisle side of the girder. HG23 & HG24 are 1.5" nests on the ends of the girder.

218. Record the measurements in excel (.xlsx) format and put the file on Windchill.

VERIFICATION POINT 31

219. Once all qualification measurements have been completed, all hardstops and limit switches must be set. Move the gap to maximum and minimum gaps using 0.004" shims to add over-travel distance to 120mm and 7.2mm gaps when setting hardstops and switches.

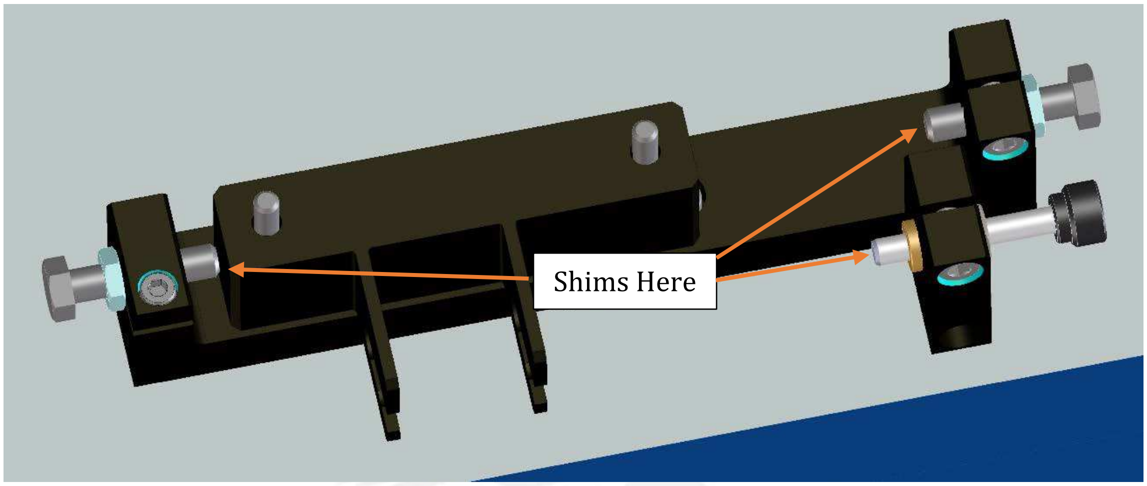


Figure 93: Set the hardstops and the over travel switch

VERIFICATION POINT 32

220. Full-gap encoders are ready to be installed.

14 Install Gap Encoder Assemblies (Dwg 29H907 and 29H908)

Full-gap encoder positions are based on Fagor encoders.

Refer to Amo GmbH's LMBA-1410 mounting instructions.

Refer to Nippon Bearing Slide Guide, SEB Type catalog.

Refer to drawings 29H907 and 29H908.

221. Modify the scale and clamps according to drawings 29L305 & 29L306

222. In a clean environment, mount slide rail to the encoder mount plate (29H899). 29H907 and 29H908 are mounted on opposite sides. Remember to put washers under the end screws to prevent slide block from falling off the rail. Torque M2 screws to 0.3 Nm

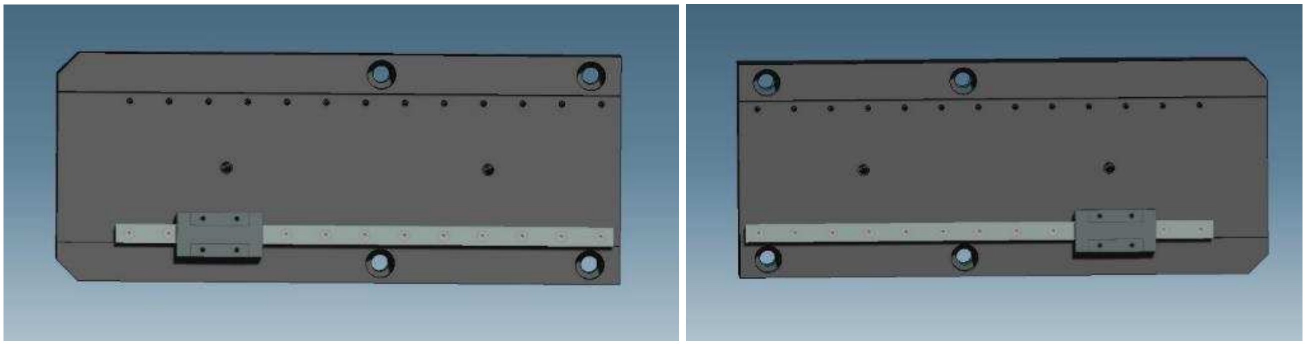


Figure 94: Slide rail position for Gap Encoder Assy 1, 29H907 (left) and Gap Encoder Assy 2, 29H908 (right)

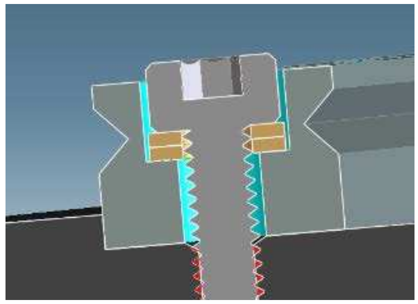


Figure 95: Washers under end screw to prevent slide from coming off the rail

223. Loosely attach scale base to the encoder mount plate. The low profile socket head cap screw goes near the chamfers and the shoulder screw with Belleville washer goes through the modified slot in the scale near the sharp corner side of the encoder mount plate.

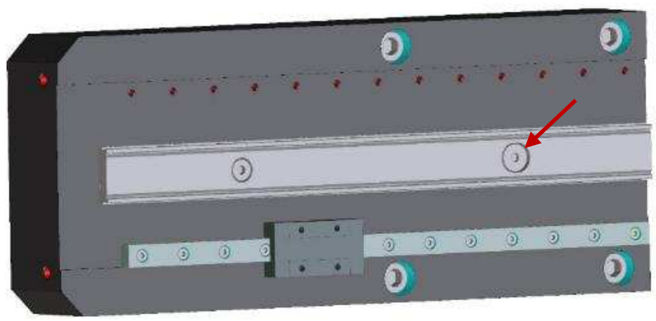


Figure 96: Scale base orientation on encoder mount plate. Larger screw in slot, away from chamfers.

224. Tighten the shoulder screw to 2 Nm. Set the width of the adjustable near the shoulder screw end. Then use the adjustable parallel to establish the gap at the SHCS (chamfer) end. This will make the slide rail and scale parallel. Torque SHCS to 2 Nm.

Figure 97: Set width of Adjustable Parallel near shoulder screw (left) Use Adjustable Parallel to set scale distance from slide rail near the SHCS (right).

225. Be careful not to get fingerprints or grease on the scale. Wearing gloves recommended.

226. Put scale onto base according to installation instructions. The absolute scale (the irregular side) needs to match with the black dot (or "A") on the readhead. This means that when the chamfered corners of the encoder mount plate are to the right (as in Figure 96) the irregular side should be on top, and the regular side on the bottom.

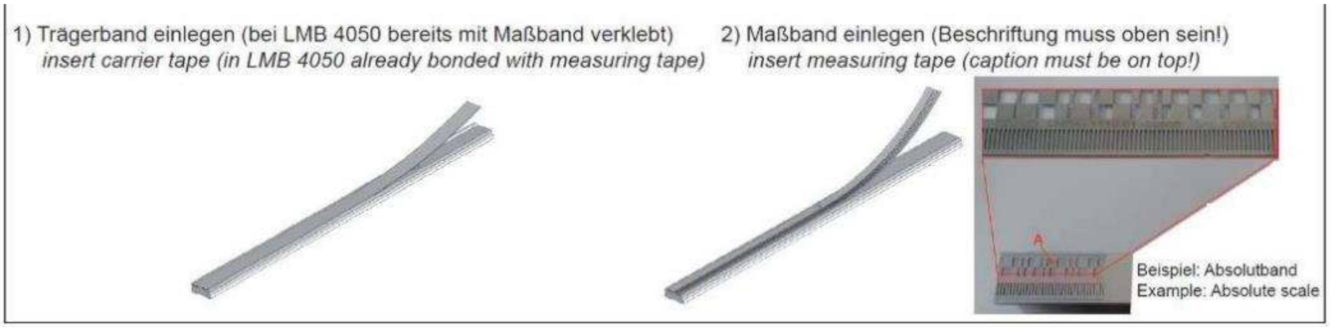


Figure 98: From the LMBA-1410 mounting instructions

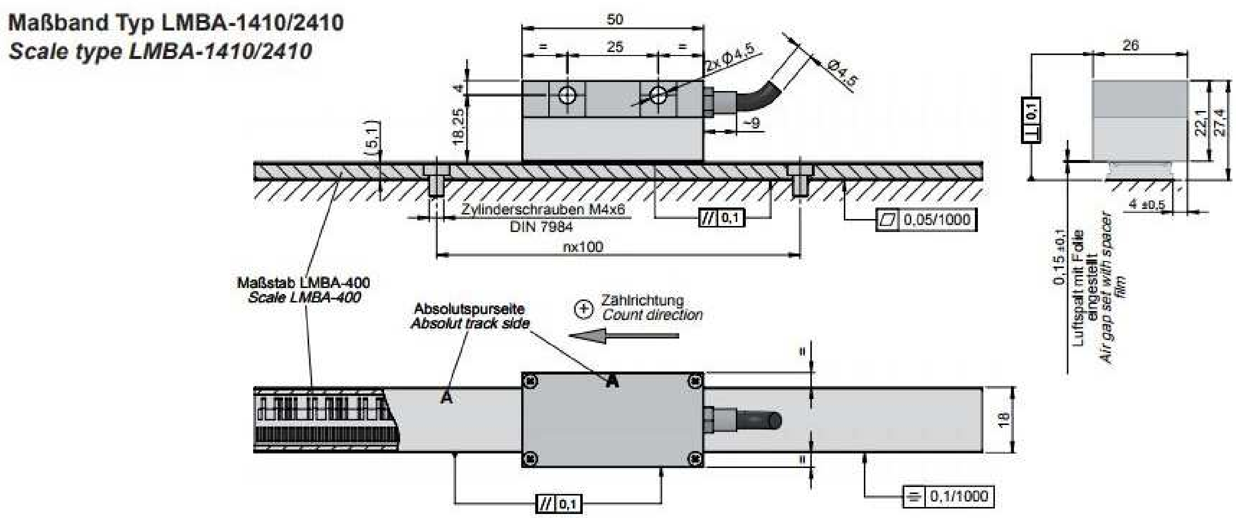


Figure 99: From the LMBA-1410 mounting instructions – absolute/irregular side matches with black dot/ "A" on the readhead

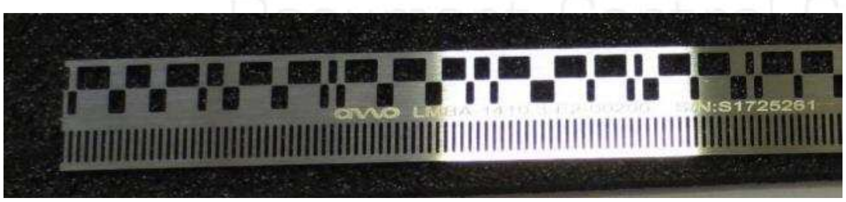



Figure 100: LMBA-1410, absolute side up (left) and readhead, absolute side up (right)

227. Now mount the protective tape. Do not kink, damage, get fingerprints on the tape or the scale. If protective tape is damaged, remove completely and try again, no more than 3 times.

Figure 101: From the LMBA-1410 mounting instructions

228. Mount clamp at both ends and insert screws. Tighten until snug. Note that screw placement should be over the part of the scale that has no holes in it.

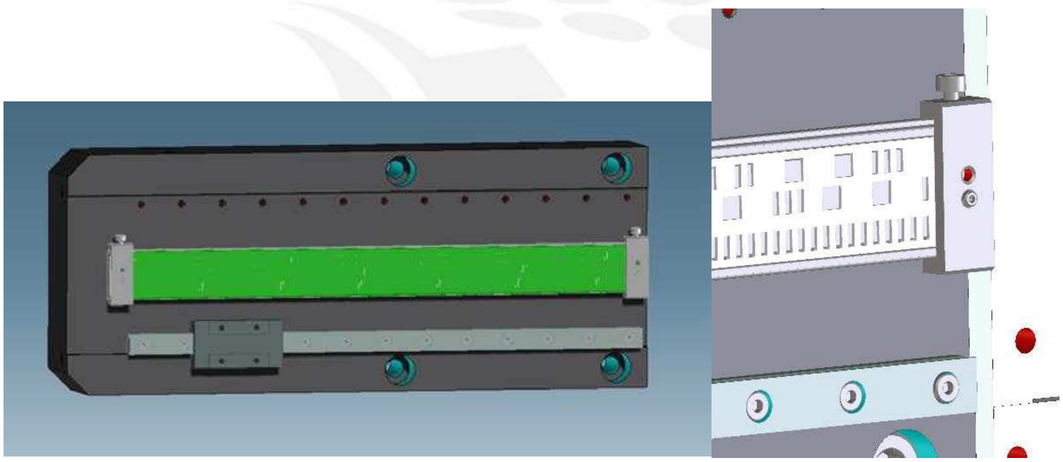


Figure 102: Scale on encoder mount plate (left), clamping screw over solid portion of scale (right).

229. Attach the tooling ball to the readhead mount.

230. Attach 4mm gap block (drawing 29L308) to readhead mount.

231. Loosely fasten the readhead mount to the slide carriage.

232. Push the gap block up against the scale mount and then tighten the 4 M2 screws.

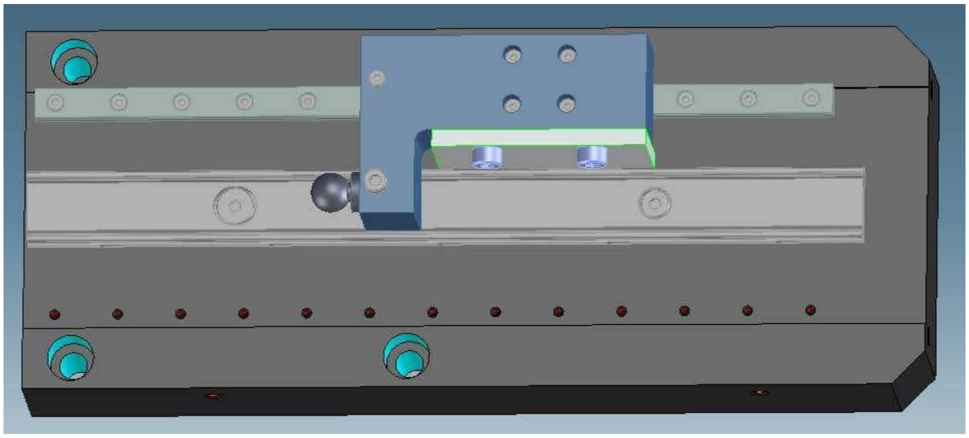


Figure 103: 4 mm gap block up against scale to set readhead position in comparison to scale.

233. Remove the 4 mm gap block, and attach the readhead to the readhead mount.

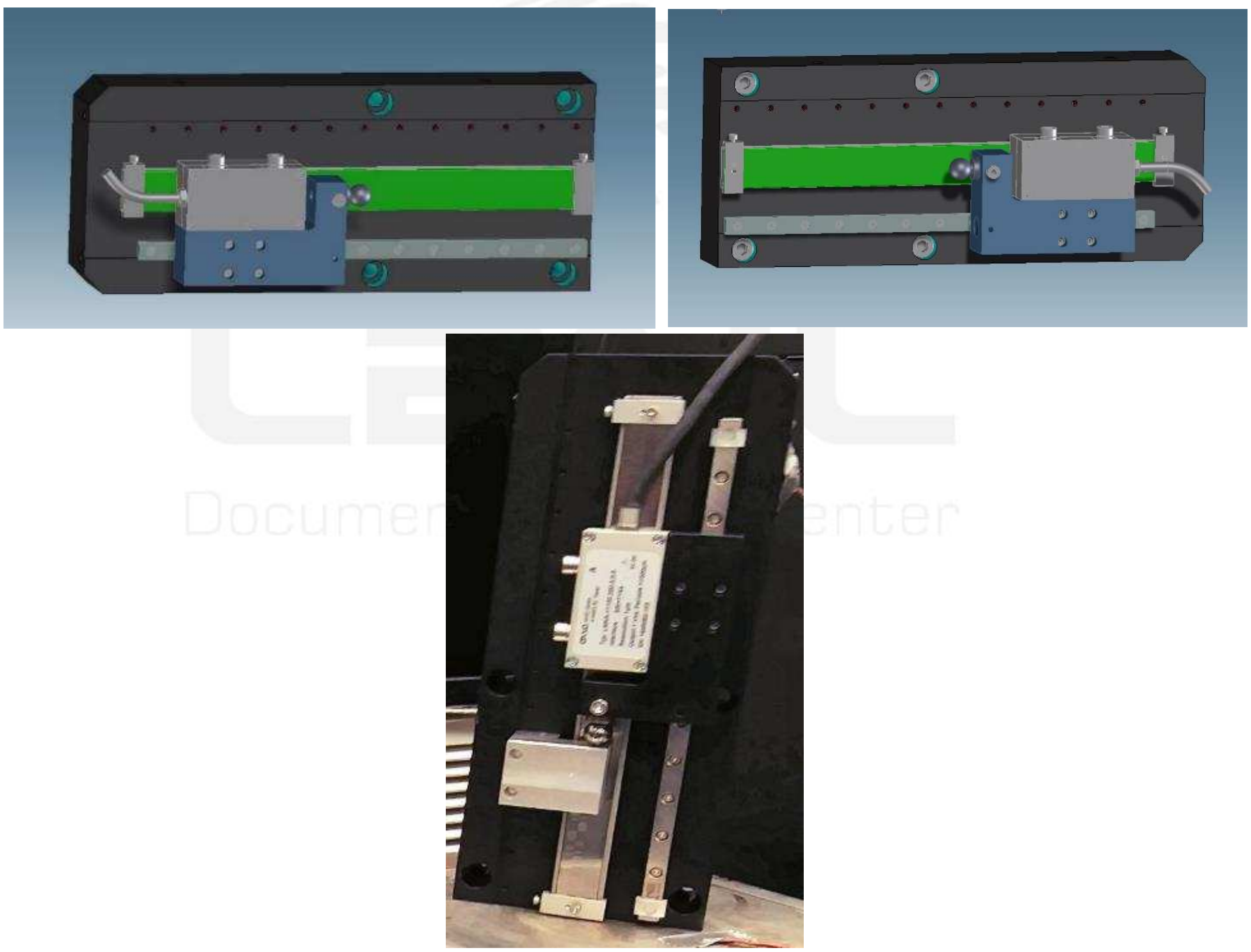


Figure 104: Readhead mounted on slide rail.

234. Use benchtop tester and slide back and forth to check that system reads for the entire length of the scale.

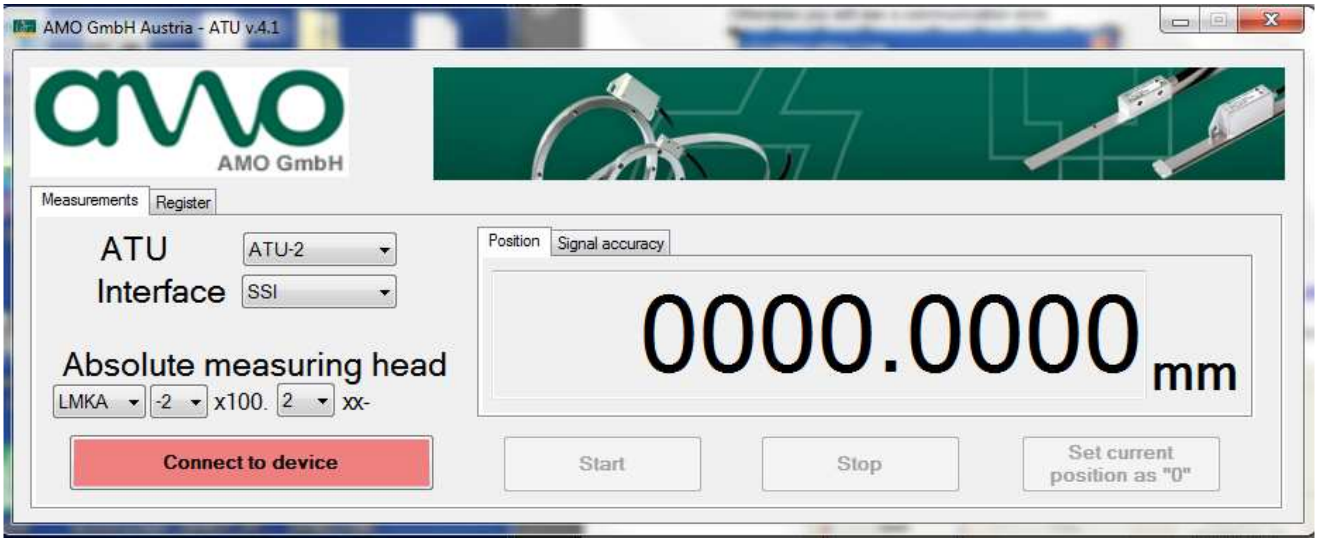


Figure 105: Benchtop tester settings

235. Attach actuator plate to actuator arm using actuator clamp and 2 screws.

Figure 106: Ceramic block clamped to actuator arm.

236. Install Slide Assembly.
   a. Encoder Lead Insert
   b. Slide assembly
   c. M6x30 SHCS (qty 4) (Torque 8.7 Nm, 77 in-lbs)

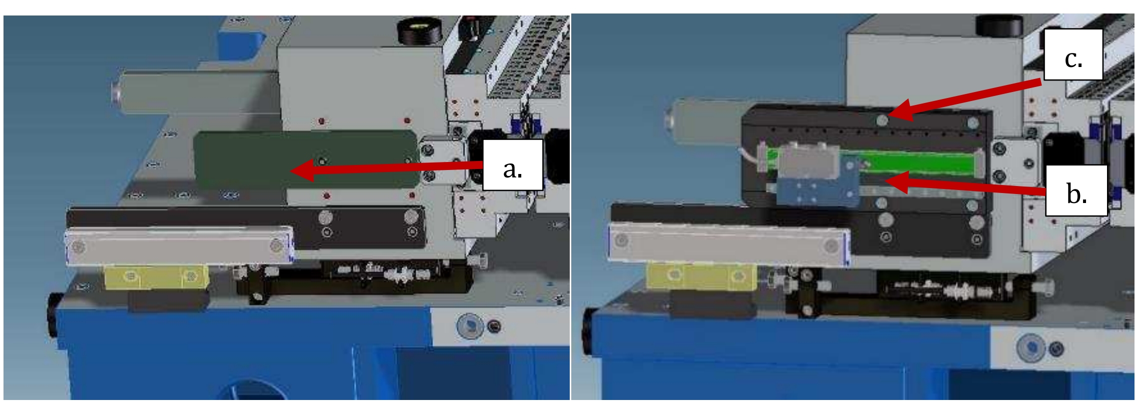


Figure 107: Installing the slide assembly.

237. Install actuator arm. (M6 screws torque to 8.7 Nm, 77 in-lbs)

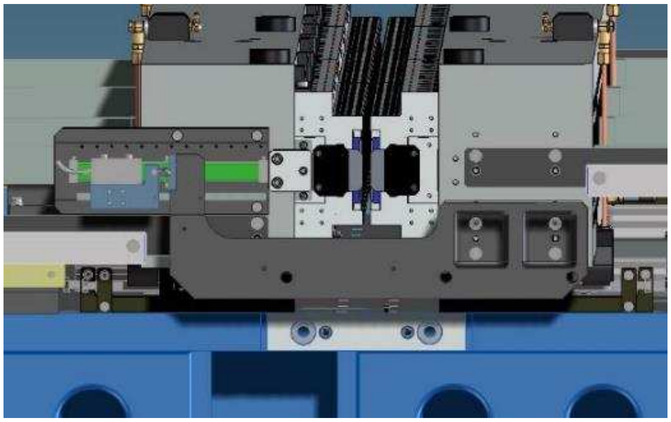


Figure 108: Attach actuator arm to other strongback.

238. Attach spring to actuator arm and readhead mount.

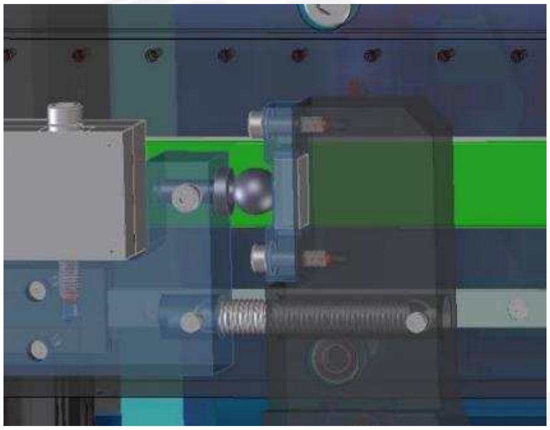


Figure 109: Spring keeping tooling ball touching ceramic plate.

239. Install Linear Encoder Lead Cover
    a. Encoder Lead Cover
    b. M4x14 SHCS
    c. M4 Washer

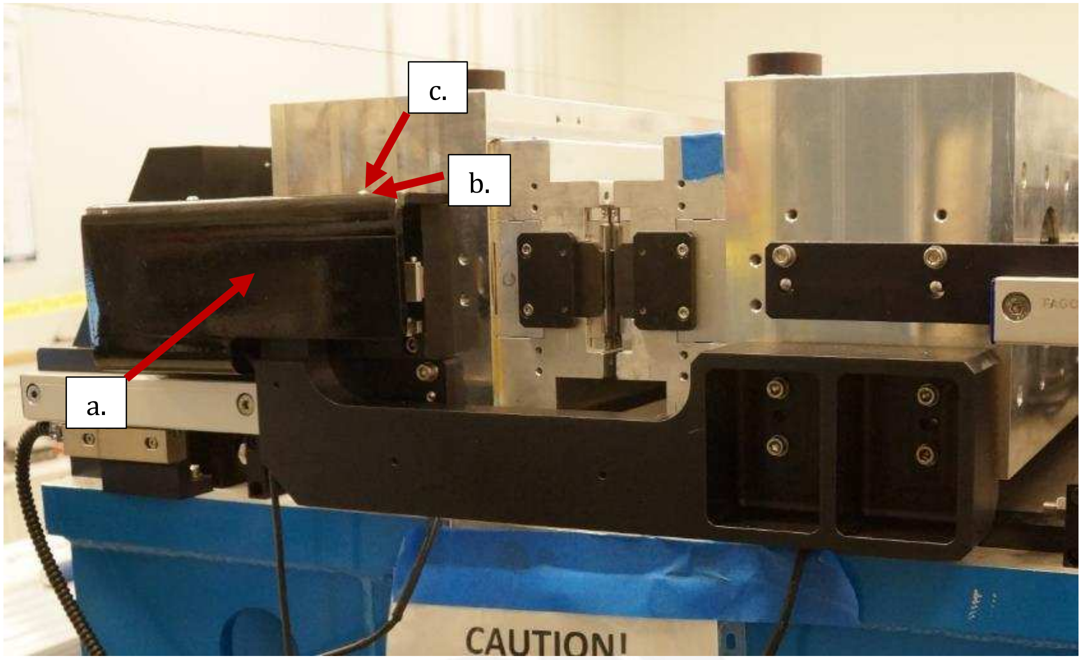


Figure 110: Lead cover installed.

240. Connect Gap Encoders to control system and open and close gap. Ensure that the gap encoders are reading correctly.

241. Set the Full Gap Encoder offsets based on the half gap encoder readings (adjust the "Offset" window until the "Value" window is the sum of the 2 half gap encoders) (See Figure 111.)

VERIFICATION POINT 33

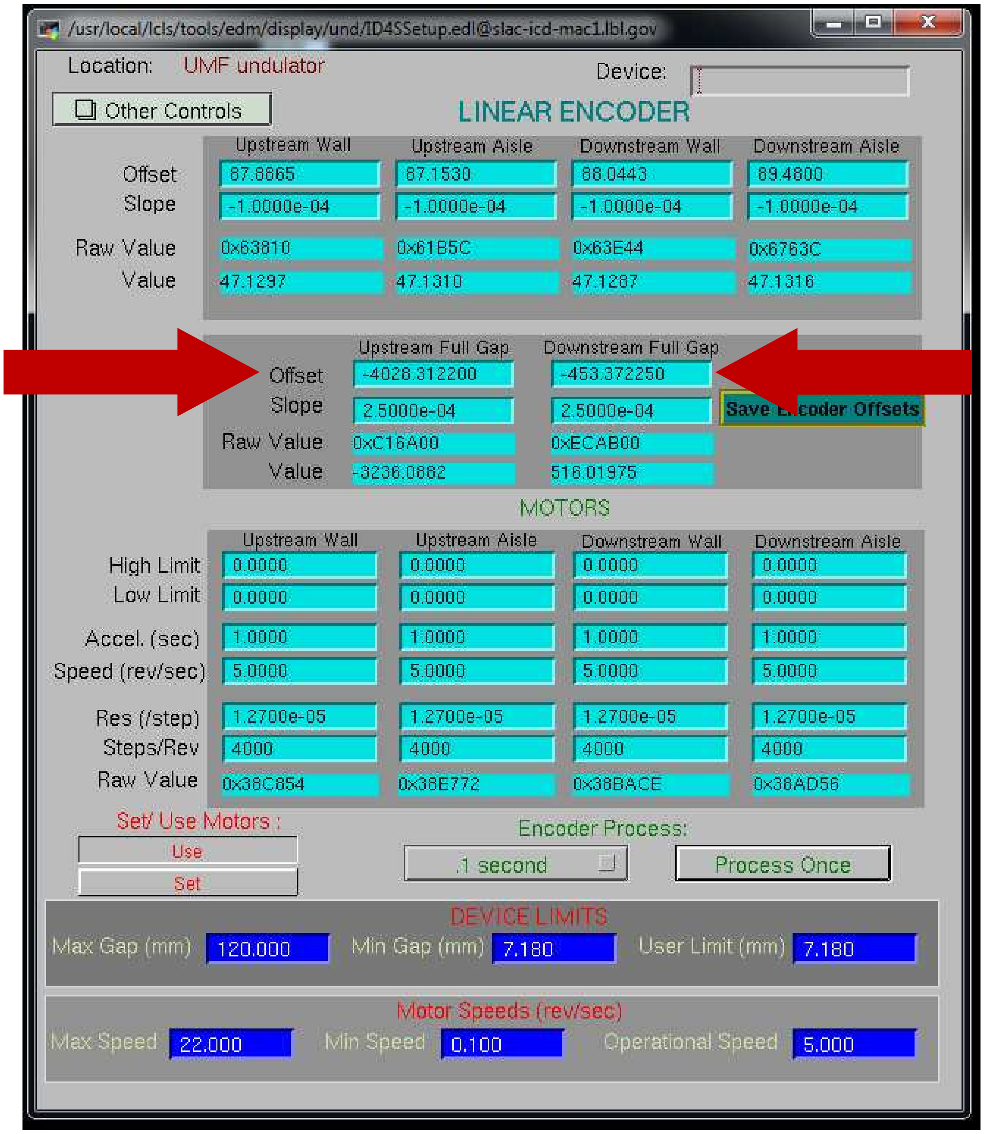


Figure 111: Where to set full gap encoder offset

15 Finish Wiring (Dwg 29L130)

242. Now that all shimming steps are complete, put blue Airtech Flashbreaker 5 tape over the shims (both top and bottom on both strongbacks) to ensure that the shims do not cut technicians during the tuning steps that will be performed after shipment.

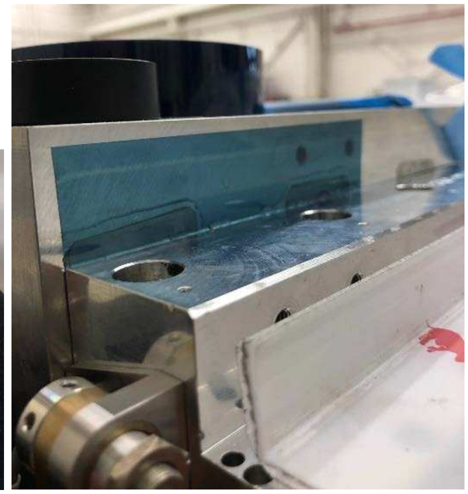


Figure 112: Tape on the roll (left) Tape over the shims (right)

243. Install the panduits on top of the panduit adapters.

244. Install the motor guard assemblies.

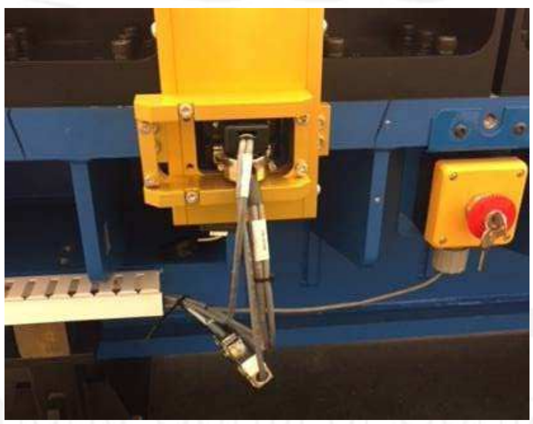


Figure 113: Motor and E-stop cables into Panduit. Aisle Side.

245. Install vacuum chamber sensors. The switch should protrude into the gap, such that they are taller than the poles (~12 mm from the bracket). There should be space between the yellow and silver piece to allow for adjustment. Use a little oil on the fine screw threads when putting the switch together.

Figure 114: Vacuum chamber switch

246. Route the Cables according to drawing 29L130.

Figure 115: Limit Switch Interface box. Wall Side.

Figure 116: Limit switch interface box. Wall Side. Note 2 connectors are disconnected. These are the dummy vacuum chamber switch cables. The vacuum switch and dummy vacuum switch share their input connector.

Figure 117: Downstream, Aisle vacuum chamber switches, hardstop switches, half-gap encoder wiring

16 Install Wedge Blocks

247. Mount the wedge blocks (also referred to as kinematic mount, or cam rollers). (29K388 Upstream Left, 29K390 Downstream Right, 29K389 Downstream Left, 29H991 Upstream Right) Put the wedge blocks on the innermost pad to keep them out of the way of lifting slings.

248. Bolts are M12x1.75x22. Torque to 95 Nm (31 ft-lbs).

249. Install 29H992 with 6 M6 screws on the Upstream Right side. (Torque M6 screws to 11.3 Nm)

250. Install 29H990 with 2 M6 screws on the Upstream Left side.

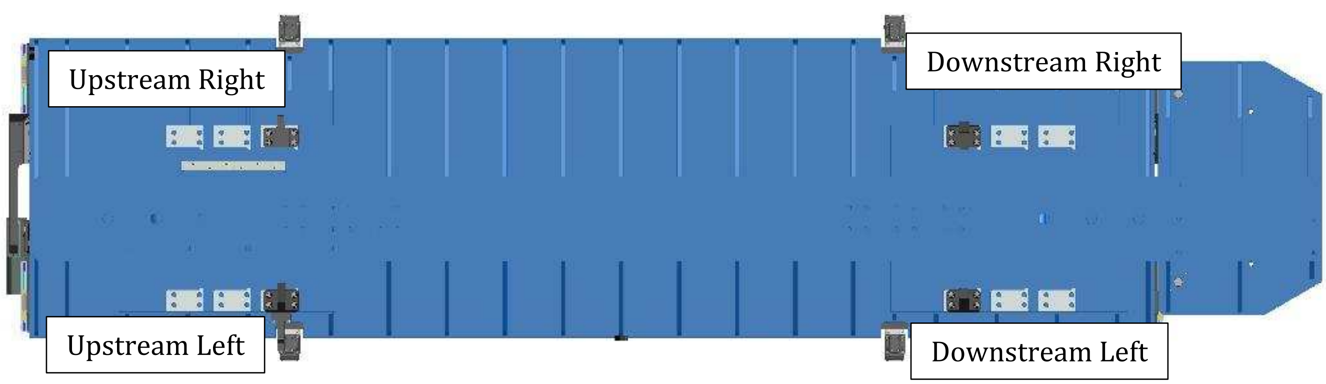


Figure 118: Wedgeblocks

17 Gap Control Acceptance Tests

The gap control system shall be capable of adjusting the center position, pitch, and tapering with accuracy better than 20 μm and repeatability better than 1 μm. The requirements for the accuracy and repeatability, as shown below, are stricter than the physical requirements [see LCLSII-3.2-PR-0038-R2]. The requirement for the roll of the strongbacks with varying gap is that it should be smaller than 1 mrad [see LCLSII-3.2-PR-0038-R2].

Requirements for the Gap Control System:

Parameter	Requirement
Gap repeatability over operational gap range 7.2 -20 mm	<1 μm
Vertical center position accuracy	<20 μm

Components of the gap control system:

Item	Number of units
Incremental encoder servomotor	4
Drive system limit switches	8
Full-Gap absolute linear encoders	2
Half-Gap absolute linear encoders	4
Vacuum chamber limit switches	8

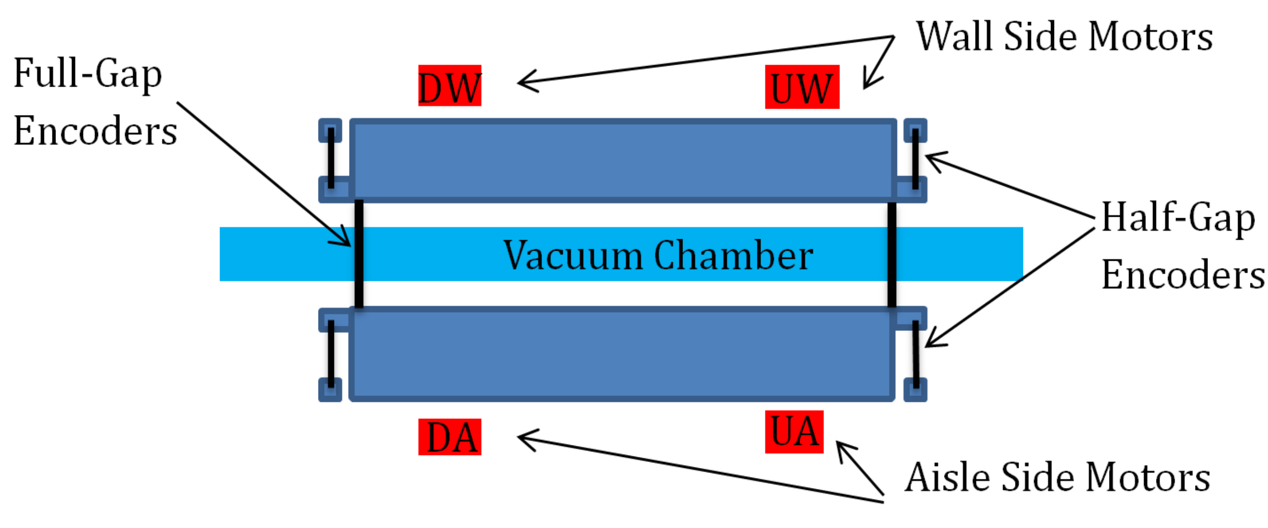


Figure 119: Diagram of the main sensing components (two full-gap encoders and four half-gap encoders) and the four incremental encoders.

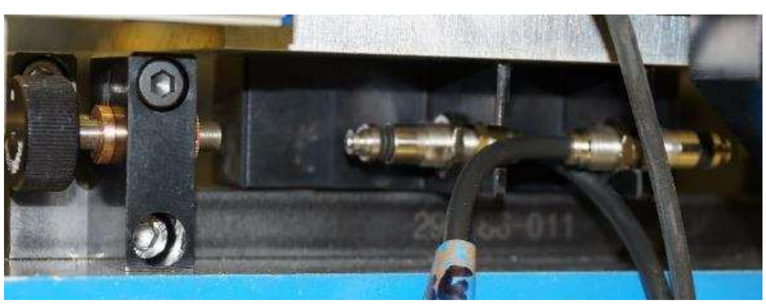


Figure 120: Limit switches on the drive system prevent over travel scenarios

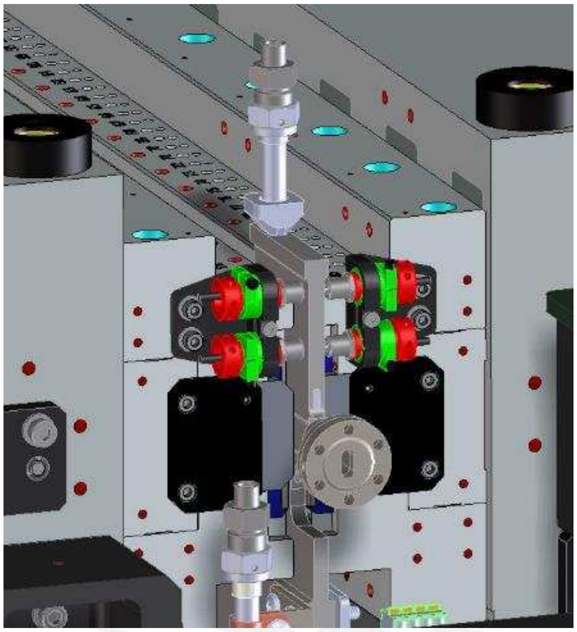


Figure 121: Limit switches are attached to the strongbacks to prevent contact between the pole surfaces and the vacuum chamber.

17.1 Attach Labels to Both Ends of Control Cables

251. Attach the stickers provided by SLAC to the motors, linear encoders, switches, and the motion control boxes. Attach label to all control cables with the undulator assembly with a destination and source label on each end.

VERIFICATION POINT 34

17.2 Complete the LCLS-II HGVPU Undulator Motion Controls Checkout Procedure

252. Complete the LCLS-II HGVPU Undulator Controls Checkout Procedure.

VERIFICATION POINT 35

17.3 Set the Absolute Scale of the Half-Gap and Full-Gap Encoders

253. Align the strongbacks symmetrically around the nominal horizontal center with a gap of 30 mm with the centering fixture and a CMM.

254. Read and record the half-gap and full-gap encoder values for reference.

VERIFICATION POINT 36

17.4 Power Loss Test

255. Disconnect the controller from wall power.

256. After ~30 seconds, reconnect the gap control system to wall power. Record the position readings of the encoder.

VERIFICATION POINT 37

17.5 Check the Gap Reading against a Precision Ground Block

257. Set the gap to be 0.15 mm larger than the thickness of the precision ground block. Carefully slide the block along the length of the undulator and verify that the gap is uniform along the full length.

258. Set the gap to be 0.1 mm smaller than the thickness of the precision ground block. Carefully try to insert the block through the length of the undulator and verify that it cannot enter anywhere along the gap.

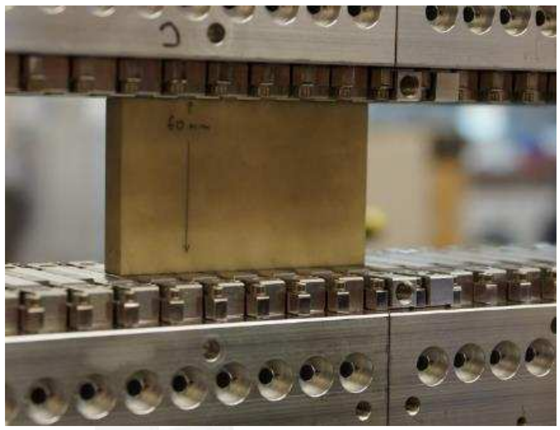


Figure 122: Slide precision ground block through the gap (different undulator design shown)

VERIFICATION POINT 38

17.6 Set the Software Limit Switches

259. Set the software limit switches for minimum gap, maximum gap, taper, and symmetry by typing in values outside of the tolerances and ensuring the drive system does not move.

VERIFICATION POINT 39

17.7 Set the Hard Stops

260. Move the strongbacks in to a nominal gap of 7.2 mm. Using a 0.004” (~100 μm) shim, set the inner hard stops and tighten. Move the strongbacks to a gap of 7.3 mm, then back to 7.2 mm and re-check the hard stop is properly set with the shim.

261. Move the strongbacks out to a nominal gap of 120 mm. Using a 0.004” (~100 μm) shim, set the outer hard stops and tighten. Move the strongbacks to a gap of 199 mm, then back to 120 and re-check the hard stop is properly set with the shim.

VERIFICATION POINT 40

17.8 Set the Over-Travel Limit Switches

262. Open the gap to the maximum value of 120 mm. When the gap of 120 mm has been reached, adjust the bolts so the limit switches are triggered at 120 mm and not 199. Tighten the bolts in place and re-check.

NOTE: Tolerance of setting over travel limit switches is ~0.03 mm.

VERIFICATION POINT 41

18 Install Firmware on Motors

Steps to install new firmware onto motors. Must be completed after all other steps, as the control program provided to the vendors cannot work with the new firmware, and the control program at the tuning lab needs the new firmware.

Tools:

- Windows PC
  - Serial port or SerialToUSB converter
- 24VDC power supply
- Cable (3 ends, 7W2 connector for motor, 24VDC connection & DB9 connector for serial port)
- SmartMotor Interface Program: http://www.animatics.com/index.php?option=com_content&view=article&id=104&Itemid=9&dir=JSROOT%2Ftop+level%2F3.+SMI+Software+And+Drivers/SMI+Software
- SLAC program "HGVPU_SmartMotor_ProgramRefactor.sms"

263. DO NOT PLUG OR UNPLUG THE MOTOR INTO THE POWER SUPPLY WHILE IT IS ON.
264. Plug the motor into the turned off 24VDC power supply and the computer.
265. Turn on the power supply.
266. Open the SmartMotor Interface program.
267. You should see two panels: Configuration and Terminal
268. Use the Configuration Panel to locate the motor.
    a. By clicking the "Find Motors" button
    b. By knowing/finding the COM port number of the SerialToUSB converter you're using, right clicking on that in the Configuration Panel, and selecting "Detect Motors"
269. When a motor is detected, select it and move to the Terminal Panel.

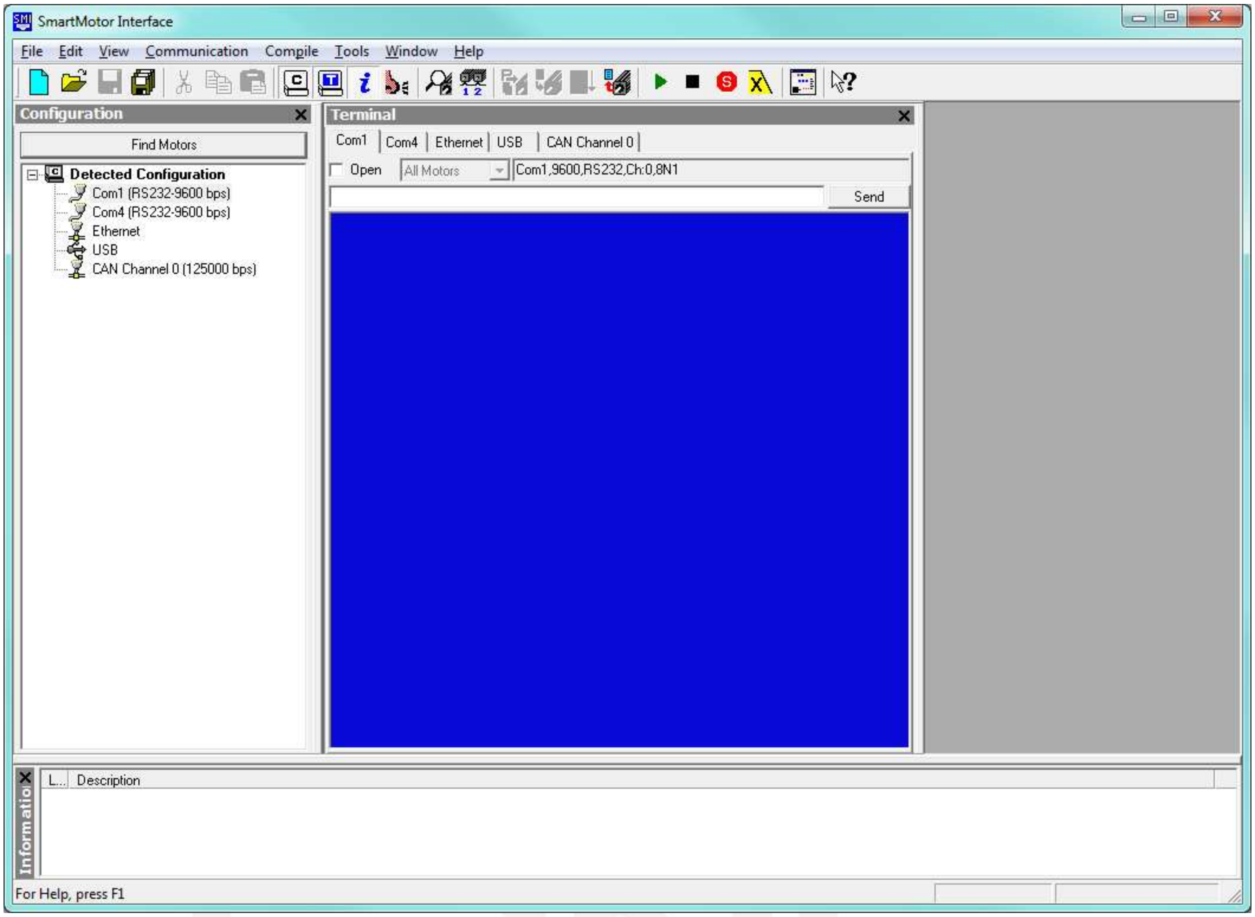


Figure 123: SmartMotor Interface Program

270. Set the CAN address of the motor by issuing command CADDR=X in the Terminal Panel

X	Name	Motor Description
1	USW	Upstream Wall motor
2	DSW	Downstream Wall motor
3	DSA	Downstream Aisle motor
4	USA	Upstream Aisle motor

271. Type RCADDR into the Terminal Panel to check that the CAN address is correct.

272. Open the SLAC program HGVPU_SmartMotor_ProgramRefactor.sms

273. Load the SLAC program onto the motor by pressing [Compile and Download Program] 

274. In the popup window, select the correct port and motor and click [OK].

275. When the program is done compiling and loading, reset the controller by typing [Z] into the Terminal Panel.

276. Verify the Can address one more time by typing [RCADDR] in the Terminal Panel.

277. Check that the proper program is on the motor by clicking "upload program" from the controller.

278. TURN OFF THE POWER SUPPLY BEFORE UNPLUGGING THE MOTOR

279. Move to the next motor and repeat the steps for all 4.

19 Completion

280. Ensure all component serial numbers are entered in the Verification Signoff Sheet.

281. Enter the completion date and temperature in the Verification Signoff Sheet.

282. Have Verification Signoff Sheet signed and dated by Quality Assurance.

283. Prepare the undulator for shipment, see document LC-1004-2854, "HGVPU Full Assembly Shipping and Handling"

Verification Signoff Sheet

EACH MECHANICAL SYSTEM IS REQUIRED TO HAVE A COMPLETED VERIFICATION SHEET.
VERIFICATION MUST BE DONE BY AN ENTITY OTHER THAN THE ASSEMBLY TECHNICIAN.

SERIAL NUMBER:	
ASSEMBLY START DATE:	**ASSEMBLY COMPLETION DATE:**
AMBIENT TEMPERATURE AT ASSEMBLY START:	**AMBIENT TEMPERATURE AT ASSEMBLY COMPLETION:**
WORK INSTRUCTIONS NUMBER AND REVISION:	
COMPLETE ASSEMBLY VERIFIED BY (Sign and Date):	

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29H866	GIRDER WELDMENT	1		
29L222	STRONGBACK FLEXURE	4		
29L034	CARRIAGE BRACKET 1	2		
29L039	CARRIAGE BRACKET 2	2		

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29L035	SPRING CUP BRACKET	4		
29K386	HARDSTOP BRKT, LONG L, ASM, VPU	2		
29H942	HARDSTOP BRKT, LONG R, ASM, VPU	2		
29H945	HARDSTOP BRKT, SHORT, VPU	4		
29H990	VERTICAL POTENTIOMETER INTERFACE BRACKET	1		
29H991	UPSTREAM WEDGE BLOCK (FLAT)	1		
29H992	VERTICAL POTENTIOMETER POSITION BRACKET	1		
29K388	UPSTREAM WEDGE BLOCK (DOUBLE CAM)	1		
29K389	DOWNSTREAM WEDGE BLOCK (42.8 DEG)	1		
29K390	DOWNSTREAM WEDGE BLOCK (25.6 DEG)	1		

STRONGBACK LEFT ASSEMBLY (29H896)				
PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29H914	STRONGBACK ASSEMBLY	1		
29H881	ENTRANCE MODULE LEFT	1		
29H872	CENTER MODULE LEFT	1		
29H882	EXIT MODULE LEFT	1		
29H924	MOUNT, BALL SCREW, VPU	2		
29K240	FIDUCIAL MOUNT ASSY	4		
29H927	PRESS PLATE	2		
29H926	MODULE END CLAMP	2		

STRONGBACK RIGHT ASSEMBLY (29H897)				
PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29H914	STRONGBACK ASSEMBLY	1		
29H893	ENTRANCE MODULE RIGHT	1		
29H894	CENTER MODULE RIGHT	1		
29H895	EXIT MODULE RIGHT	1		
29H924	MOUNT, BALL SCREW, VPU	2		
29K240	FIDUCIAL MOUNT ASSY	4		
29H927	PRESS PLATE	2		
29H926	MODULE END CLAMP	2		

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29H952	HARDSTOP BRACKET UPPER LEFT	2		
29H950	HARDSTOP BRACKET UPPER RIGHT	2		
29L046	GREASE FITTING MANIFOLD	4		
29H902	TILT ENCODER BRACKET TALL	2		
29H903	TILT ENCODER BRACKET SHORT	2		
29L317	FAGOR ENCODER PLATE 1	2		
29L331	FAGOR BACKING BAR 1	2		
29L318	FAGOR ENCODER PLATE 2	2		
29L332	FAGOR BACKING BAR 2	2		
29L319	FAGOR NUT PLATE	4		
29H778		4		

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)		
	VAC CHAMBER LIMIT SWITCH BKT				
29K261	KINEMATIC MOUNT, THREADED BLOCK	3			
29K268	KINEMATIC MOUNT, THREADED ROD	3			

MOTOR AND GEAR ASSEMBLY, VPU (29H934), 4 MOTORS				
PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)	
29L024	GEARBOX ADAPTER	4		
29L025	BRACKET – DRIVE MOTOR ASSY	4		
29L027	BEARING HOUSING STOP	4		
29L026	BEARING MOUNT & COUPLING HOUSING	4		
	LOAD CELLS	8	USAT	DSAT
			USAB	DSAB
			USWT	DSWT
			USWB	DSWB

GAP ENCODER ASSY 1 (29H907)			
PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)
29H890	ACTUATOR ARM 1	1	
29H899	ENCODER MOUNT PLATE	1	
29H898	READHEAD MOUNT 1	1	
29H871	ACTUATOR PLATE CLAMP	1	

GAP ENCODER ASSY 2 (29H908)			
PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)
29H900	ACTUATOR ARM 2	1	
29H899	ENCODER MOUNT PLATE	1	
29H901	READHEAD MOUNT 2	1	
29H871	ACTUATOR PLATE CLAMP	1	

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)
29H913	SPRING CAGE UNCUT	20	
29H860	SPRING CAGE CUT	16	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
1		GIRDER CMM REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
2		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (27 ft-lb/36.6 Nm)	TOOL ID LAST CAL DATE	
3		PARALLELISM CMM REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
4		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (27 ft-lb/36.6 Nm)	TOOL ID LAST CAL DATE	
5		NO BINDING 4X CARRIAGE/SPRING SYSTEMS	N/A	
6		STRONGBACK INSPECTION REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
7		MAGNET MODULE RECEIVING DATA UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
8		BOX FLEXURE PARALLELISM	TOOL ID LAST CAL DATE	
9		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (50 in-lb)	TOOL ID LAST CAL DATE	
10		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (50 in-lb)	TOOL ID LAST CAL DATE	
11		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (50 in-lb)	TOOL ID LAST CAL DATE	
12		MAGNET ORIENTATION OK, ARROWS OK, CORRECT MODULES, LEFT VS RIGHT STRONGBACK OK, PHOTO OF 0.002” FEELER GAUGE BETWEEN MODULE & STRONGBACK	N/A	
13		Junction Shim Thickness US Left/Aisle; DS Left/Aisle US Right/Wall; DS Right/Wall	N/A	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
14		LOAD CELL VALUES USA up / DSA up / USW up / DSW up USA low / DSA low / USW low / DSW low	N/A	
15		CMM REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
16		CMM REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
17		ANTI-SEIZE APPLIED TO SCREWS	N/A	
18		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (31 ft-lb/42 Nm)	TOOL ID LAST CAL DATE	
19		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (77 in-lb/8.7 Nm)	TOOL ID LAST CAL DATE	
20		TEMPERATURE @ TIME OF TORQUE TORQUE VALUE (11 ft-lb/15 Nm)	TOOL ID LAST CAL DATE	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION				CAL INFO	VERIFICATION BY (Sign & Date)
21		COUPLING SCREW TORQUE (3.5 Nm/31 in-lbs) BOTH SCREWS, 1.2 MM GAP				TOOL ID LAST CAL DATE	
		US-R	DS-R	DS-L	US-L		
22		TOP TO BOTTOM LOAD CELL DIFFERENCE <50 N				TOOL ID LAST CAL DATE	
23		ENCODER UPSTREAM LEFT		UPSTREAM RIGHT		N/A	
		DOWNSTREAM LEFT		DOWNSTREAM RIGHT			
24		MOTORS CAN OPEN GAP FROM 30 MM TO 100 MM				N/A	
25		LOAD CELL VALUES				N/A	
		USA up	DSA up	USW up	DSW up		
		USA low	DSA low	USW low	DSW low		
26		ENCODER UPSTREAM LEFT		UPSTREAM RIGHT		N/A	
		DOWNSTREAM LEFT		DOWNSTREAM RIGHT			

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
27		CMM REPORT UPLOADED TO WINDCHILL	TOOL ID LAST CAL DATE	
28		SPRING CAGE IN TOLERANCE (check mark)	TOOL ID LAST CAL DATE	
29		LOADCELL DATA RECORDED AT 30, 20, 15, 10, 8, 7.2, 8, 10, 15, 20, 30 MM GAP	N/A	
30		CMM REPORT	TOOL ID LAST CAL DATE	
31		CMM REPORT	TOOL ID LAST CAL DATE	
32		HARDSTOPS LIMIT SWITCHES SET	N/A	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION		CAL INFO	VERIFICATION BY (Sign & Date)
33		UPSTREAM OFFSET	DOWNSTREAM OFFSET	N/A	
34		ALL STICKERS ATTACHED TO MOTORS, ENCODERS, SENSORS, AND CABLES		N/A	
35		LCLS-II HGVPU Undulator Motion Controls Checkout Procedure Completed		N/A	
36		GAP FROM CMM		TOOL ID LAST CAL DATE	
		USA HALF-GAP ENCODER			
		USW HALF-GAP ENCODER			
		DSA HALF-GAP ENCODER			
		DSW HALF-GAP ENCODER			
		US FULL-GAP ENCODER			
		DS FULL-GAP ENCODER			
37		USA HALF-GAP ENCODER		TOOL ID LAST CAL DATE	
		USW HALF-GAP ENCODER			
		DSA HALF-GAP ENCODER			

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION		CAL INFO	VERIFICATION BY (Sign & Date)
		DSW HALF-GAP ENCODER			
		US FULL-GAP ENCODER			
		DS FULL-GAP ENCODER			
38		CERAMIC BLOCK PASSES AT + 0.15 mm GAP		TOOL ID	
		CERAMIC BLOCK DOES NOT PASS AT – 0.1 mm GAP		LAST CAL DATE	
39		SOFTWARE LIMIT SWITCHES SET		TOOL ID LAST CAL DATE	
40		HARD STOPS SET		TOOL ID LAST CAL DATE	
41		OVER-TRAVEL LIMIT SWITCHES SET		TOOL ID LAST CAL DATE	