Qualification Procedures for the Q3s Three-Year-Old Child Side Impact Dummy

SEPTEMBER 2018

Task Performed under Contract to:
Vehicle Research and Test Center
National Highway Traffic Safety Administration

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NOTE: All qualification procedures in this manual are illustrated for left side qualifications. Right side qualification tests mirror images of those presented and follow the same procedures unless otherwise noted (for example, lateral neck flexion). For information on reversing the assembly of the dummy to impact the right side, see the "Procedures for Assembly, Disassembly, and Inspection (PADI) of the Q3s Child Side Impact Crash Test Dummy" (PADI) document.

1. Q3S HEAD QUALIFICATION PROCEDURES

1.1. Required Instrumentation

- Head X accelerometer
- Head Y accelerometer
- Head Z accelerometer

1.2. General Head Pre-Test Preparation

- Soak the head assembly in a controlled environment at a temperature between 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Install the half mass (0.075 kg) simulated upper neck load cell using four (4) M5 x 12 FHCS (Figure 1).

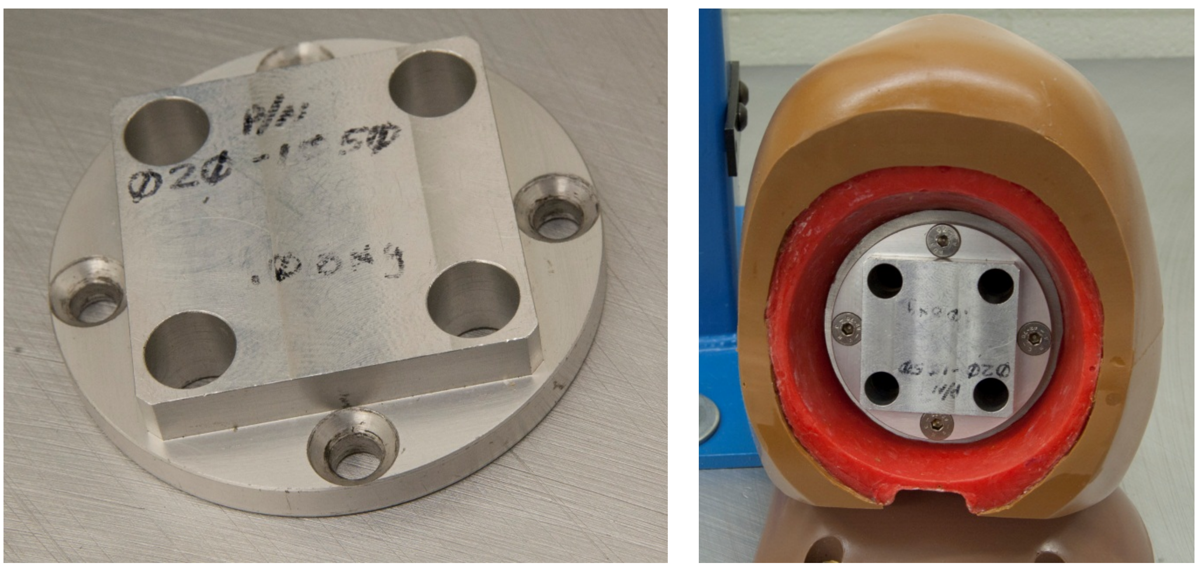

Figure 1. Half mass upper neck load cell simulator (left) installed for head qualification test (right)

- Attach the 3 accelerometers to the accelerometer mounting block using two (2) M1.4 x 3 SHCS for each accelerometer (Figure 2). Ensure that all axes are oriented properly. Note that the Z axis accelerometer is installed upside down.

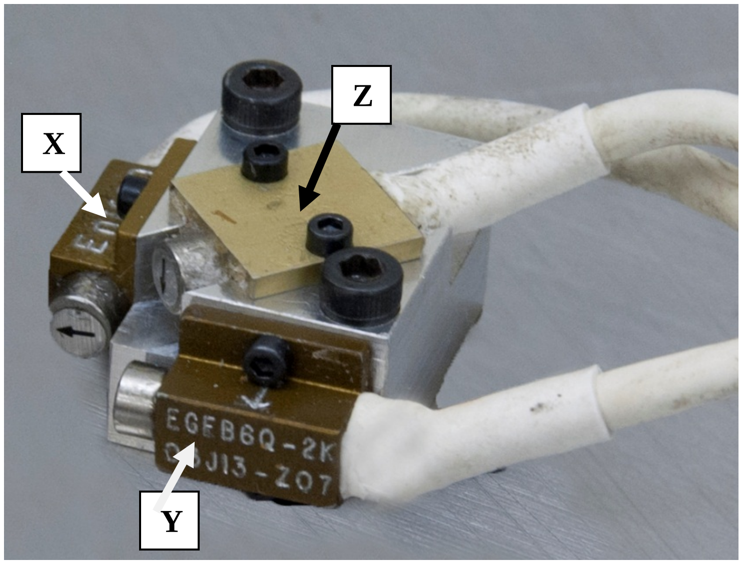

Figure 2. Install accelerometers to mounting block

- Attach the accelerometer block to the accelerometer bracket (Figure 3) using two (2) M2.5 x 0.45 x 16 SHCS. Ensure that all axes are oriented properly with respect to the bracket.

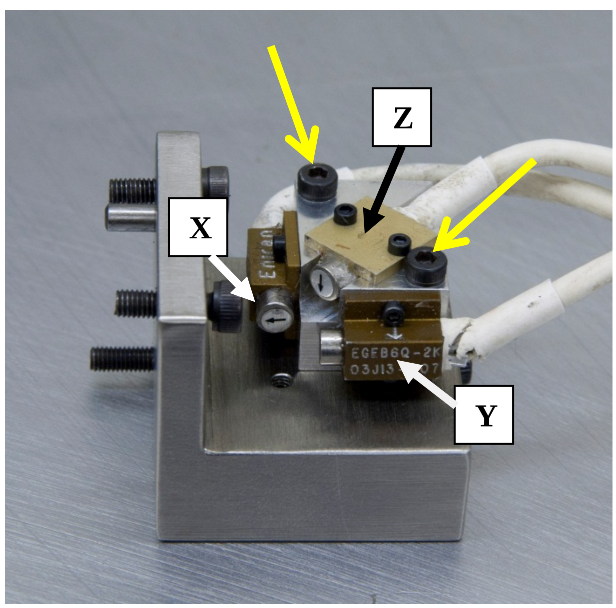

Figure 3. Accelerometers installed to bracket

- Install the accelerometer bracket, assuring that the guide pin is placed properly into the head (Figure 4). Tighten the two M3 x 10 SHCS and one M3 x 40 SHCS that hold the bracket to the head.
- Feed the head accelerometer wiring out the recessed area in the head and replace the skullcap, taking care not to damage accelerometer wiring protruding from the head. Tighten the skull cap using four (4) M5 x 12 BHCS.

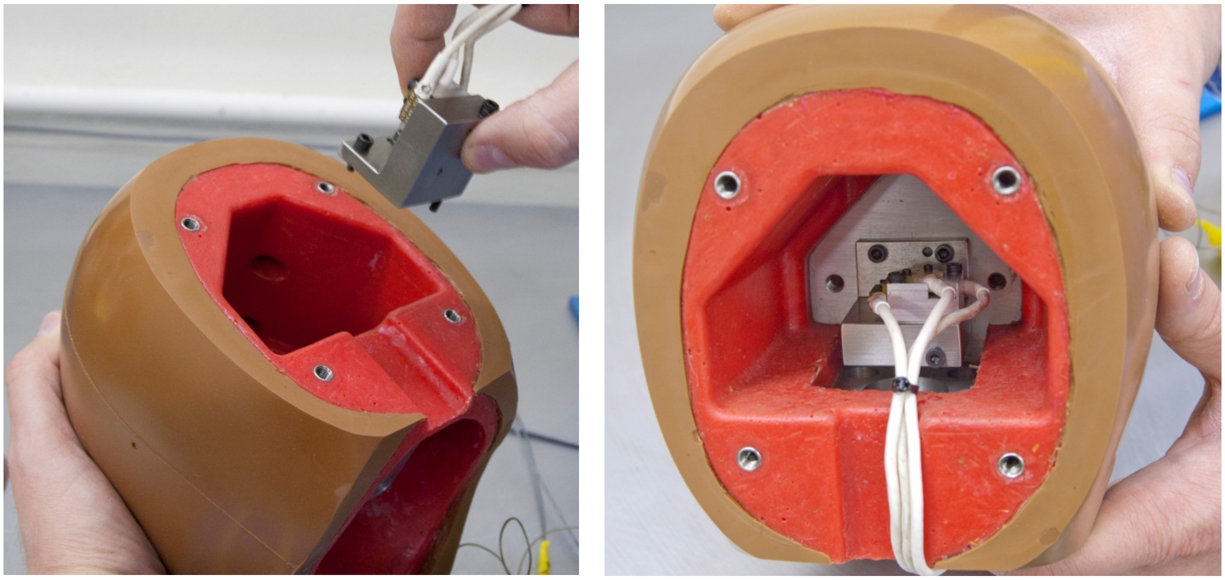

Figure 4. Install head accelerometer bracket into head

- Clean the head skin with isopropyl alcohol and allow it to dry thoroughly.
- Suspend the cable harness system for holding the head during testing (Figure 5).

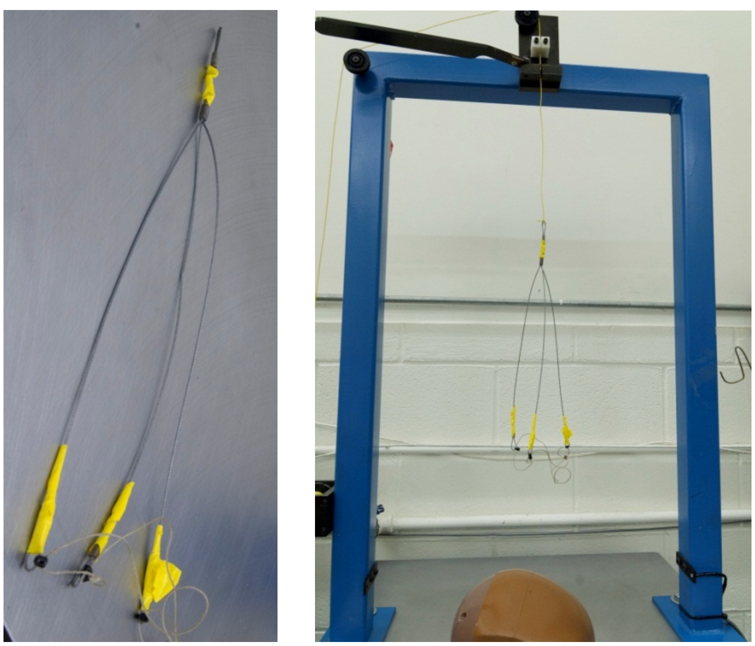

Figure 5. Cable harness setup for suspending head

1.3. **Q3s FRONTAL HEAD QUALIFICATION TESTS**

1.3.1. Frontal Head Pre-Test Preparation

- Suspend the head in the harness with forehead down (Figure 6). Be careful that the harness cable is not in the impact region of the head.
- Adjust the height so that the closest point on the forehead is approximately 376 mm from the impact surface (Figure 7).

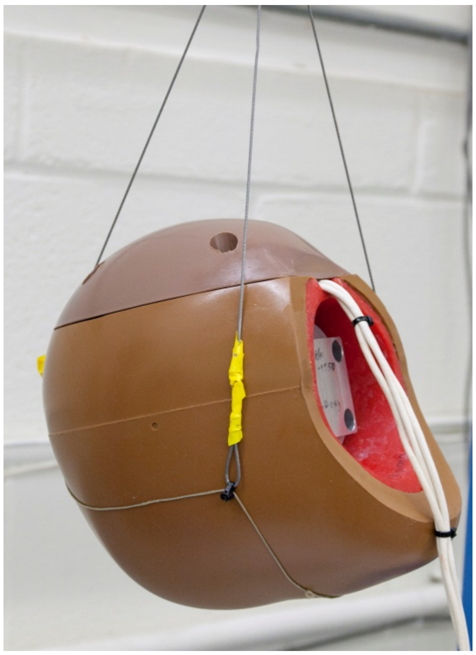

Figure 6. Harness routing for frontal head drop impact

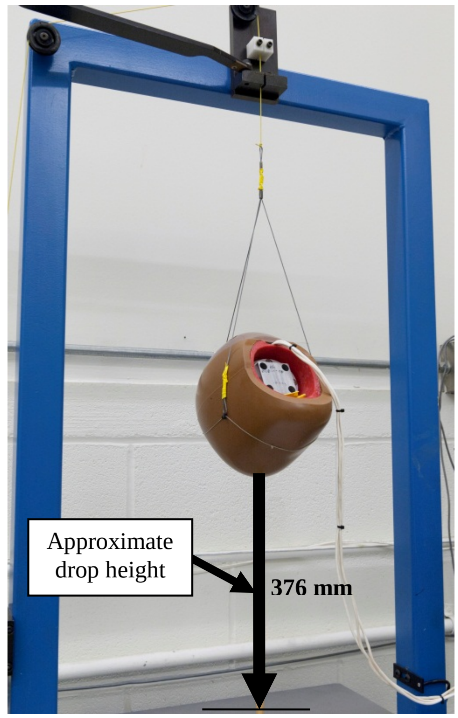

Figure 7. Initial suspension of the head using approximate drop height

- Level the head laterally (Figure 8). Placement of a bubble level along the edge of the upper neck load cell simulator may aid in this process. Paper can be wedged underneath the bubble level to ensure contact with the straight edge of the upper neck load cell simulator.

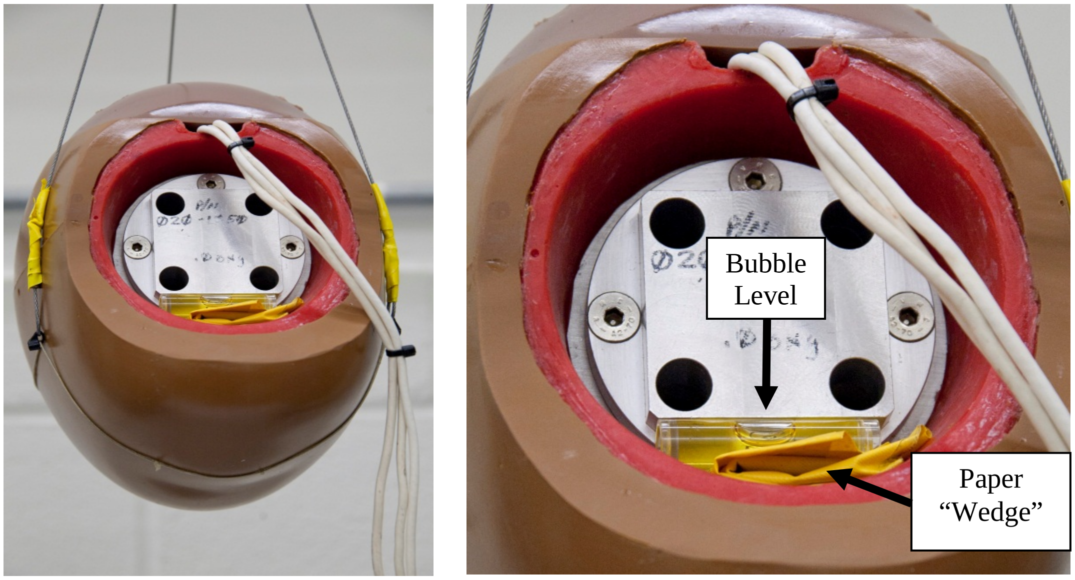

Figure 8. Ensure that the head is level in the lateral direction

- Adjust the head angle so that the upper neck load cell simulator is 28 ± 2° forward from the vertical (Figure 9). Ensure that the head remains horizontal laterally (Figure 8).

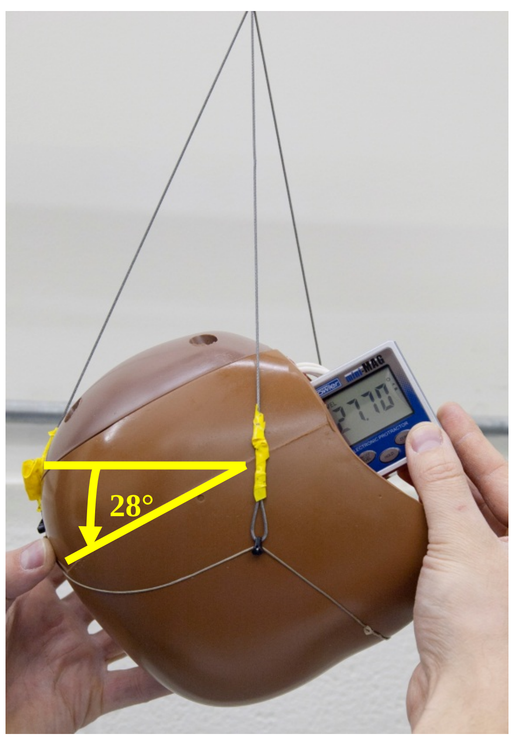

Figure 9. Adjust head angle for frontal head qualification test

- Adjust the head assembly so that it is 376 ± 1 mm (14.80 ± 0.04”) from the impact surface to the lowest point on the head (Figure 7).
- Ensure that the head angles in previous steps are still maintained.
- Be sure to ***remove the bubble level and paper wedge*** prior to test.
- Clean the impact surface with isopropyl alcohol and allow the surface to dry.

1.3.2. Frontal Head Test Procedures

- Configure the frontal head qualification test as described in the pre-test preparation above.
- Release the head assembly so that it falls freely to the impact surface at the proper temperature and humidity specifications.
- The data acquisition system conforms to SAE Recommended Practice J211 (July, 2007).
- The head accelerations are collected and filtered using a Channel Class 1000 phaseless filter.
- Time zero is defined as the time of contact between the head and the impact surface. All channels are at a zero level at this point.
- Calculate the resultant head acceleration using the formula:

$$\mathbf{a_{res} = [(a_x)^2 + (a_y)^2 + (a_z)^2]^{1/2}}$$

- The peak head resultant acceleration shall lie within the proper specifications:
  - Peak head resultant acceleration: 255 – 300 G
  - Y component acceleration (A_y): < ± 15 G
- Wait at least 2 hours between consecutive head qualification tests on the same side of the head

1.4. **Q3S LATERAL HEAD QUALIFICATION PROCEDURES**

1.4.1. Lateral Head Pre-Test Preparation

- Suspend the head in the harness with the left side of the head towards the impact surface. Be careful that the harness cable is not in the impact region of the head (Figure 10).
- Adjust the height so that the closest point on the impact side of the head is approximately 200 mm from the impact surface (Figure 11).

Figure 10. Harness routing for lateral head drop impact

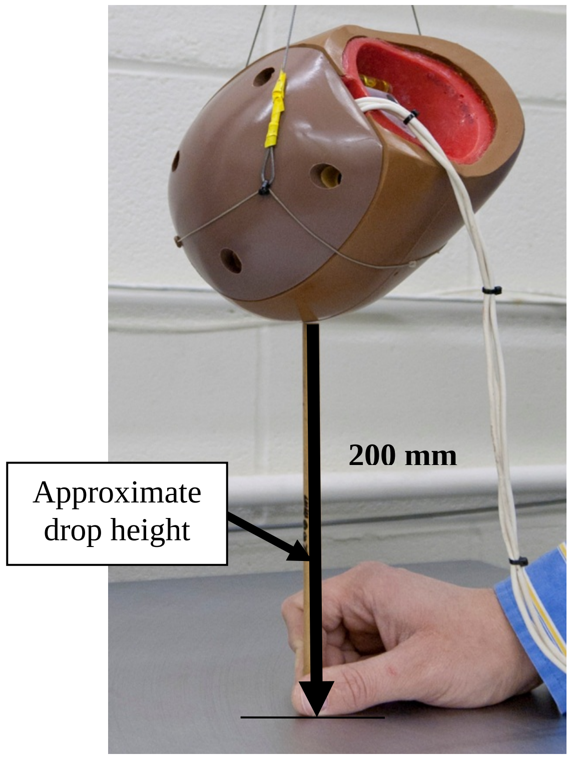

Figure 11. Approximate drop height for lateral head impact

- Ensure that the head is horizontal fore-aft (Figure 12). Placement of a bubble level along the edge of the upper neck load cell simulator may aid in this process.

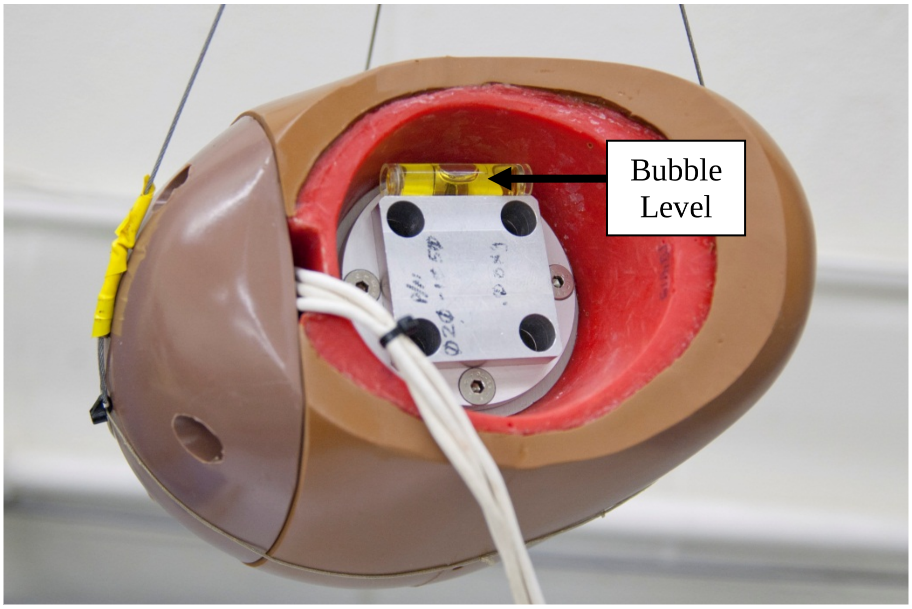

Figure 12. Ensure that the head is horizontal fore-aft

- Adjust the head angle so that the upper neck load cell simulator is 35 ± 2° forward from the vertical (Figure 13). Ensure that the head remains horizontal in the fore-aft direction (Figure 12).

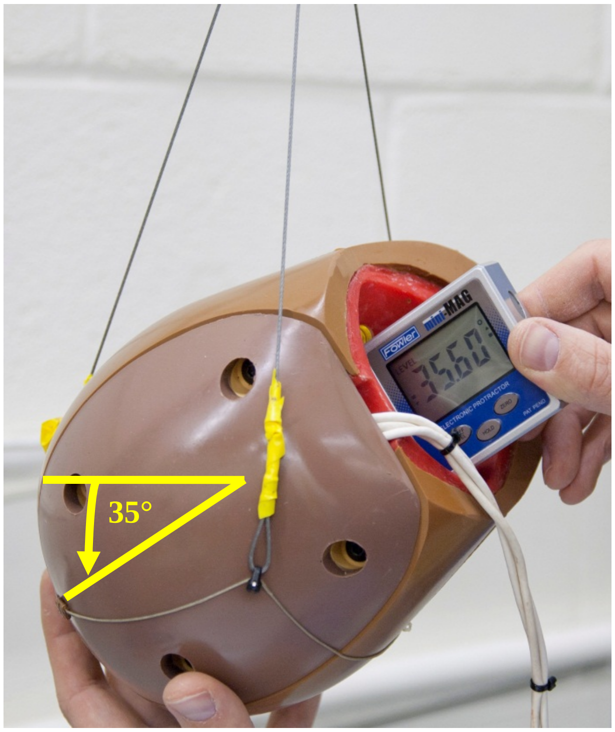

Figure 13. Adjust head angle for lateral head qualification test

- Raise the head assembly so that it is 200 ± 1 mm (7.87 ± 0.04”) from the impact point to the lowest point on the head (Figure 11).
- Ensure that the head angles in previous steps are still maintained.
- Be sure to ***remove the bubble level*** prior to test.
- Clean the impact surface with isopropyl alcohol and allow the surface to dry.

1.4.2. Lateral Head Test Procedures

- Configure the frontal head qualification test as described in the pre-test preparation above.
- Release the head assembly so that it falls freely to the impact surface at the proper temperature and humidity specifications.
- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The head accelerations are collected and filtered using a Channel Class 1000 phaseless filter.
- Time zero is defined as the time of contact between the head and the impact surface. All channels are at a zero level at this point.
- Calculate the resultant head acceleration using the formula:

$$\mathbf{a_{res} = [(a_x)^2 + (a_y)^2 + (a_z)^2]^{1/2}}$$

- The peak head resultant acceleration and peak X component acceleration shall lie within the proper specifications:
    - Peak head resultant acceleration: 114 – 140 G
    - X component acceleration (A_x): < ± 15 G
- Wait at least 2 hours between consecutive head qualification tests on the same side of the head.

2. Q3S NECK QUALIFICATION PROCEDURES

2.1. **Q3S NECK FORE-AFT FLEXION QUALIFICATION PROCEDURES**

2.1.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis upper neck load cell
- Two angular rate sensors (ARS)

2.1.2. Pre-Test Preparation

- Soak the neck assembly in a controlled environment at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the neck for deformation, tears or breaks in the rubber. Replace the neck if deformation or damage is observed.
- Install the interface plate to the bottom of the pendulum using four (4) M6 x 15 SHCS (Figure 14 and Figure 15).
- Install accelerometer to the pendulum (Figure 15).

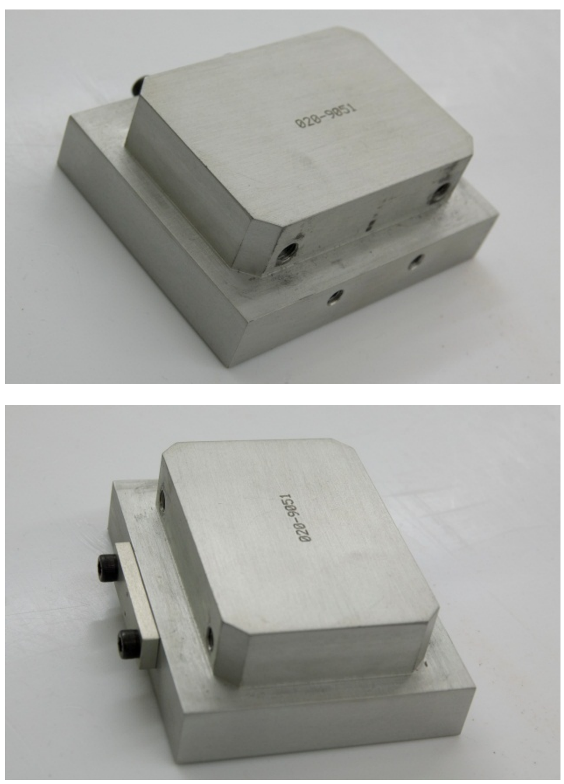

Figure 14. Interface plate for test pendulum

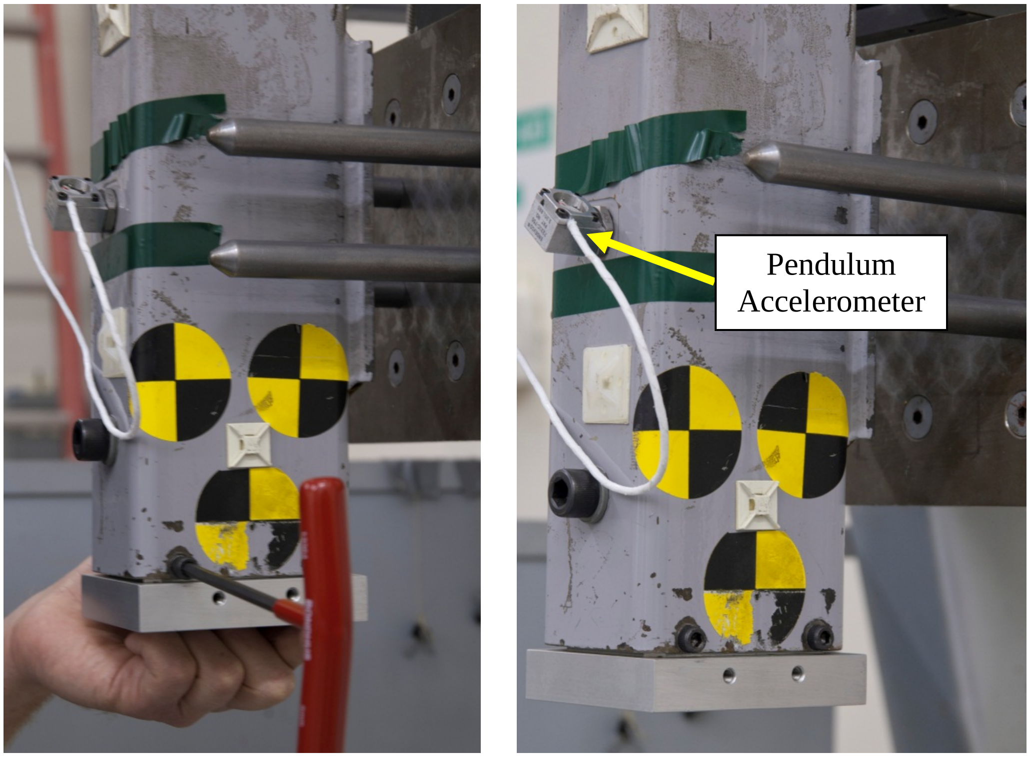

Figure 15. Install pendulum interface plate and pendulum accelerometer

- Install the Angular Rate Sensor (ARS) to the ARS mount then install the mount to the front of the headform[1] so that it measures rotational velocity about the (headform) Y axis[2] (Figure 16 and Figure 17).

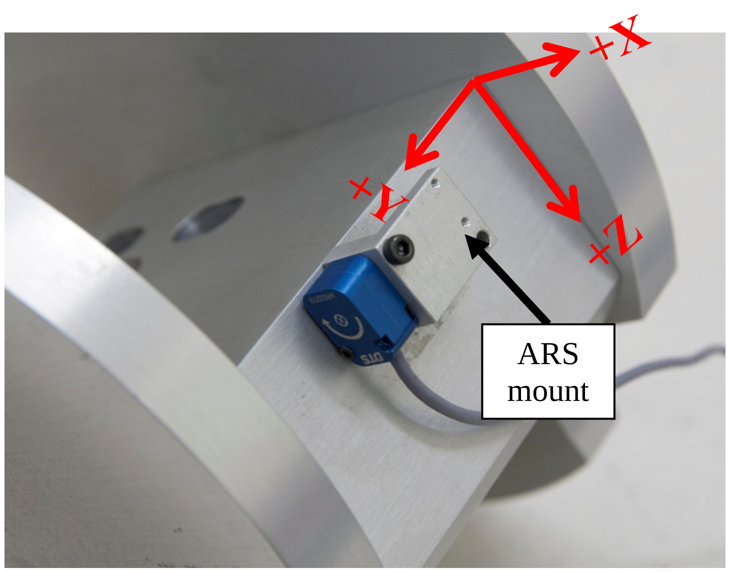

Figure 16. Install ARS mount to front of headform

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[1] Drawing #020-9050.
[2] Axis reflects J211 (July 2007) convention.

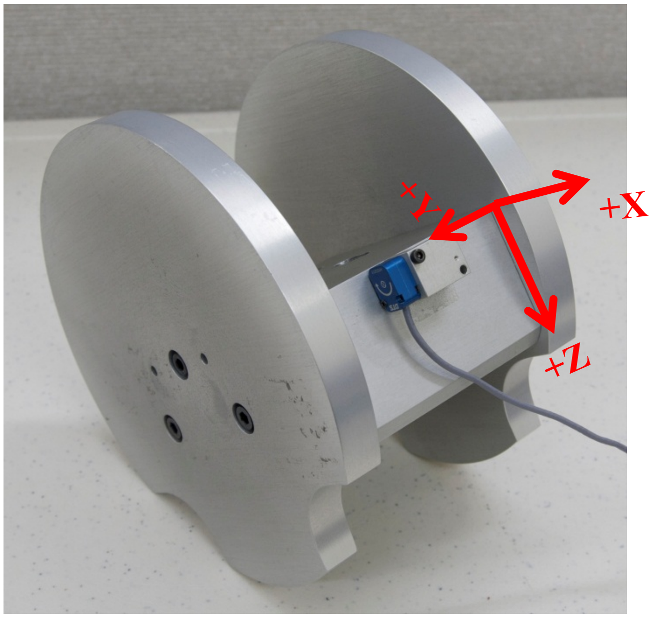

Figure 17. ARS installed to measure rotational velocity about Y axis

- Mount the 6 axis upper neck load cell to the headform using four M5 x 12 FHCS. For flexion tests, use the rear set of bolt holes for the load cell. Wiring should protrude out the back of the headform (Figure 18).

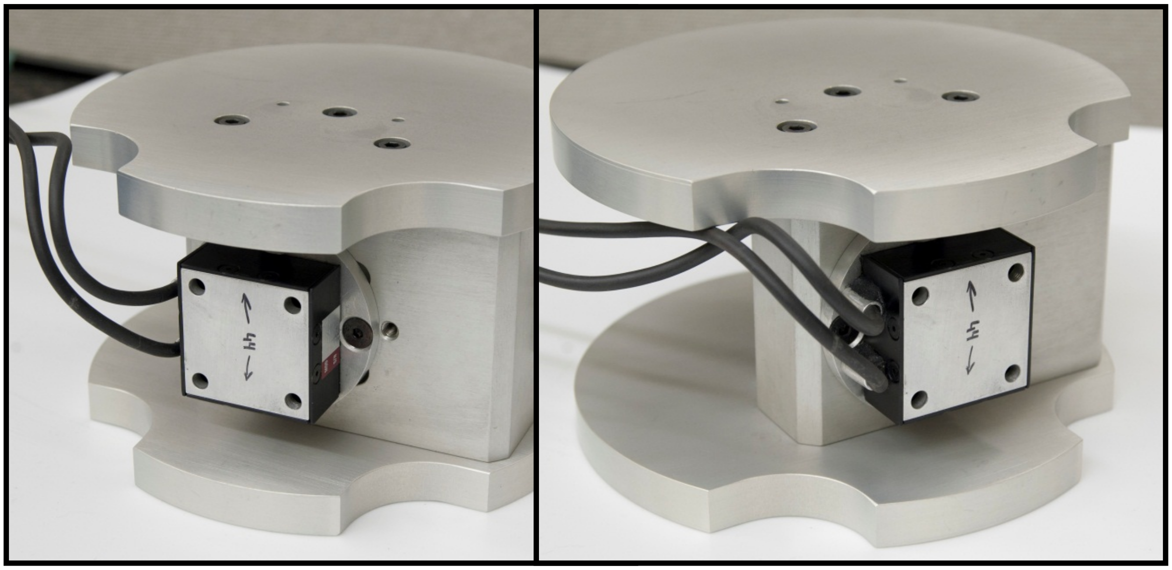

Figure 18. Mount 6 axis upper neck load cell to headform

- Position the neck interface plate at the base of the neck for mounting to the pendulum Figure 19.


Figure 19. Positioning the neck interface plate prior to mounting neck to pendulum

- Mount the neck to the pendulum. First install the two M5 x 20 SHCS on the front side of the neck (note that the front of the neck has “slits” in the rubber segments). Then install the two M5 x 20 SHCS to the rear of the neck (Figure 20).

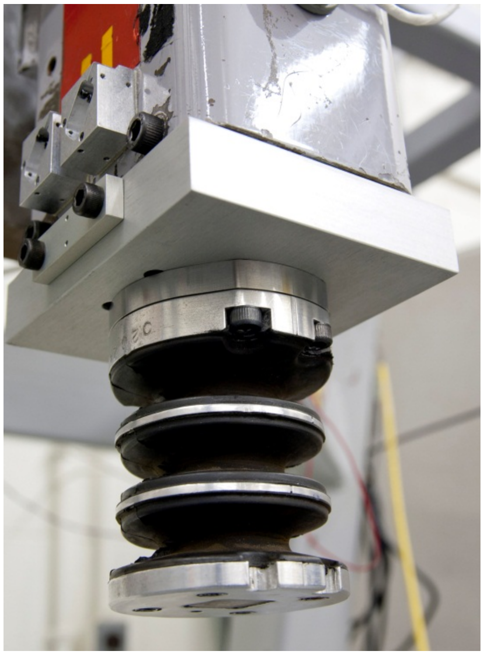
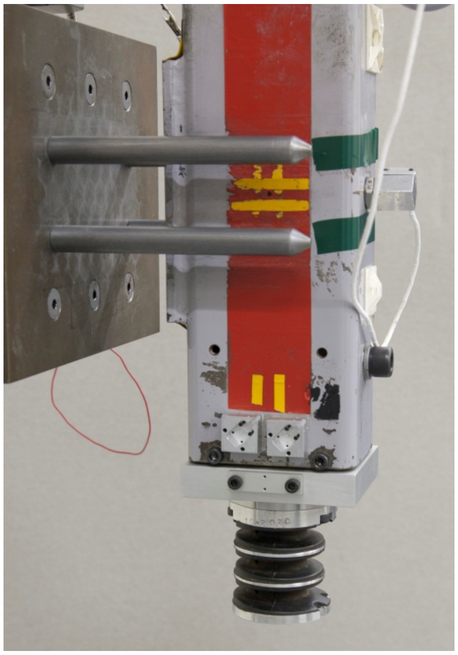

Figure 20. Mount neck to pendulum for fore-aft flexion tests

- Attach the headform and upper neck load cell to the neck with four M5 x 10 SHCS (Figure 21).

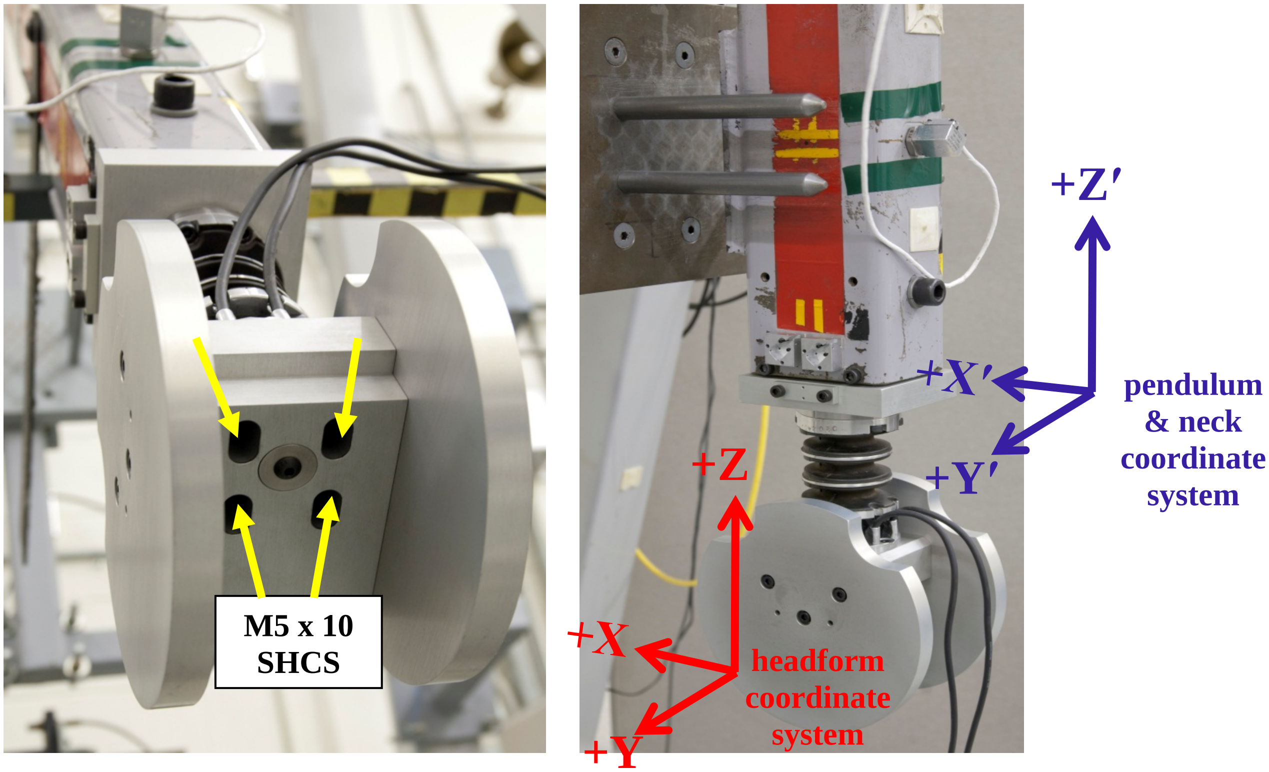

Figure 21. Install headform and upper neck load cell to neck

- Install the Angular Rate Sensor (ARS)[3] to the pendulum interface plate using two M1.4 x 8 SHCS so that it measures rotational velocity about the Y′ axis (Figure 21 and Figure 22).

Figure 22. Install ARS to pendulum

[3] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Tape and strain-relieve the instrumentation wiring leaving plenty of slack for neck flexion (Figure 23).
- In addition, zero all instrumentation channels with the pendulum vertical (Figure 23 – right).

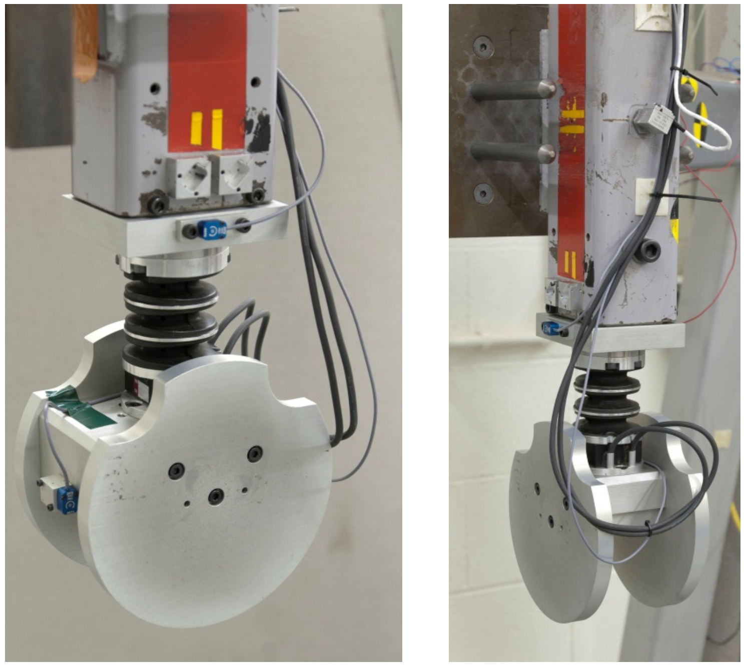

Figure 23. Tape and strain-relieve instrumentation wiring

- Install the proper size hexcell to meet the pulse requirements specified in Table 1 (Figure 24).

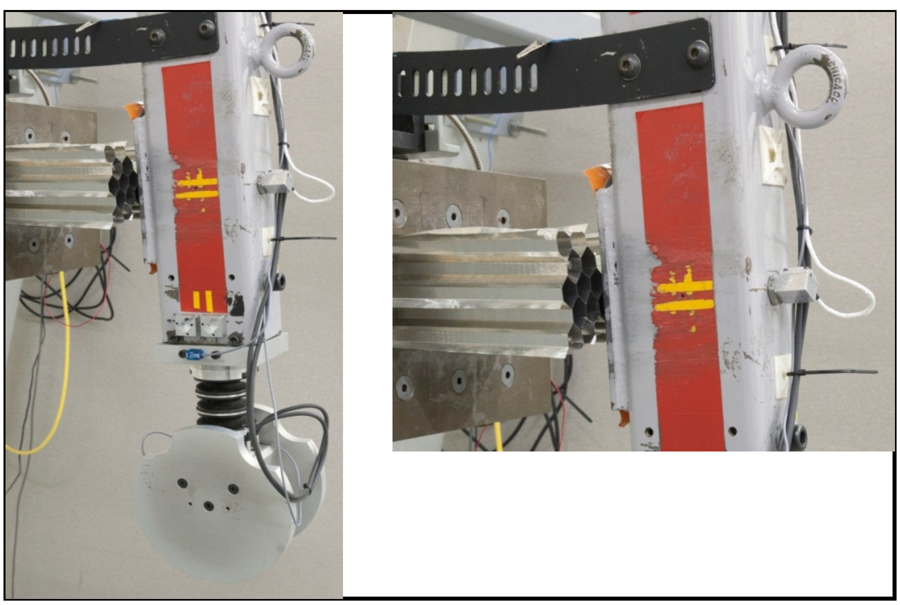

Figure 24. Install hexcell to pendulum

2.1.3. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb.
- All channels are at the zero level when the pendulum is vertical.
- Post-test offset removal of the data signals shall be performed only on the pendulum acceleration and upper neck moment signals.
- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 4.6 – 4.8 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 1.

Table 1. Q3s Fore-Aft Neck Flexion Pulse Parameters

Parameter		units	Spec. Limits	
			lower	upper
impact speed		m/s	4.6	4.8
pendulum pulse	@10 ms	m/s	1.1	2.1
	@20 ms	m/s	2.8	3.8
	@30 ms	m/s	4.1	5.1

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The ARS is filtered using a Channel Class 60 phaseless filter.
- The neck moment about the Y′-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- Determine the headform rotation using the following formula[4]:
  - Headform Rotation = $\int (\text{Headform Angular Rate})_y - (\text{Pendulum Angular Rate})_{y'}\, dt$
- The peak rotation, peak moment, and headform rotation decay time to zero shall lie within the proper specifications:
  - Peak headform rotation: 69.5 – 81.0°
  - Peak moment[5] (My′): 41.5 – 50.7 Nm
  - Headform rotation decay time to 0° from peak angle: 45 – 55 ms
- Wait at least 30 minutes between consecutive tests on the same neck.

[4] Perform this calculation *after* filtering the ARS sensors. Begin integration at time zero.
[5] Maximum moment measured during the time interval while the rotation is within the specified corridor.

2.2. **Q3S NECK LATERAL FLEXION QUALIFICATION PROCEDURES – LEFT SIDE**

2.2.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis upper neck load cell
- Two angular rate sensors (ARS)

2.2.2. Pre-Test Preparation

- Soak the neck assembly in a controlled environment at the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the neck for deformation, tears or breaks in the rubber. Replace the neck if deformation or damage is observed.
- Install the interface plate to the bottom of the pendulum using four (4) M6 x 15 SHCS (Figure 25 and Figure 26).
- Install accelerometer to the pendulum (Figure 26).

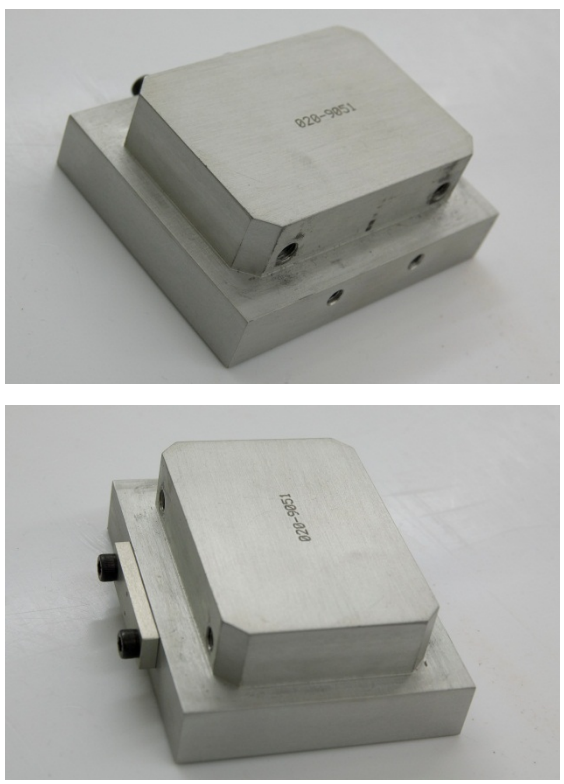

Figure 25. Interface plate for test pendulum

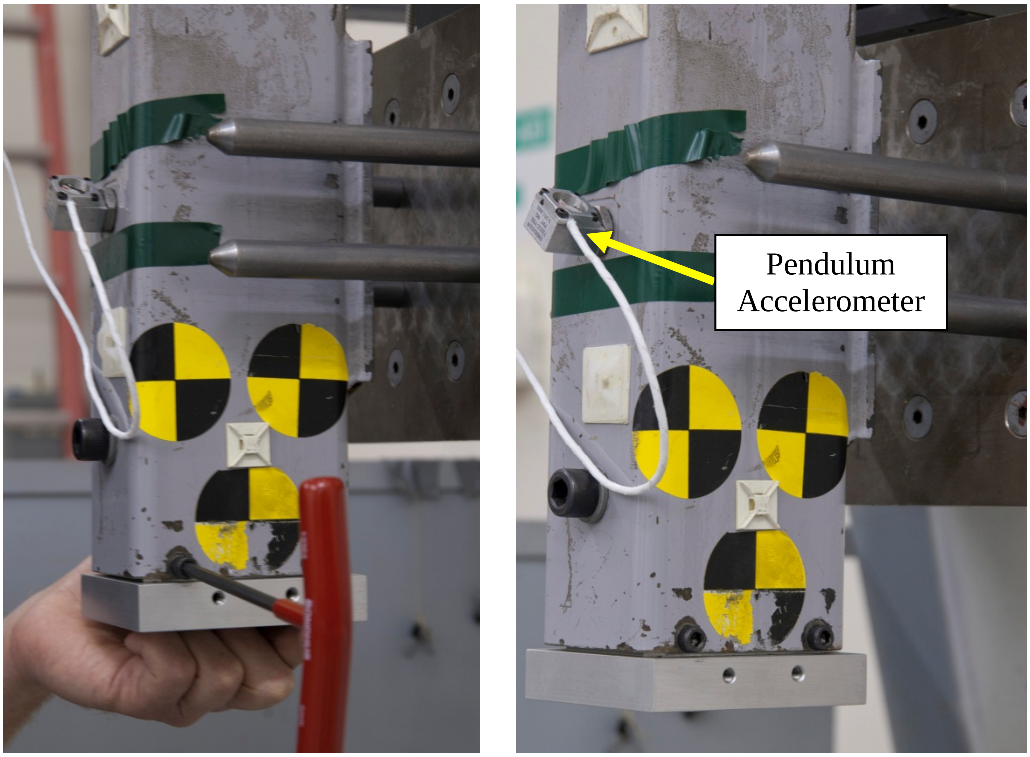

Figure 26. Install pendulum interface plate and pendulum accelerometer

- Install the Angular Rate Sensor (ARS) to the ARS mount then install the mount to the front of the headform[6]so that it measures rotational velocity about the headform Y axis[7] (Figure 27 and Figure 28).

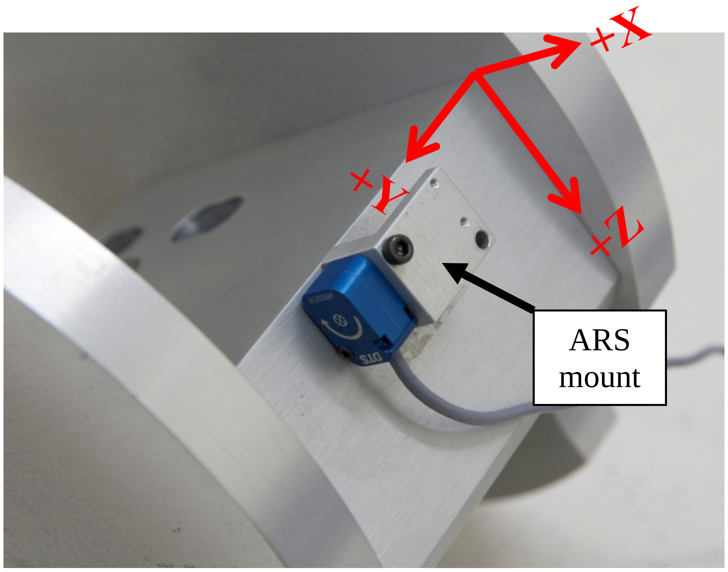

Figure 27. Install ARS mount to front of headform

[6] Drawing #020-9050

[7] Axis reflects J211(July 2007) convention.

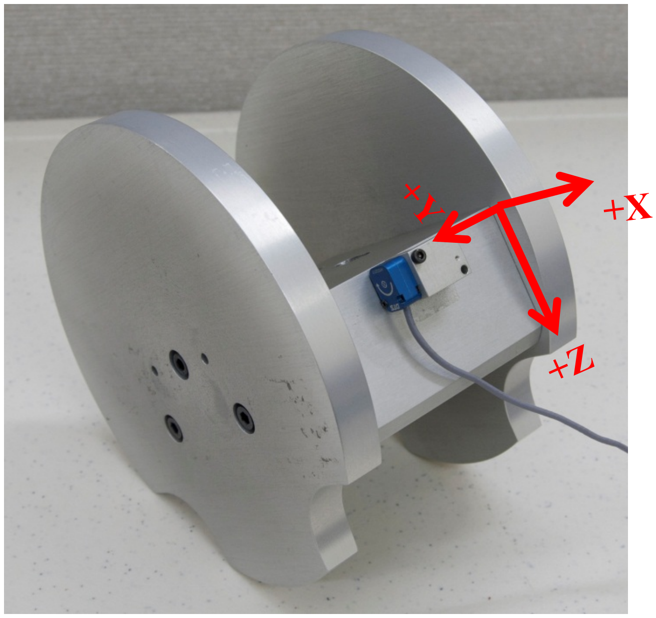

Figure 28. ARS installed to measure rotational velocity about the headform Y axis

- Mount the 6 axis upper neck load cell to the headform using four M5 x 12 FHCS. For left lateral flexion tests, use the forward set of bolt holes for the load cell. Wiring should protrude out the right side of the headform (Figure 29).

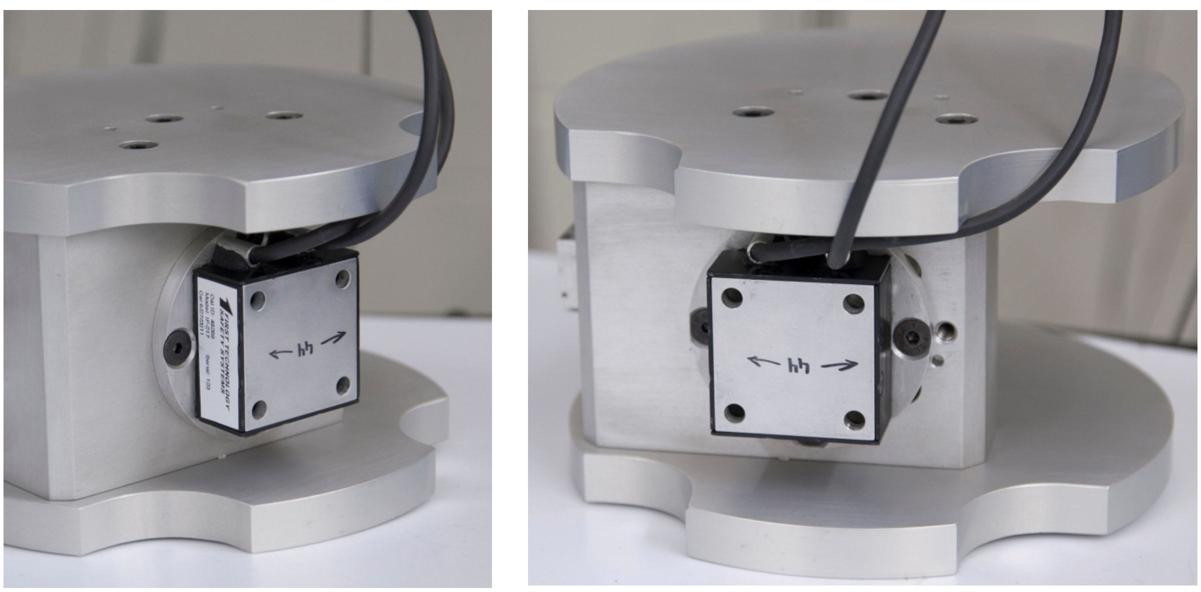

Figure 29. Mount 6 axis upper neck load cell to headform for left lateral neck tests

- Position the neck interface plate at the base of the neck for mounting to the pendulum (Figure 30).

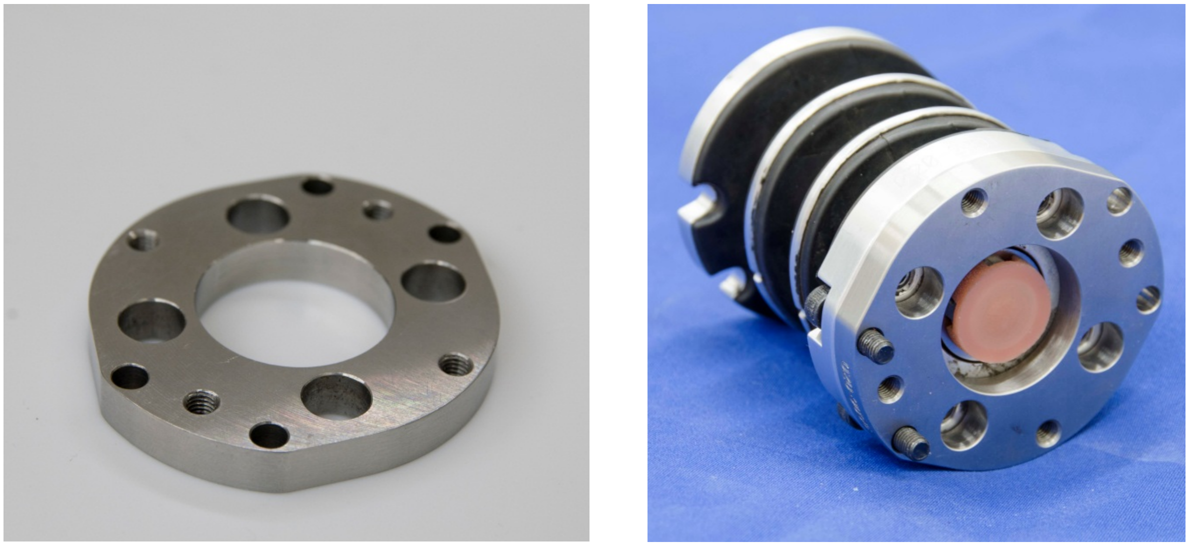

Figure 30. Positioning the neck interface plate prior to mounting neck to pendulum

- Mount the neck to the pendulum. For left lateral tests, the left side of the neck is closest to the hexcell. Note that in lateral tests, the neck coordinate system is rotated relative to the headform coordinate system. First install the two M5 x 20 SHCS on the front side of the neck (note that the front of the neck has "slits" in the rubber segments). Then install the two M5 x 20 SHCS to the rear of the neck.
- Attach the headform and upper neck load cell to the neck with four M5 x 10 SHCS (Figure 31). The load cell wiring should protrude from the right side of the headform when facing the impact surface.

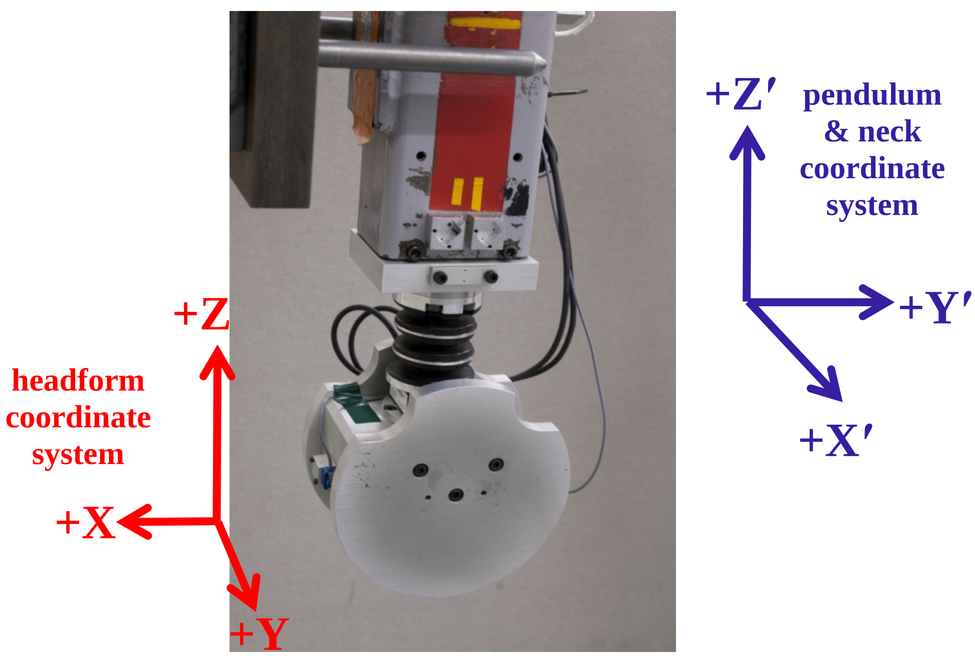

Figure 31. Attach headform to upper neck load cell for left lateral flexion tests

- Install the Angular Rate Sensor (ARS)[8] to the pendulum interface plate using two M1.4 x 8 SHCS so that it measures rotational velocity about the X′ axis (Figure 32).

Figure 32. Install ARS to pendulum

- Tape and strain-relieve the instrumentation wiring leaving plenty of slack for neck extension (Figure 33).
- In addition, zero all instrumentation channels with the pendulum vertical (Figure 33).

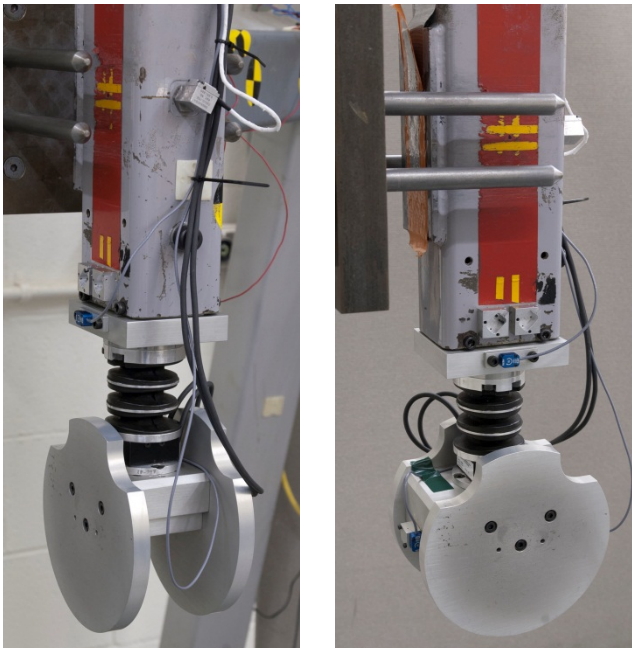

Figure 33. Tape and strain-relieve instrumentation wiring

[8] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Install the proper size hexcell to meet the pulse requirements specified in Table 2 (Figure 34).

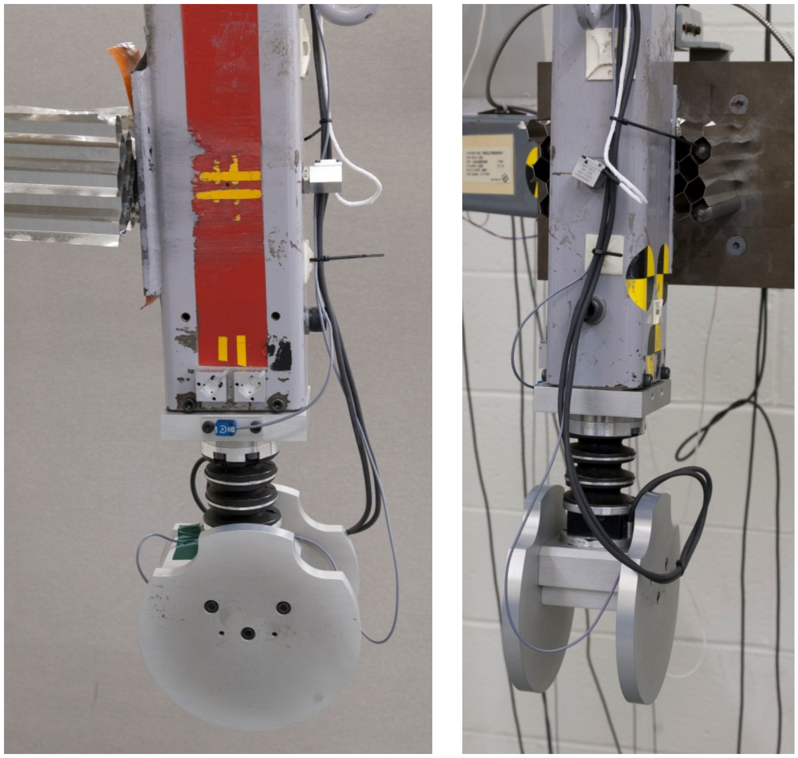

Figure 34. Install hexcell to pendulum

2.2.3. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb.
- All channels are at the zero level when the pendulum is vertical.
- Post-test offset removal of the data signals shall be performed only on the pendulum acceleration and upper neck moment signals.
- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 3.7 – 3.9 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 2.

Table 2. Q3s Neck Lateral Flexion Pulse Parameters

Parameter		units	Spec. Limits lower	Spec. Limits upper
impact speed		m/s	3.7	3.9
pendulum pulse	@10 ms	m/s	1.7	2.2
	@15 ms	m/s	2.5	3.0
	@20 ms	m/s	3.4	3.9

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The ARS is filtered using a Channel Class 60 phaseless filter.
- The neck moment about the X′-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- Determine the headform rotation using the following formula[9]:
    - Headform Rotation = $\int$(Headform Angular Rate)$_y$ - (Pendulum Angular Rate)$_{x'}$ *dt*
- The peak rotation, peak moment, and headform rotation decay time to zero shall lie within the proper specifications:
    - Peak headform rotation: 76.5 – 87.5°
    - Peak moment[10] ($M_{X'}$): 25.3 – 32.0 Nm
    - Headform rotation decay time to 0° from peak angle: 61 – 71 ms
- Wait at least 30 minutes between consecutive tests on the same neck.

[9] Perform this calculation *after* filtering the ARS sensors. Begin integration at time zero.
[10] Maximum moment measured during the time interval while the rotation is within the specified corridor.

2.3. Q3S NECK LATERAL FLEXION QUALIFICATION PROCEDURES – RIGHT SIDE

2.3.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis upper neck load cell
- Two angular rate sensors (ARS)

2.3.2. Pre-Test Preparation

- Soak the neck assembly in a controlled environment at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the neck for deformation, tears or breaks in the rubber. Replace the neck if deformation or damage is observed.
- Install the interface plate to the bottom of the pendulum using four (4) M6 x 15 SHCS (Figure 35 and Figure 36).
- Install accelerometer to the pendulum (Figure 26).

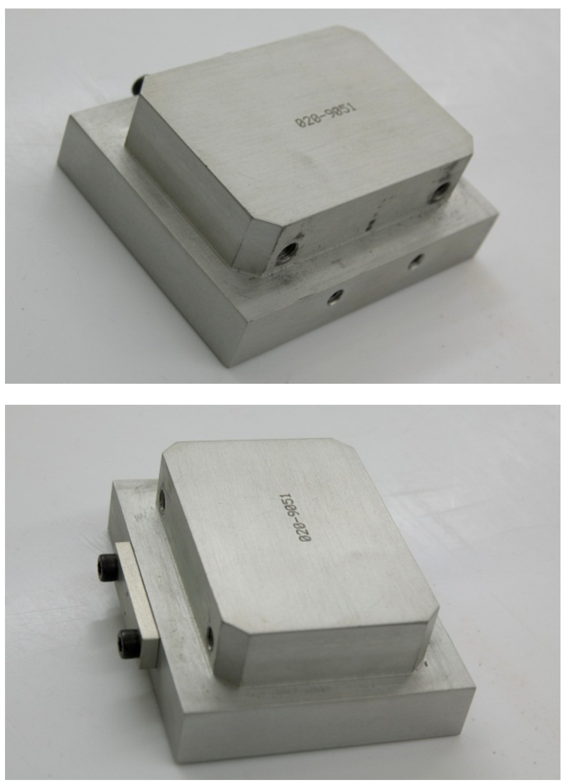

Figure 35. Interface plate for test pendulum

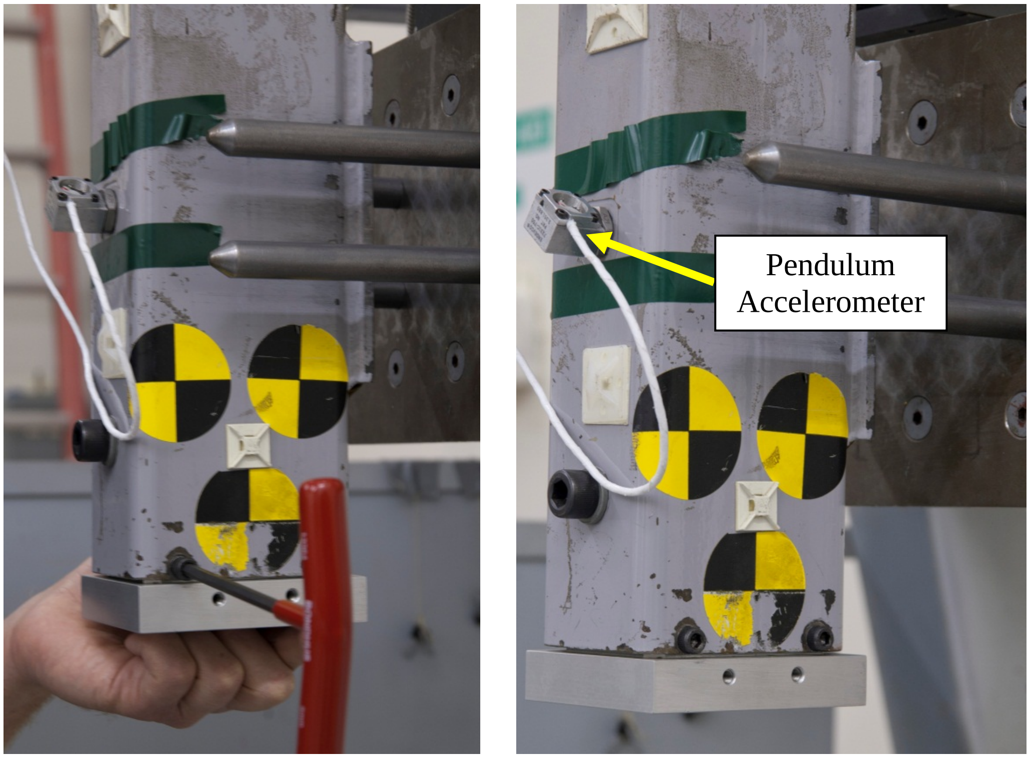

Figure 36. Install pendulum interface plate and pendulum accelerometer

- Install the Angular Rate Sensor (ARS) to the ARS mount then install the mount to the front of the headform[11] so that it measures rotational velocity about the (headform) Y axis (Figure 37 and Figure 38).

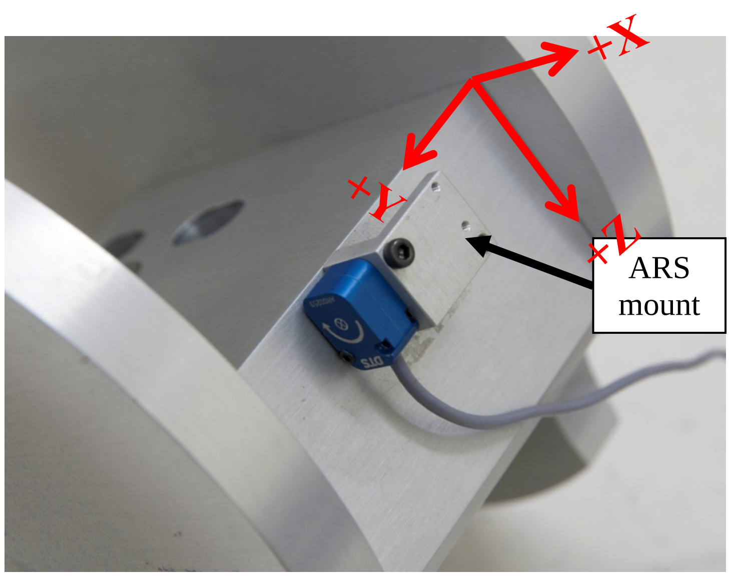

Figure 37. Install ARS mount to front of headform

[11] Drawing #020-9050.

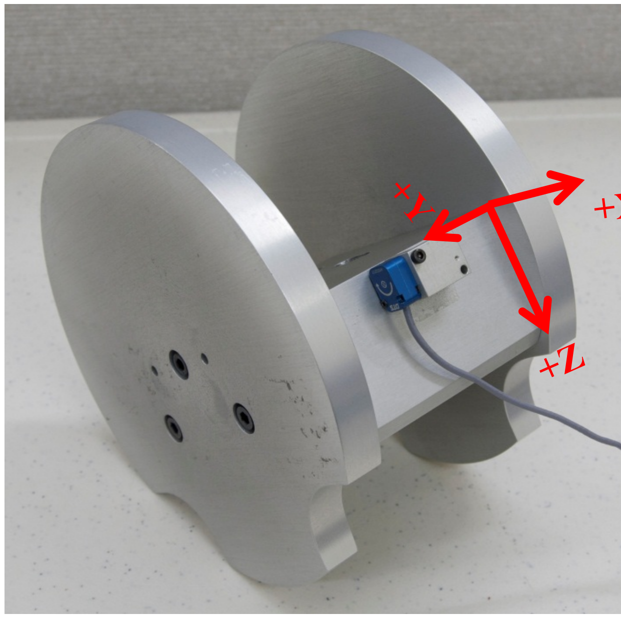

Figure 38. ARS installed to measure rotational velocity about the headform Y axis

- Mount the 6 axis upper neck load cell to the headform using four M5 x 12 FHCS. For right lateral flexion tests, use the forward set of bolt holes for the load cell. Wiring should protrude out the left side of the headform (Figure 39).

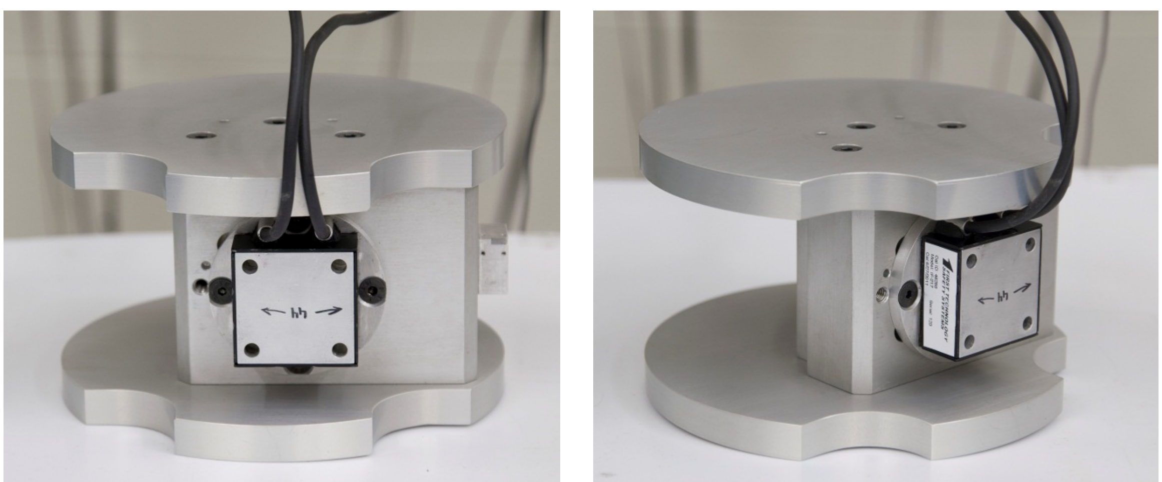

Figure 39. Mount 6 axis upper neck load cell to headform for right lateral neck tests

- Position the neck interface plate at the base of the neck for mounting to the pendulum (Figure 40).

Figure 40. Positioning the neck interface plate prior to mounting neck to pendulum

- Mount the neck to the pendulum. For right lateral tests, the right side of the neck is closest to the hexcell. Note that in lateral tests, the neck coordinate system is rotated related to the headform coordinate system. First install the two M5 x 20 SHCS on the front side of the neck (note that the front of the neck has "slits" in the rubber segments). Then install the two M5 x 20 SHCS to the rear of the neck.
- Attach the headform and upper neck load cell to the neck with four M5 x 10 SHCS (Figure 41). The load cell wiring should protrude from the left side of the headform when facing the impact surface.

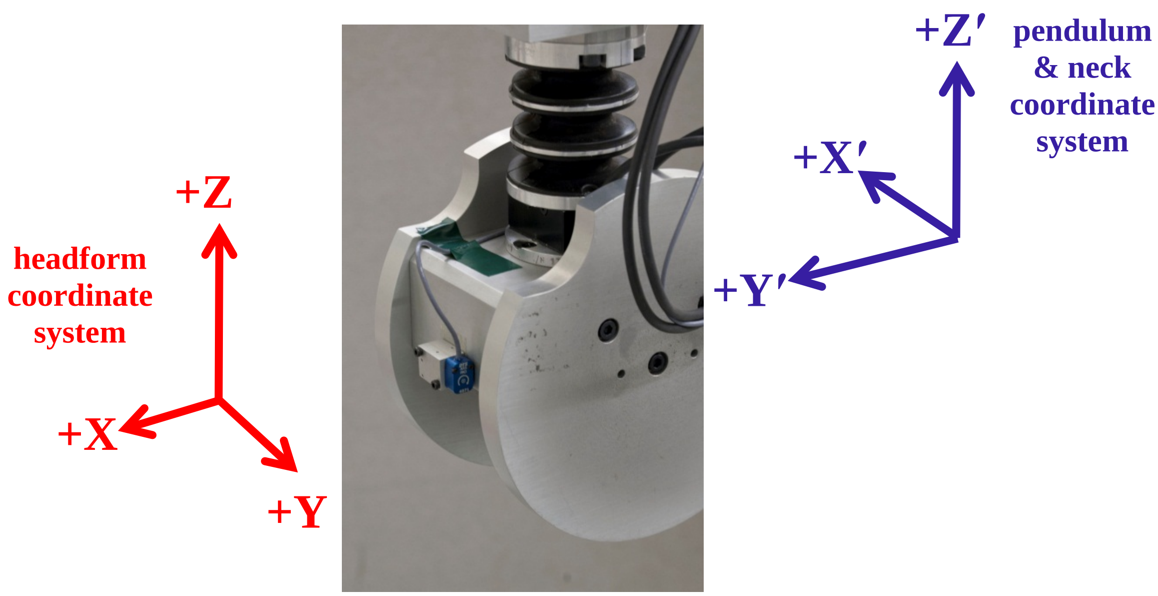

Figure 41. Attach headform to upper neck load cell for right lateral flexion tests

- Install the Angular Rate Sensor (ARS)[12] to the pendulum interface plate using two M1.4 x 8 SHCS so that it measures rotational velocity about the X′ axis (Figure 42).

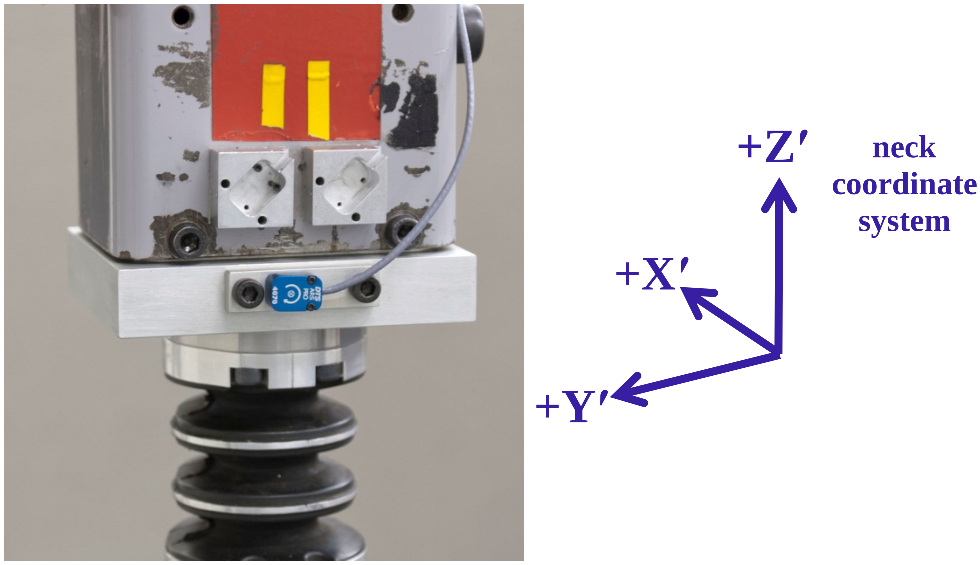

Figure 42. Install ARS to pendulum

- Tape and strain-relieve the instrumentation wiring leaving plenty of slack for neck extension (Figure 43).
- In addition, zero all instrumentation channels with the pendulum vertical (Figure 43).

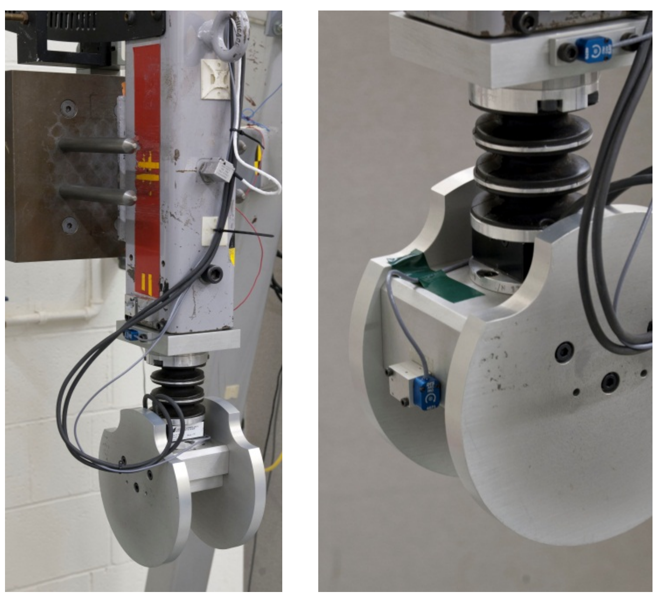

Figure 43. Tape and strain-relieve instrumentation wiring

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[12] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Install the proper size hexcell to meet the pulse requirements specified in Table 3 (Figure 44).

Figure 44. Install hexcell to pendulum

2.3.3. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb.
- All channels are at the zero level when the pendulum is vertical.
- Post-test offset removal of the data signals shall be performed only on the pendulum acceleration and upper neck moment signals.
- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 3.7 – 3.9 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 3.

Table 3. Q3s Neck Lateral Flexion Pulse Parameters

Parameter		units	Spec. Limits lower	Spec. Limits upper
impact speed		m/s	3.7	3.9
pendulum pulse	@10 ms	m/s	1.7	2.2
	@15 ms	m/s	2.5	3.0
	@20 ms	m/s	3.4	3.9

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The ARS is filtered using a Channel Class 60 phaseless filter.
- The neck moment about the X′-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- Determine the headform rotation using the following formula[13]:
  - Headform Rotation = $\int$(Headform Angular Rate)$_y$ - (Pendulum Angular Rate)$_{x'}$ *dt*
- The peak rotation, peak moment, and headform rotation decay time to zero time shall lie within the proper specifications:
  - Peak headform rotation: 76.5 – 87.5°
  - Peak moment[14] ($M_{X'}$): 25.3 – 32.0 Nm
  - Headform rotation decay time to 0° from peak angle: 61 – 71 ms
- Wait at least 30 minutes between consecutive tests on the same neck.

[13] Perform this calculation *after* filtering the ARS sensors. Begin integration at time zero.
[14] Maximum moment measured during the time interval while the rotation is within the specified corridor.

2.4. Q3S NECK TORSION QUALIFICATION PROCEDURES

2.4.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis upper neck load cell
- One rotational potentiometer

2.4.2. Pre-Test Preparation

- Soak the neck assembly in a controlled environment 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the neck for deformation, tears or breaks in the rubber. Replace the neck if deformation or damage is observed.
- Assemble the neck adapter plate assembly to the lower neck using four M5 x 12 SHCS (Figure 45).

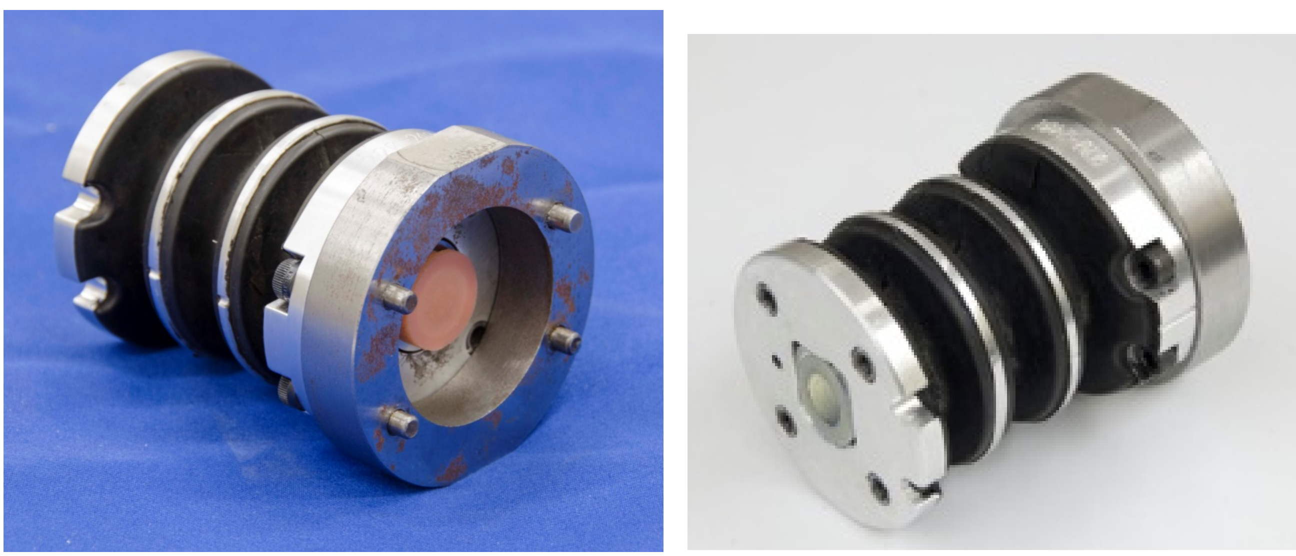


Figure 45. Assemble neck adapter plate assembly to lower neck

- Assemble upper neck load cell to the twist fixture[15] end plate using four M5 x 12 FHCS (Figure 46).

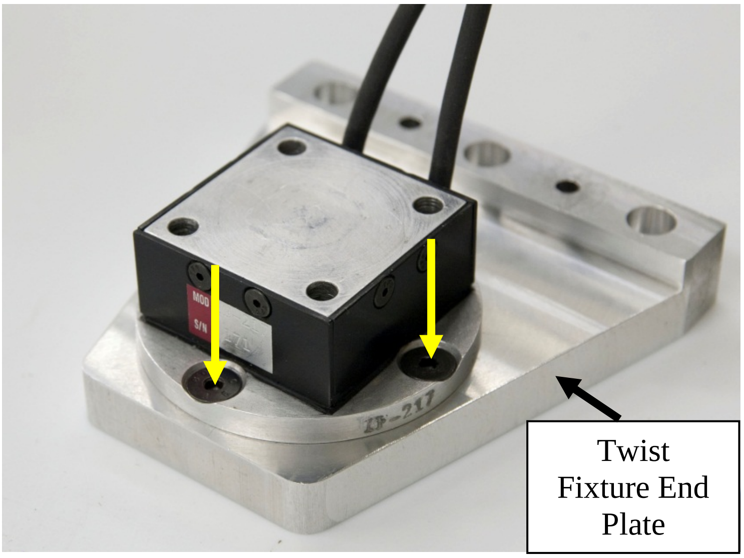


Figure 46. Assemble upper neck load cell to twist fixture end plate

- Assemble neck to upper neck load cell using four (4) M5 x 10 SHCS inserted through the bottom of the twist fixture end plate (Figure 47).

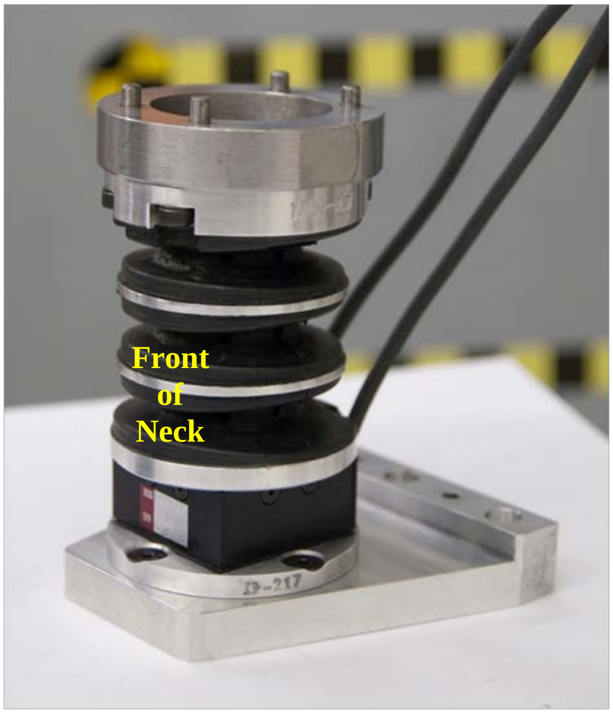


Figure 47. Assemble neck to upper neck load cell

[15] Drawing DL210-200.

- Install the neck torsion fixture assembly to the bottom of the test pendulum using four (4) ½ - 20 x 1” SHCS (Figure 48 and Figure 49). Be sure the zero pins are installed into the neck adapter plate assembly in the fore-aft positions (Figure 49) and the pendulum weight on the torsion fixture is properly located on the pendulum rod assembly (Figure 50).

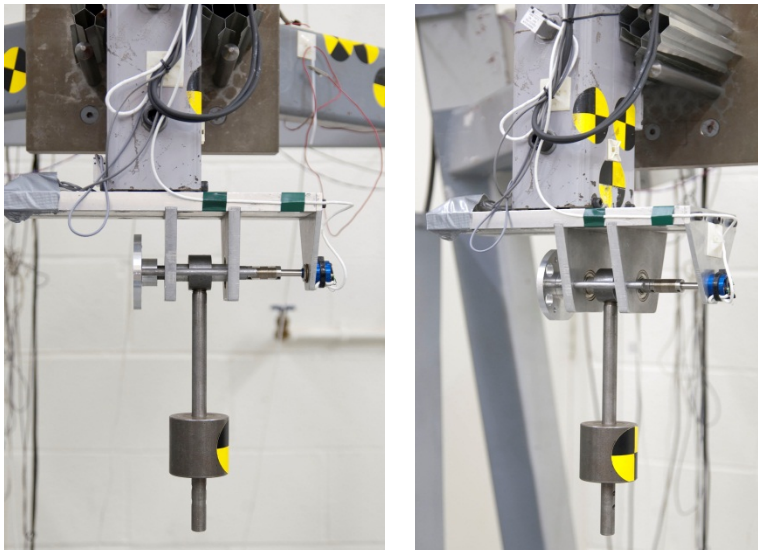


Figure 48. Torsion fixture (without neck) installed on pendulum

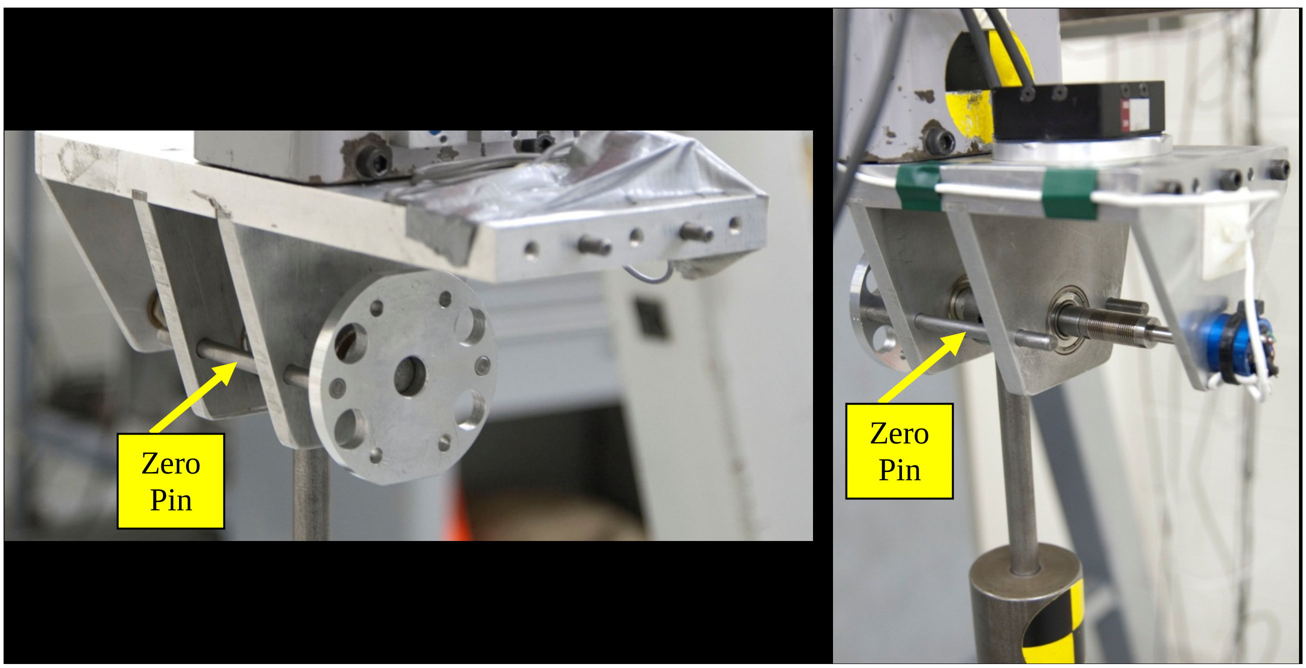


Figure 49. Neck torsion fixture details (neck not installed)

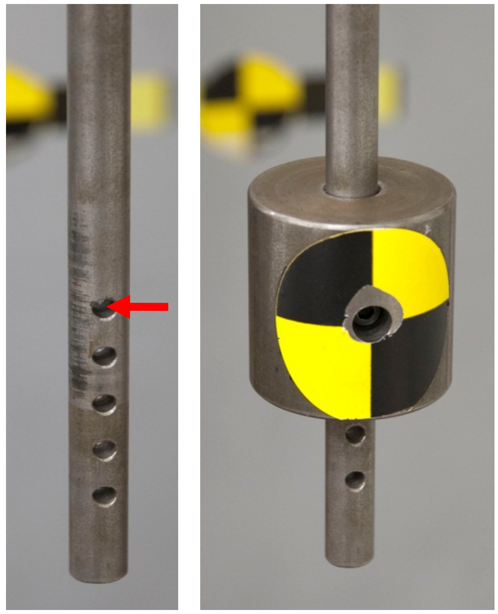


Figure 50. Placement for torsion

- To install the neck to the twist test fixture, align the pins on the torsion fixture end plate and the neck adapter plate assembly into the fixture (Figure 51).

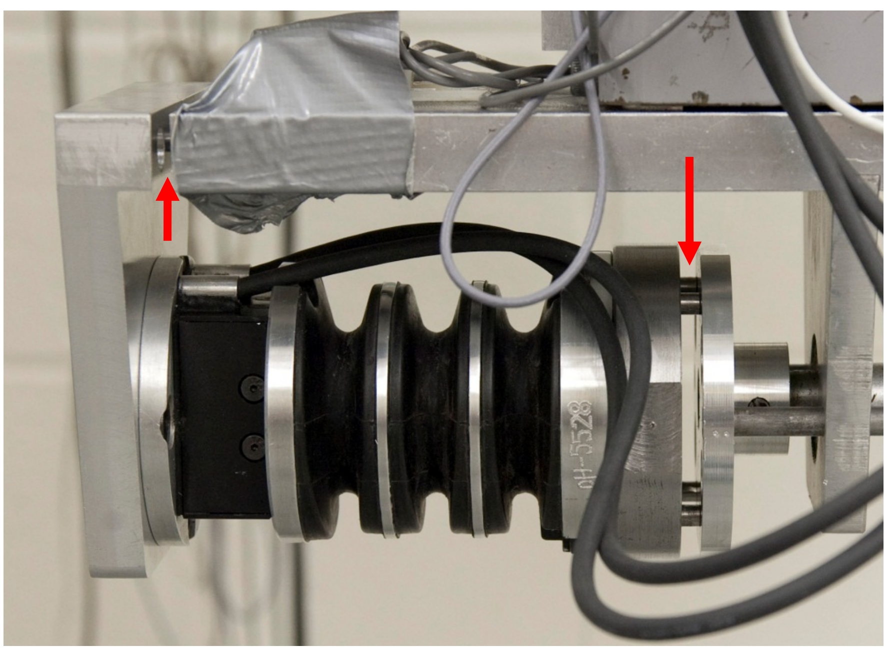


Figure 51. Align pins in torsion fixture end plate and neck adapter plate assembly into torsion fixture

- Secure the torsion fixture end plate to the top plate assembly using three #10-24 x 1" SHCS (Figure 52). Figure 53 shows the neck fully installed with zero pins in place.

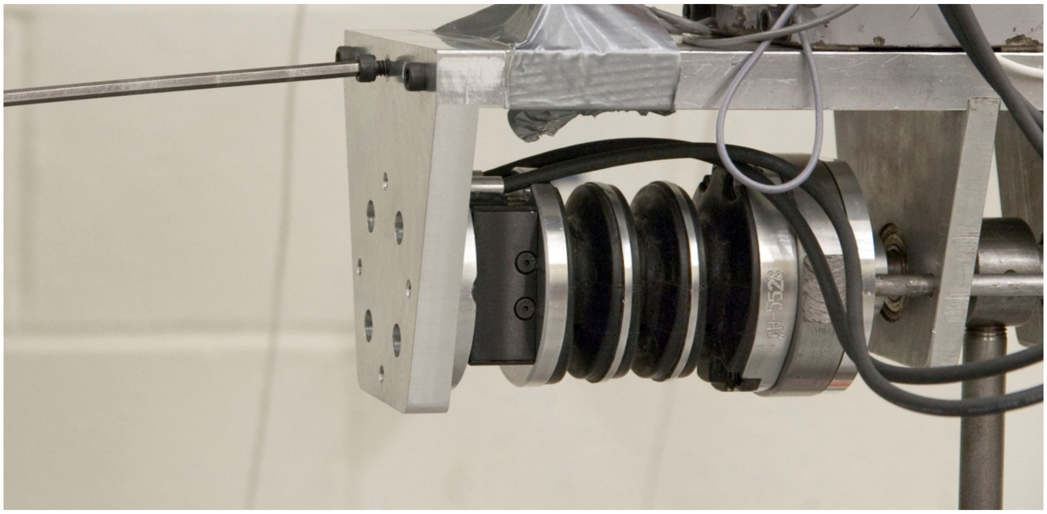


Figure 52. Bolt end plate (upper neck end) to torsion fixture

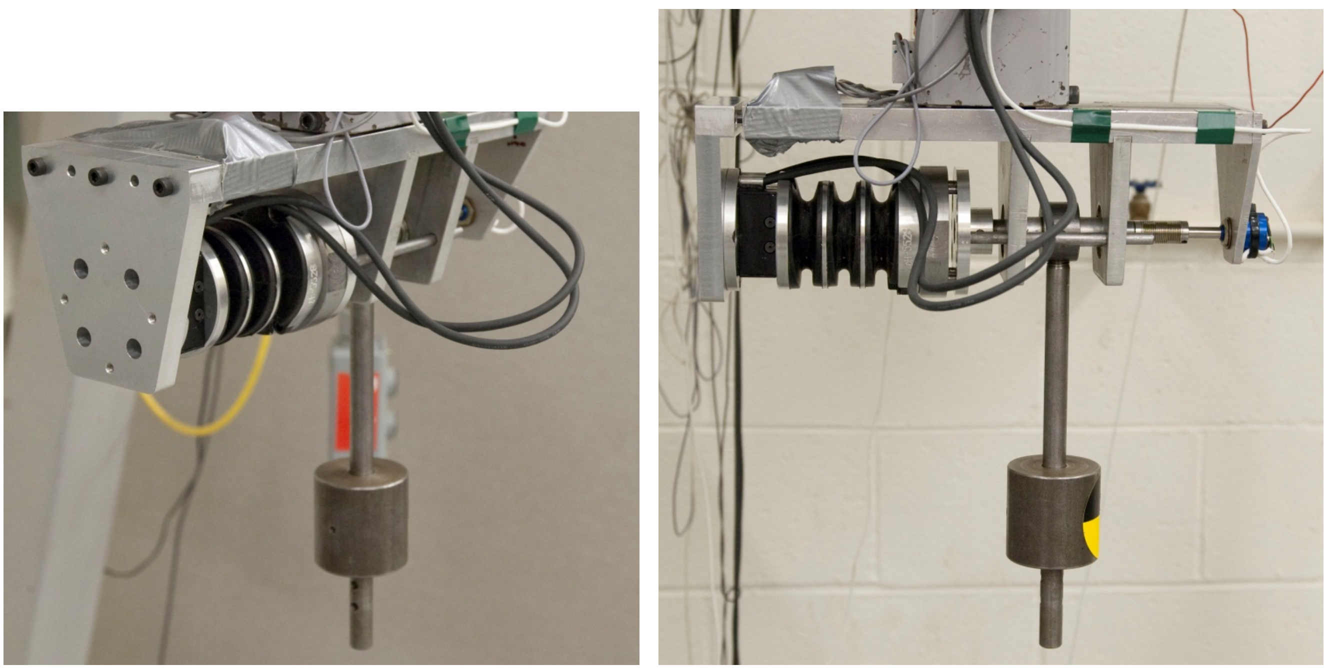


Figure 53. Torsion fixture with neck fully installed (zero pins in place)

2.4.3. Opposite Side Test Preparation

To test torsion response on the opposite side of the neck, follow these steps:

- Remove the entire assembly from the pendulum, rotate it 180 degrees and reassemble the neck mounting plate to the pendulum (Figure 54).

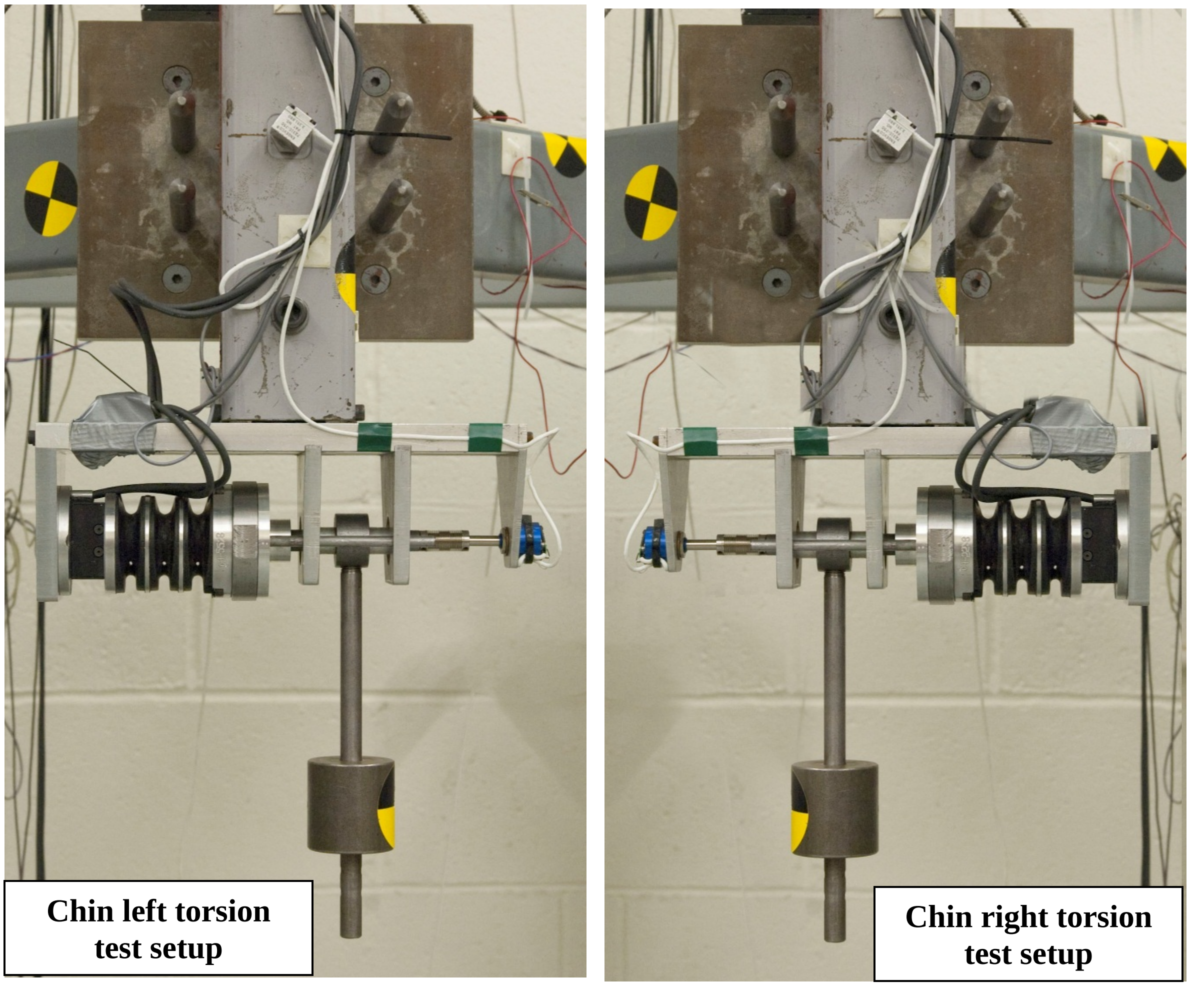


Figure 54. Torsion test setups for chin left and chin right side tests

2.4.4. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- The potentiometer and load cell transducers must measure zero rotation when the neck is not in torsion. Prior to testing, with the zero pins (Figure 49) in place, remove the bias on these test data channels. No further pre or post-test bias removal of these data signals shall be performed.
- Once the bias is removed from the potentiometer and load cell data channels, be certain to remove the zero pins to prevent damage (Figure 55)!

- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb. Only the pendulum acceleration bias is removed at time zero.

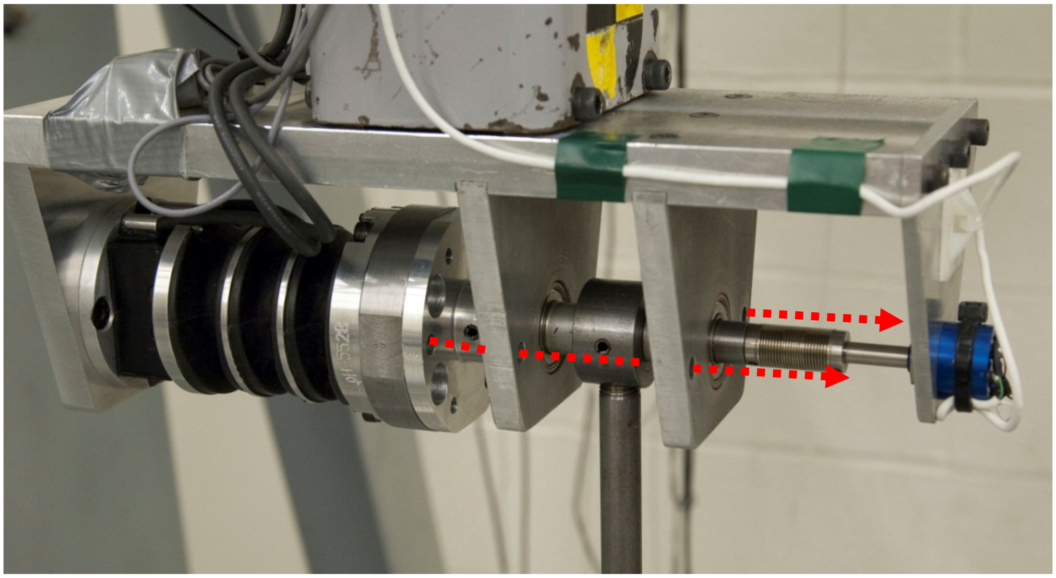


Figure 55. Uninstall zero pins prior to test

- The final test setup configuration is shown in Figure 56.

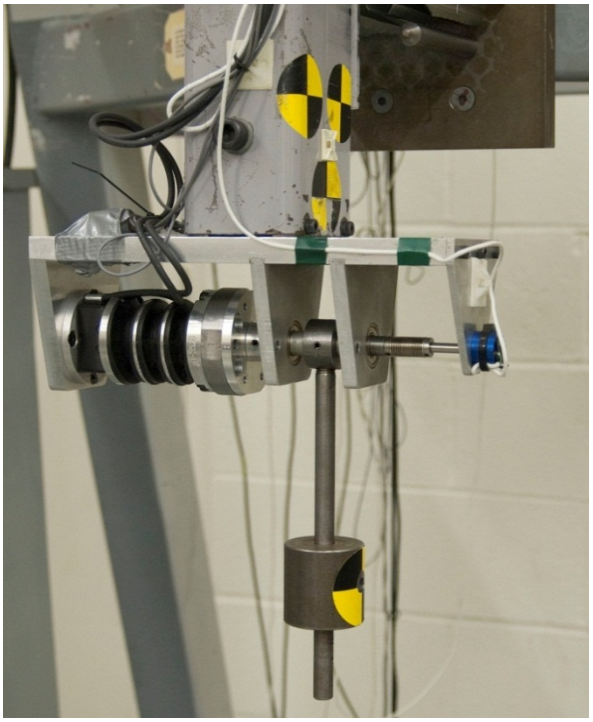


Figure 56. Final configuration for neck torsion test

- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 3.5 – 3.7 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 4.

Table 4. Q3s Torsion Pulse Parameters

Parameter		units	Spec. Limits lower	Spec. Limits upper
impact speed		m/s	3.5	3.7
pendulum pulse	@10 ms	m/s	0.9	1.3
pendulum pulse	@15 ms	m/s	1.4	2.0
pendulum pulse	@20 ms	m/s	2.0	2.6

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The potentiometer is filtered using a Channel Class 60 phaseless filter.
- The neck moment about the Z-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- The peak rotation, peak moment, and headform rotation decay time to zero shall lie within the proper specifications:
    - Peak rotation: 74.5 – 91.0°
    - Peak moment[16] (Mz): 8.0 – 10.0 Nm
    - Rotation decay time to 0° from peak angle: 85 – 102 ms
- Wait at least 30 minutes between consecutive tests on the same neck.

[16] Maximum moment measured during the time interval while the rotation is within the specified corridor.

3. Q3S SHOULDER QUALIFICATION TESTS

3.1. Required Instrumentation

- Shoulder string potentiometer
- Test probe accelerometer
- Speed trap

3.2. Optional Instrumentation

- Dual axis tilt sensor installed in spine box

3.3. Pre-Test Preparation

- With the pendulum in its lowest resting position, draw a reference line along the bench support surface along the path of the pendulum; using a line laser device[17] (set for vertical) positioned on a tripod (Figure 57) will aid in this process.
- Align the laser vertically along the back of the probe, along the top of the centerline of the probe (Figure 58), and along the probe path reference line on the support surface. Leave the laser in this position for the duration of the setup.

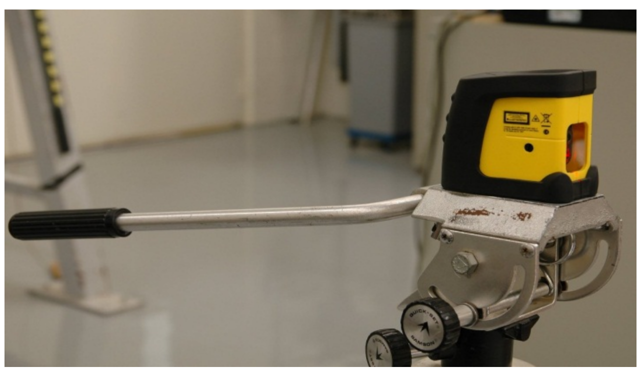


Figure 57. Laser line device set on tripod

[17] For ease of setup, a laser line device is utilized in this procedure. However, any method which achieves the same result is acceptable if such a device is unavailable.

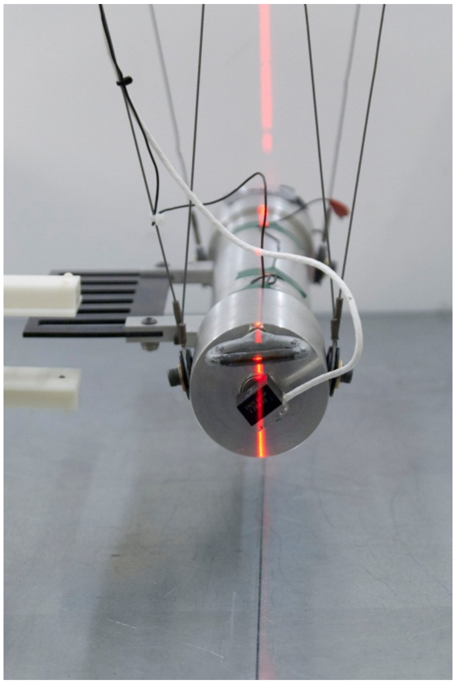


Figure 58. Align laser with probe centerline and pendulum path reference line on support surface

- Unfasten the upper portion of the suit jacket and electrically ground the dummy using a cable between a metal component of the dummy and the ground such as that shown in Figure 59.

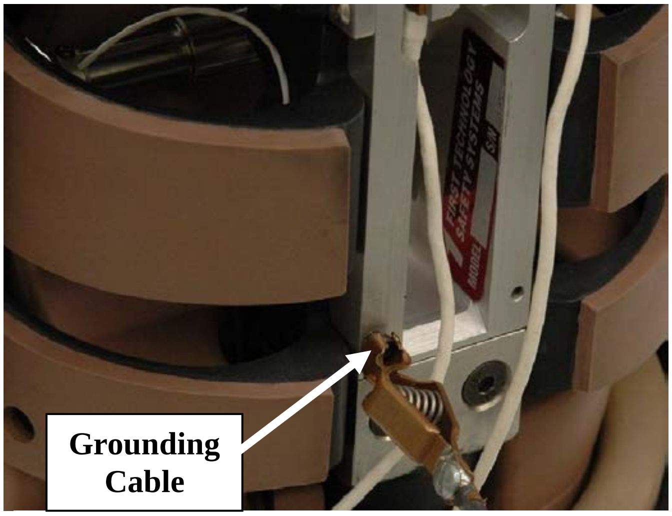


Figure 59. Grounding the dummy

- To determine the center of impact point on the shoulder, draw a reference line between the center of the shoulder and the bolts at the distal (elbow) end of the upper arm. Draw a line connecting the centers of the lower shoulder bolts (Figure 60). Next, measure 15mm up from the line through the lower shoulder bolts along the arm reference line. This is the point of impact.

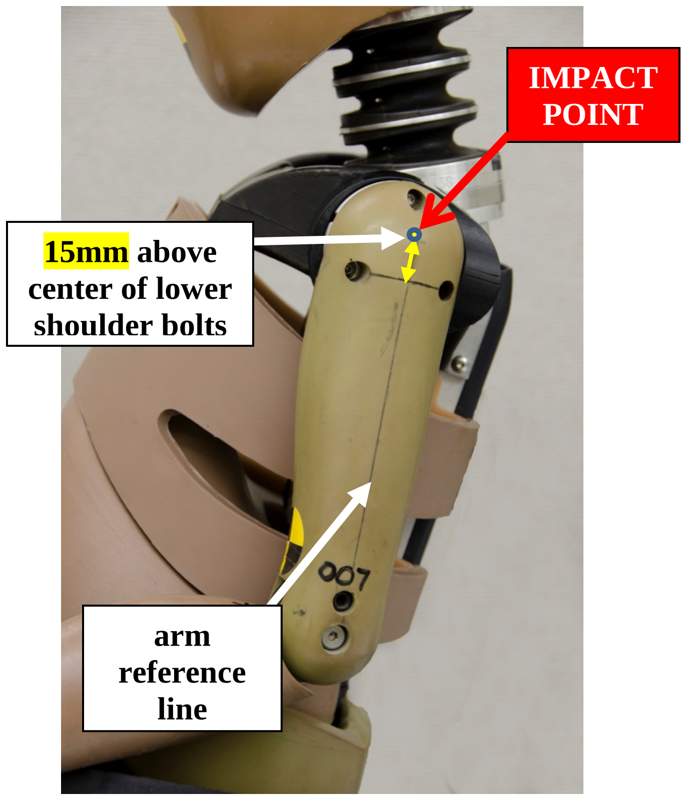


Figure 60. Determine the shoulder impact point

- Reinstall the jacket.
- The dummy wears only the jacket for this procedure. No additional clothing or shoes are placed on the dummy.
- Place the qualification bench[18] (Figure 61) in the probe's impact area so that the dummy can be impacted in the shoulder.
- Seat the dummy on a sheet of 387 x 521 mm PTFE (Teflon®) (2-mm thick) on the bench. The edge of the sheet must be along the impact side of the bench's seat pan.
- Place a sheet of 514 x 514 mm PTFE (Teflon®) (2-mm thick) between the seatback and the dummy's posterior thorax; the edge of the sheet must be along the impact side of the bench's seatback.
- The probe impact surface has a 70.0 ± 0.25 mm diameter face, and a mass of 3.81 ± 0.02 kg.
- The probe longitudinal axis should be positioned level (0 ± 1º).

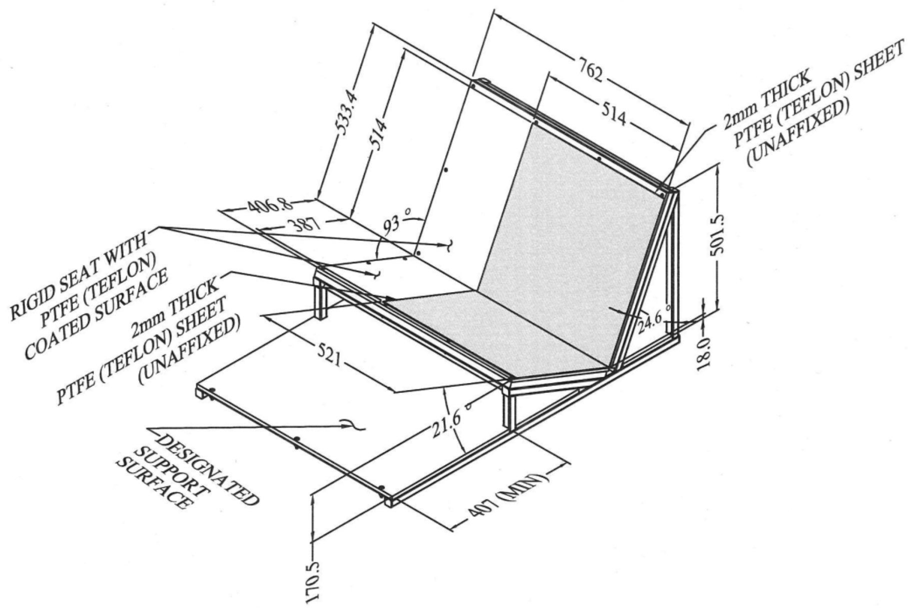


Figure 61. Qualification bench seat specifications for Q3s qualification tests

[18] This is the same bench specified for WorldSID and SID-IIsD qualification procedures.

- To prepare to install the Q3s positioning tool[19] (Figure 62) between the dummy's knees, push the femurs and tibias downward so that the legs make full contact with the test surface.

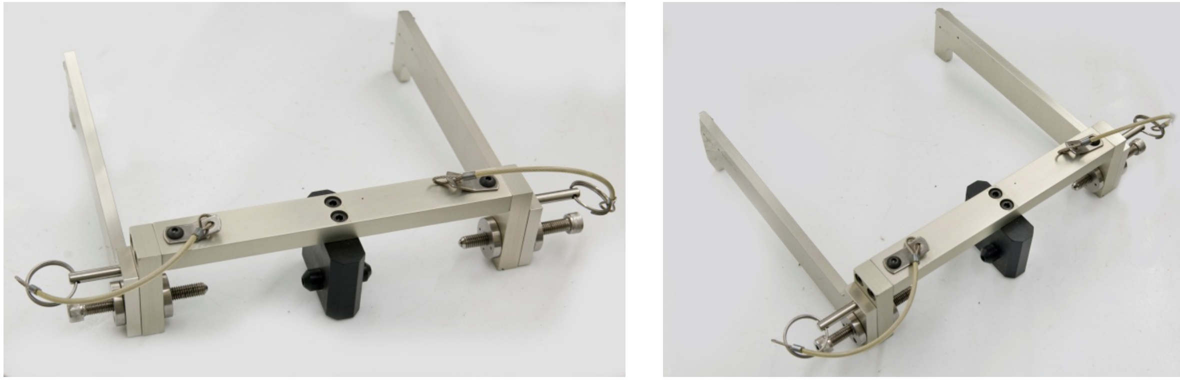


Figure 62. Q3s positioning device for Q3s

- Ensure that the instrumentation umbilical exits the dummy from the non-impact side of the pelvis. In addition, fastening the hook and loop closure which connects the thoracic part of the jacket to the pelvis portion with a small overlap allows for easier adjustment of the jacket (Figure 63).

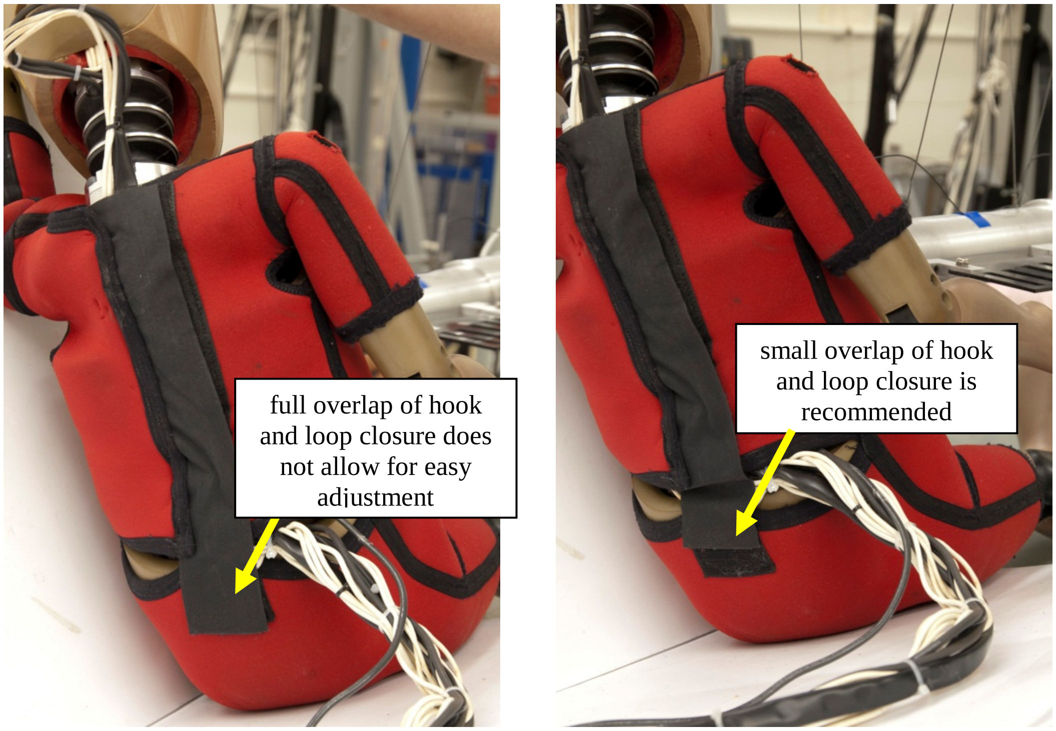


Figure 63. Proper umbilical placement and jacket closure

[19] "*Q3s Positioning Tool*", First Technology Safety Systems, Drawing # 020-9000, June 22, 2010.

- Ensure that the jacket is not tucked into the pelvis/femur interface during the setup procedures (Figure 64). If it is, pull the suit upwards near the shoulders.

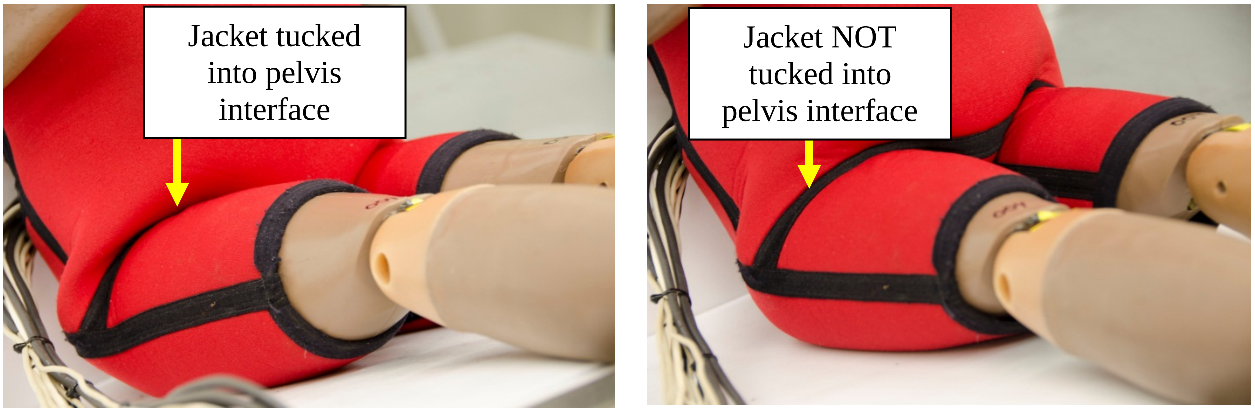


Figure 64. Ensure that jacket is not tucked into pelvis/femur interface

- For this procedure, the pins on either side of Q3s positioning device should both be installed (Figure 65).

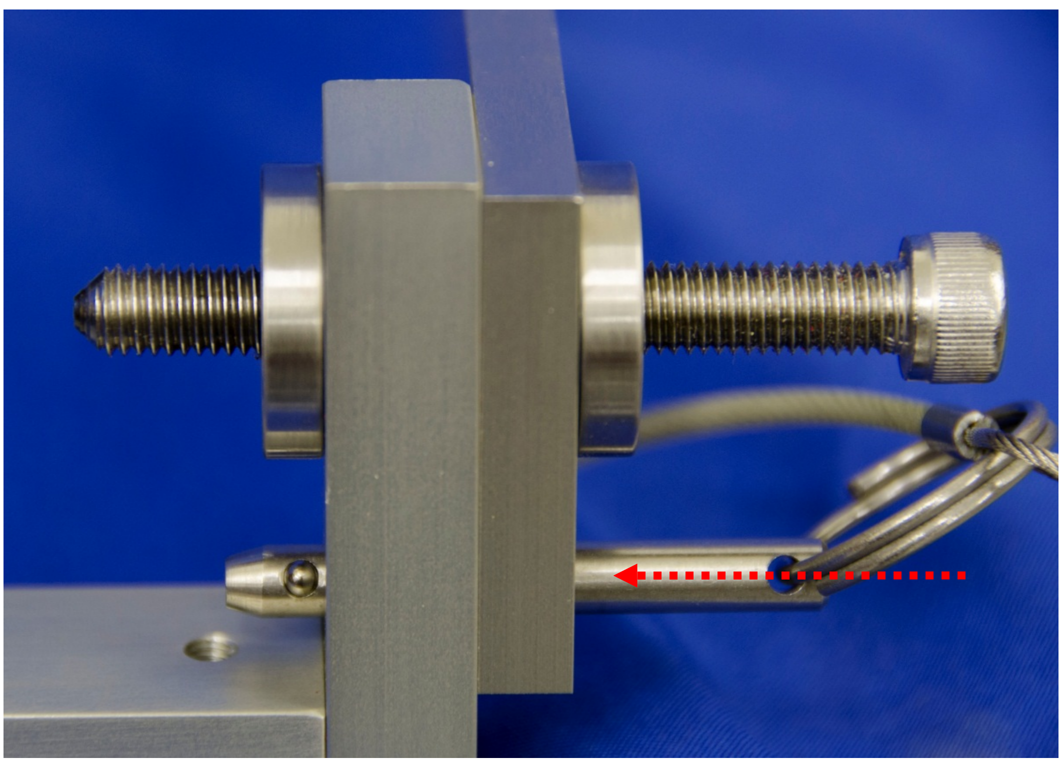


Figure 65. Insert pins into Q3s positioning device

- Be sure the bolts on the positioning tool are correctly seated into the knee (Figure 66).

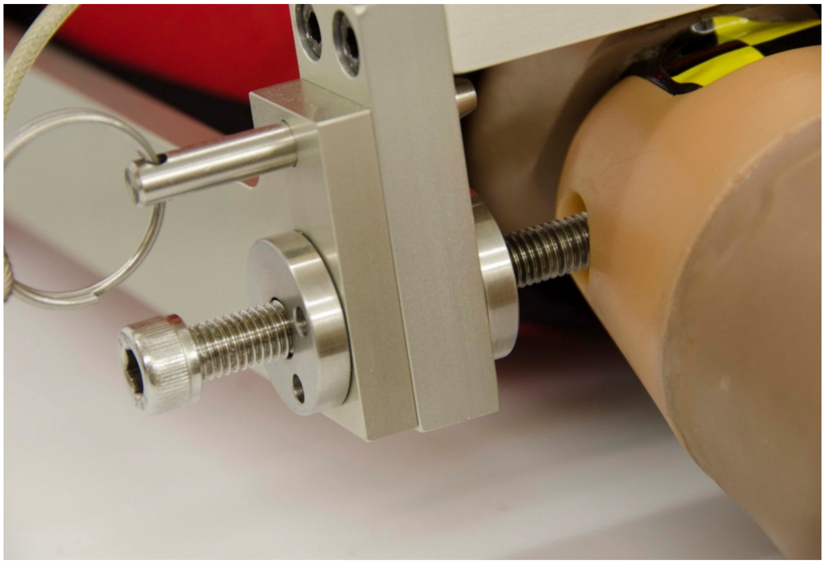


Figure 66. Position bolts into the knee

- Pull the feet apart while hand-tightening either left or right bolt (Figure 67) until the inner side of the knee *just touches* the center spacer of the positioning tool (Figure 68).

Figure 67. Pull feet apart while tightening bolt on positioning tool

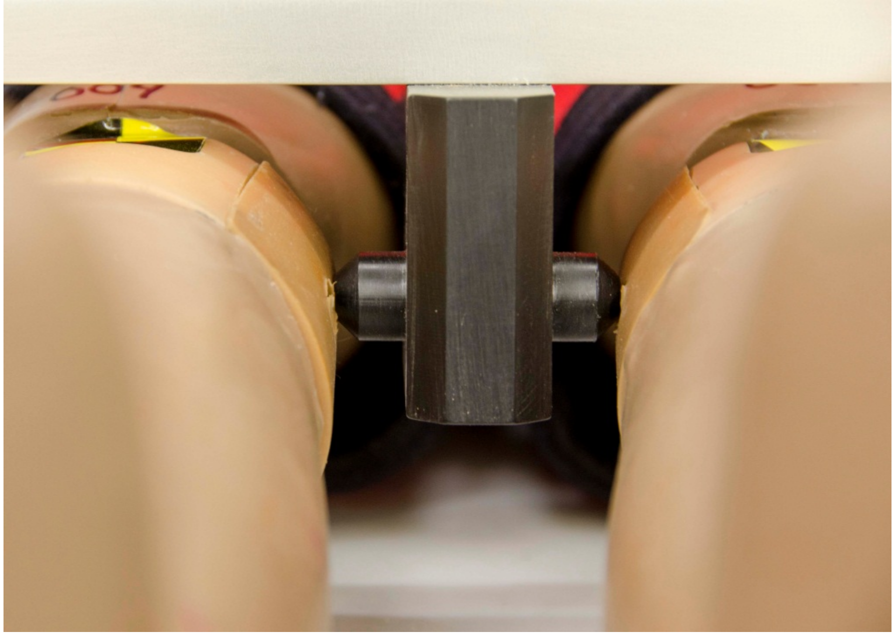


Figure 68. Knees just touching the inner spacing bar on the positioning device

- Push the dummy's chest toward the seatback, so that the ribs make full contact with the seatback. If the optional tilt sensor is installed, the sensor should indicate 24.6 ± 1º.
- Push the feet towards the seatback to position the pelvis.
- Adjust the pelvis position so that both left and right extensions of the Q3s positioning device are equidistant from the seatback (Figure 69). This "squares" the dummy with the seat.

Figure 69. Squaring the dummy to the seat using the Q3s positioning tool

- Move the arm inwards (medially) until initial contact occurs between the sleeve and the portion of the suit covering the thorax (Figure 70).

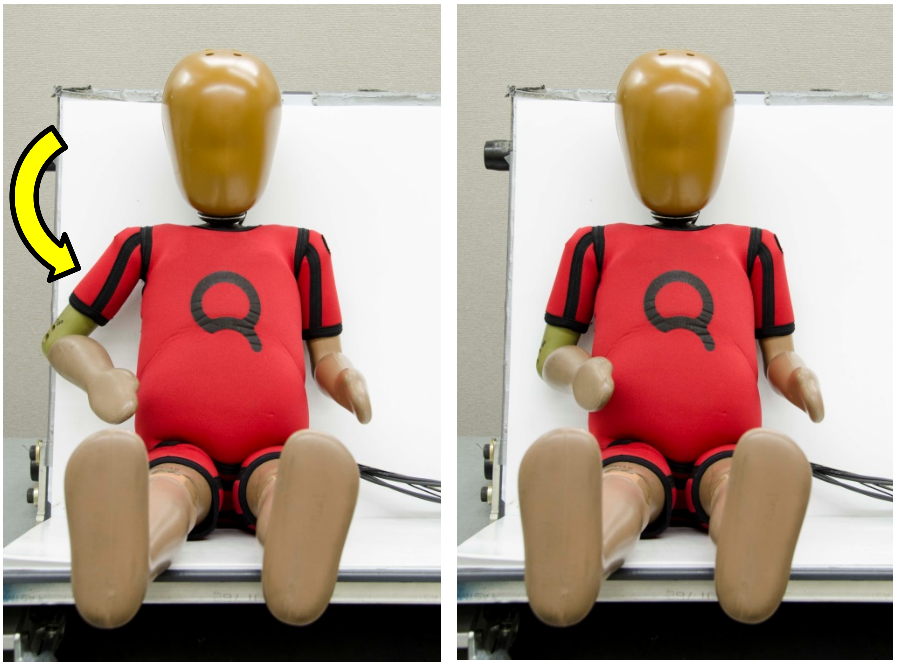


Figure 70. Setting the arm medially for shoulder tests

- Assure that the lower arm is parallel to the sagittal plane (Figure 71).

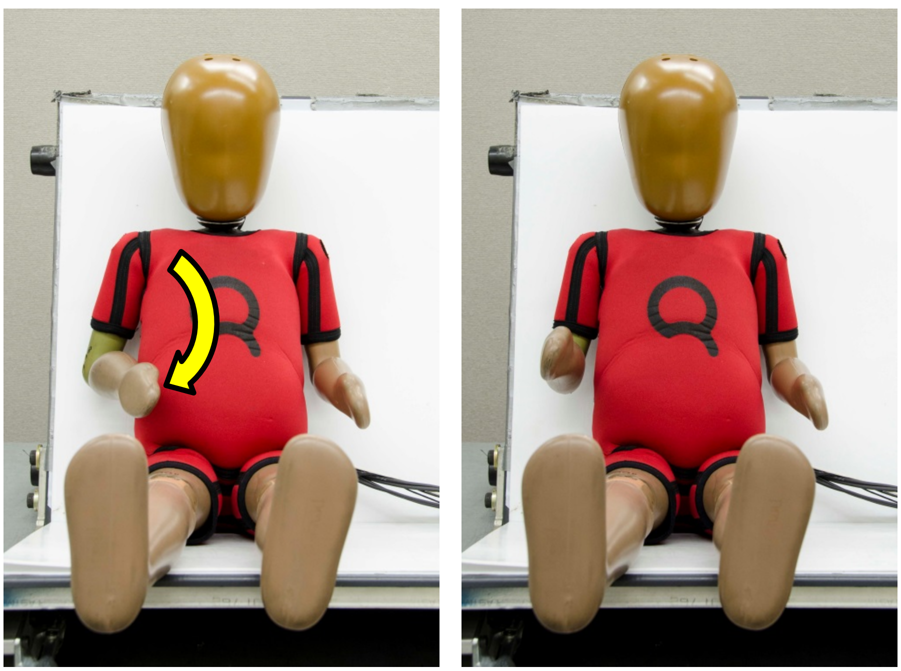


Figure 71. Setting the arm parallel to sagittal plane for shoulder tests

- Position each arm so that the upper arm is parallel to the seatback; the lower arm should be perpendicular to the upper arm. To ensure that the arm is parallel to the seatback, measure the distance between the arm reference line (Figure 72) at the shoulder and the reference line near the elbow. Both should be equidistant from the seatback.

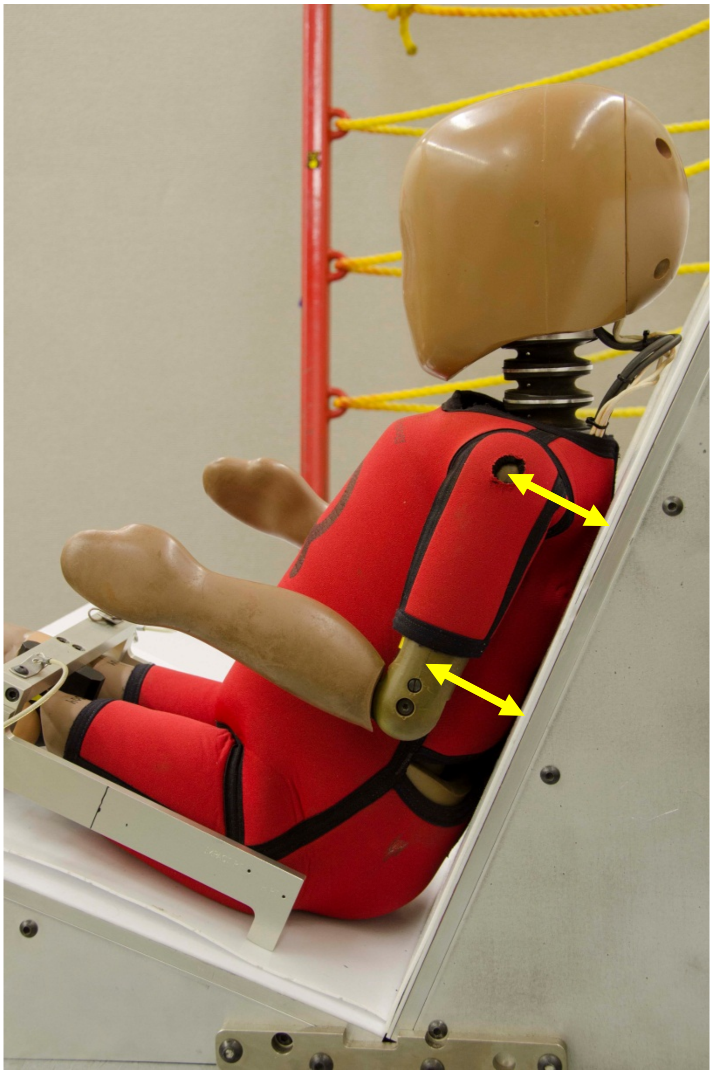


Figure 72. Using arm reference line to ensure that arm is parallel to seat back

- Adjust the bench position (roughly) so that the probe contacts the shoulder near the impact point. When the pendulum probe is at its lowest position during travel, it should be just touching the shoulder. Using the lateral laser device will aid in the process.
- Square the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 73). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the shoulder positioning at the probe.

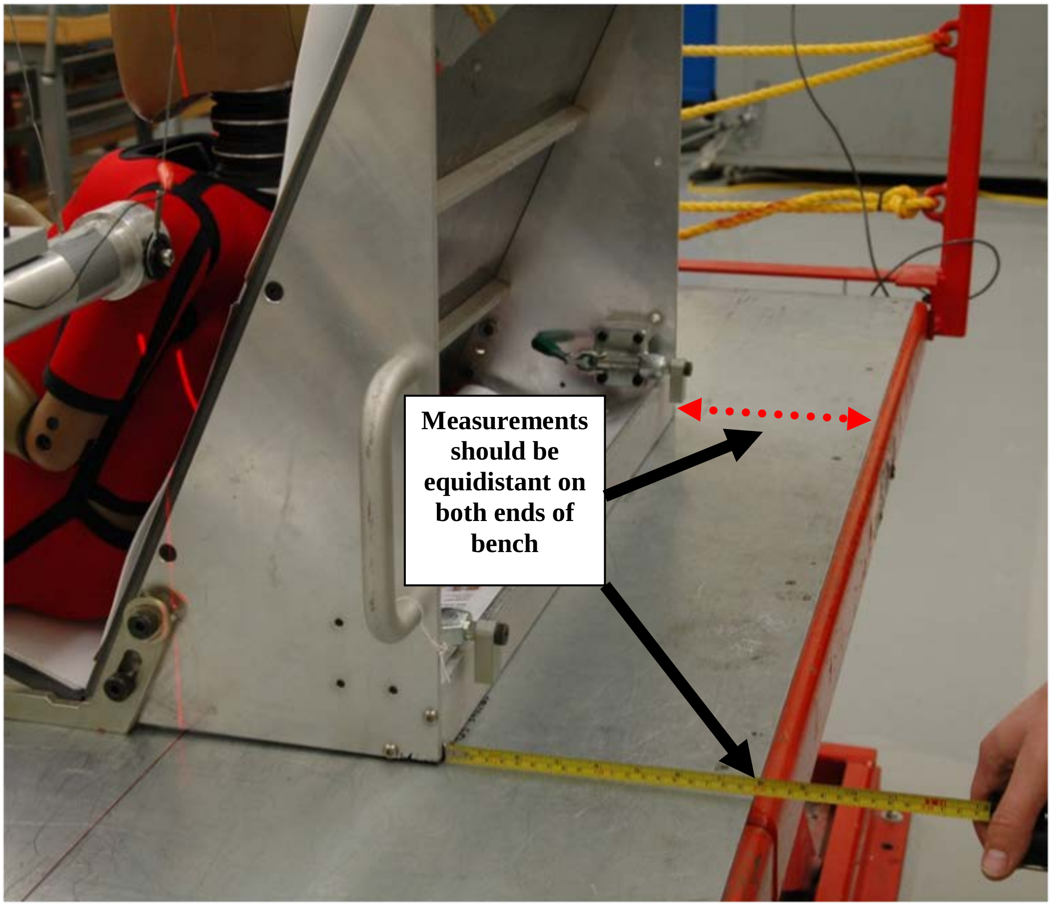


Figure 73. Checking that the bench is square

- To ensure that the dummy is seated upright (not leaning laterally), using a laser device positioned in front of the dummy, align the laser between the feet and along the dummy's midsagittal plane (Figure 74). Align the laser between the feet and along the centerline of the Q3s positioning tool. Placing a measuring tape between the feet to ensure the dummy is upright may be useful. As an alternative, if the optional tilt sensor device is installed in the spinebox, ensure that the lateral positioning of the dummy is 0 ± 1º. Adjust the dummy as necessary to achieve these results.

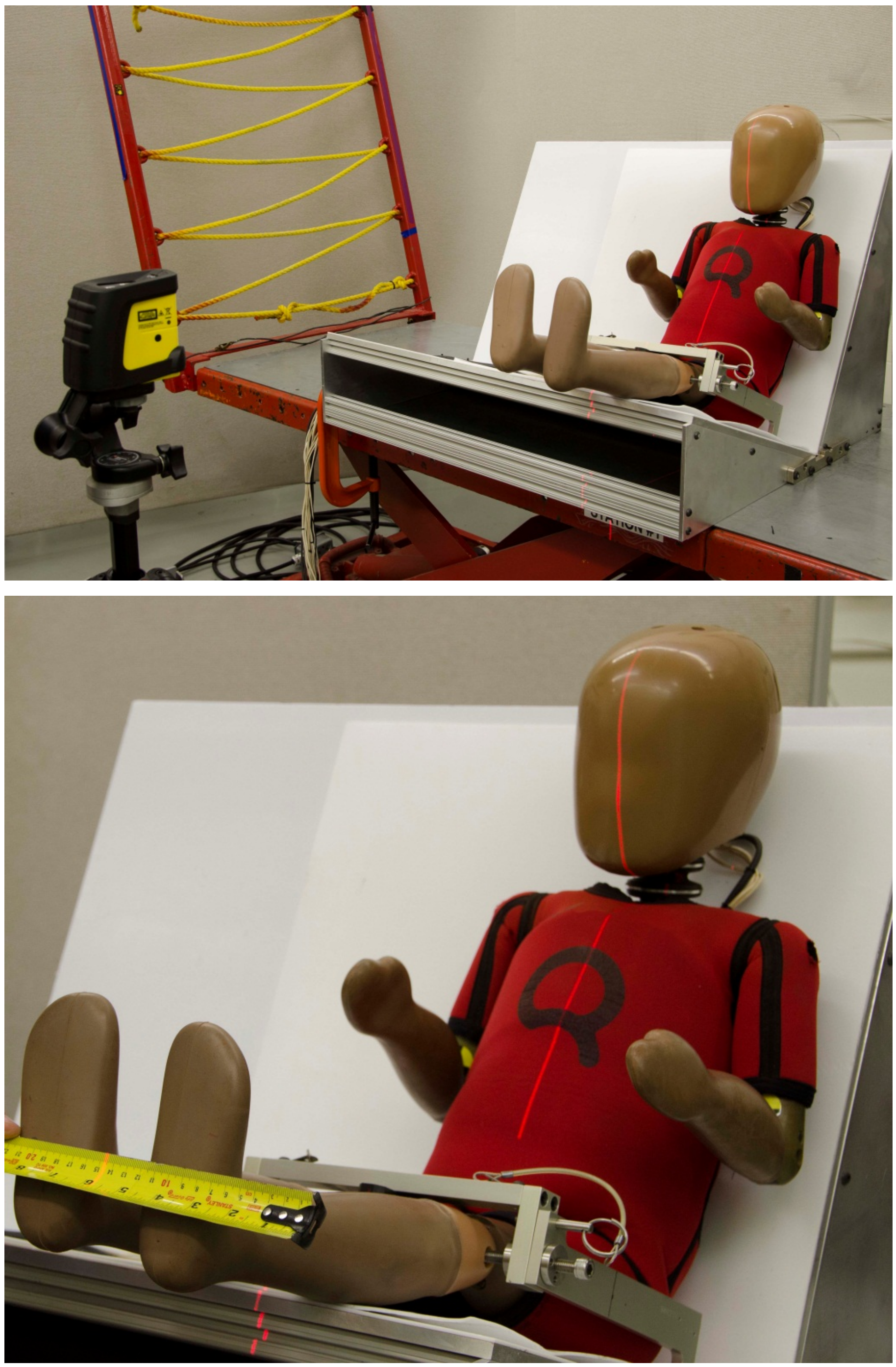


Figure 74. Use laser to align dummy laterally

- To aid in determining probe positioning, place a pointer device in the centerline of the probe (Figure 75).

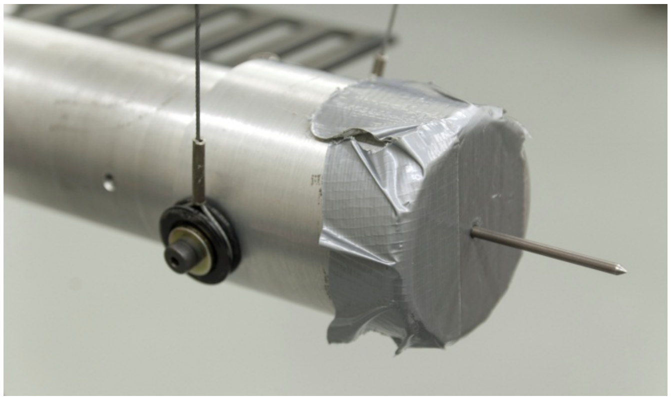


Figure 75. Pointer inserted into center of probe

- Align the center of the probe with the shoulder impact point. The lateral laser will aid in this process. In addition, pulling back the probe and using a small pointer inserted into the center of the probe face may facilitate this task (Figure 75 and Figure 76). Move the seat or adjust the table up or down as needed to achieve the desired results taking care to maintain the square seat position. Remove the pointer after the shoulder impact point is set.

Figure 76. Align probe with shoulder impact point

- Recheck that the bench is square (Figure 73). Adjust as necessary.
- Recheck that the dummy is upright using either the frontal laser or optional tilt sensor (Figure 74) and adjust if necessary.
- Recheck that the dummy is fully seated against the seatback. The optional tilt sensor should indicate 24.6 ± 1º. Adjust as necessary.
- Recheck that the centerline of the probe is centered on the impact point of the shoulder (Figure 76). Be sure to remove the pointer after this step.
- Secure the bench to the support surface using a clamp or any suitable method.
- Carefully remove the Q3s positioning tool.
- Figure 77 shows the final setup for the shoulder qualification test.

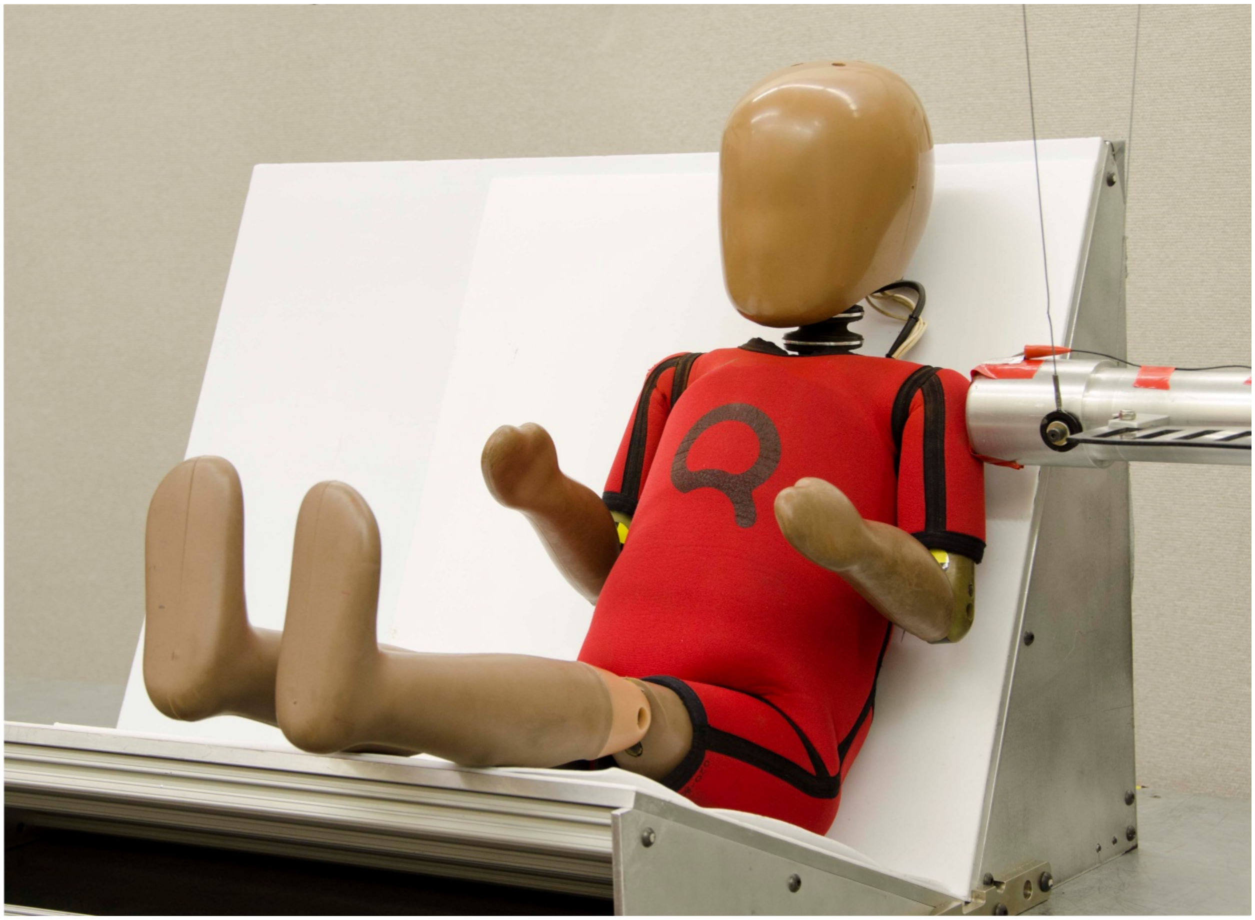


Figure 77. Final setup for shoulder qualification test

3.4. **Test Procedures**

- The test probe should have a mass of 3.81 ± 0.02 kg[20] with a 70.0 ± 0.25 mm face diameter, and a 6.4 - 12.7 mm radius.
- Mount an accelerometer on the test probe with its sensitive axis in line with the longitudinal centerline of the test probe.
- Release the test probe within the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% specifications so that it achieves a velocity between 3.5 – 3.7 m/s at the instant of contact with the dummy.
- At the instant of contact, the probe should be horizontal (± 1º), and the centerline of the probe should be within 2 mm of the dummy's shoulder rotation centerline.
- The data acquisition system should conform to SAE Recommended Practice J211 (July 2007).
- The probe acceleration is collected and filtered using a Channel Class 180 phaseless filter.
- The shoulder deflection is collected and filtered using a Channel Class 180 phaseless filter.
- Time zero is defined as the time of contact between the impact probe and the shoulder. All channels should be at a zero level at this point.
- Calculate probe force using the filtered probe acceleration[21]:
    - $F_{probe} = (m_{probe})x(a_{probe})$
- The peak lateral shoulder displacement and peak probe force shall lie within the proper specifications:
    - Peak lateral shoulder displacement: 17.0 – 22.0 mm
    - Peak probe force: 1123 – 1437 N
- Wait at least 30 minutes between consecutive shoulder impact tests on the same shoulder.

[20] Mass includes probe mass and all rigidly attached hardware, plus 1/3 of supporting cable weight.
[21] Mass should be measured in kg and acceleration should be measured in m/s^2.

4. Q3S THORAX WITH ARM QUALIFICATION TESTS

4.1. **Required Instrumentation**

- Thorax IRTRACC displacement device
- Test probe accelerometer
- Speed trap

4.2. **Optional Instrumentation**

- Dual axis tilt sensor installed in spine box

4.3. **Pre-Test Preparation**

- With the pendulum in its lowest resting position, draw a reference line along the bench support surface along the path of the pendulum; using a line laser device[22] (set for vertical) positioned on a tripod (Figure 78) will aid in this process.
- Align the laser vertically along the back of the probe, along the top of the centerline of the probe (Figure 79), and along the probe path reference line on the support surface. Leave the laser in this position for the duration of the setup.

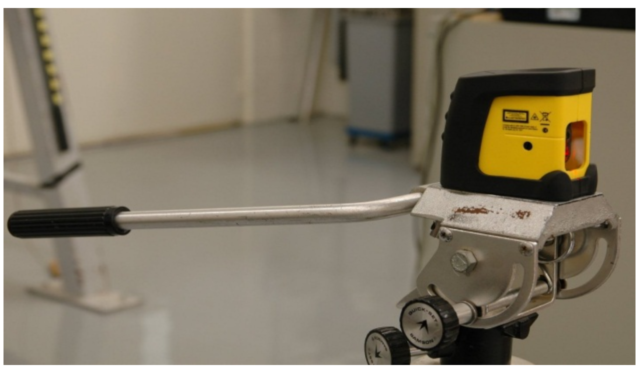


Figure 78. Laser line device set on tripod

[22] For ease of setup, a laser line device is utilized in this procedure. However, any method which achieves the same result is acceptable if such a device is unavailable.

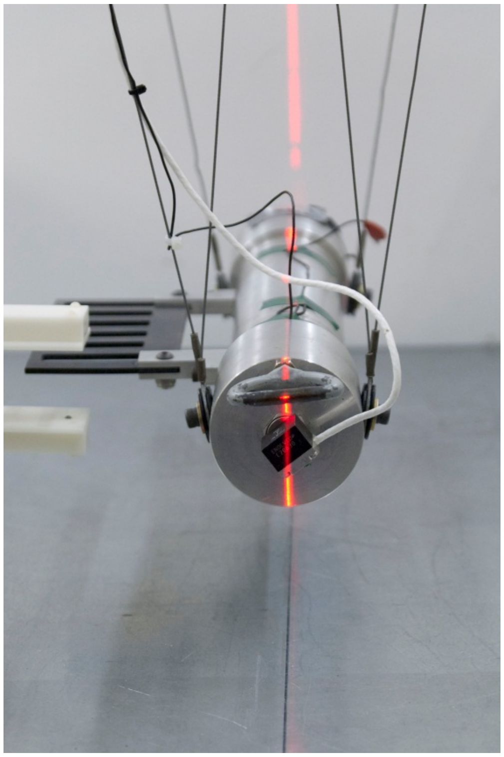


Figure 79. Align laser with probe centerline and pendulum path reference line on support surface

- Unfasten the upper portion of the suit jacket and electrically ground the dummy using a cable between a metal component of the dummy and the ground such as that shown in Figure 80.

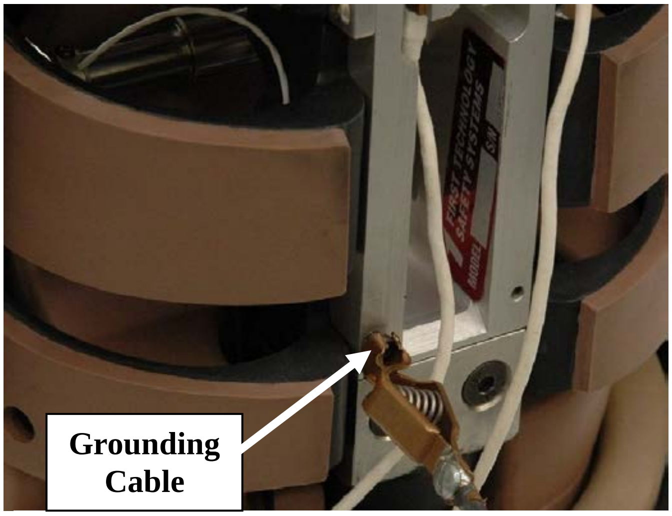


Figure 80. Grounding the dummy

- Draw a reference line between the center of the shoulder and the bolts at the distal (elbow) end of the upper arm. (Figure 81).

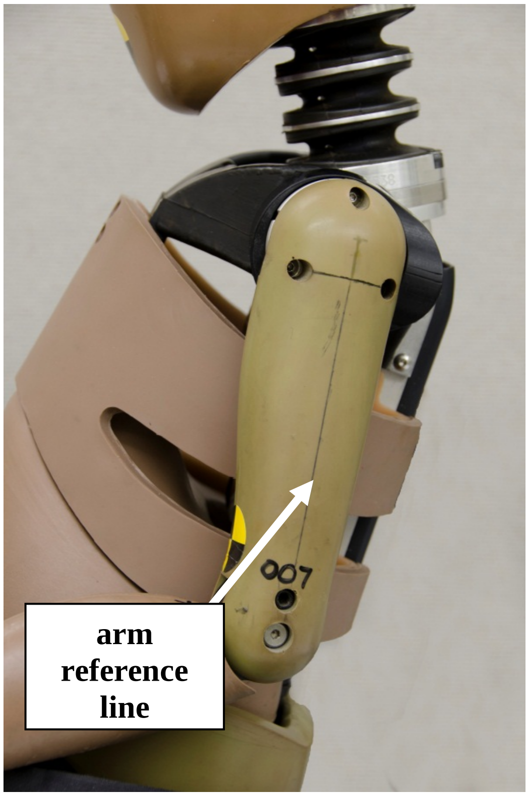


Figure 81. Draw a reference line on the upper arm

- Reinstall the jacket.
- The dummy wears only the jacket for this procedure. No additional clothing or shoes are placed on the dummy.
- Place the qualification bench[23] (Figure 82) in the probe's impact area so that the dummy can be impacted on the arm.
- Seat the dummy on a sheet of 387 x 521 mm PTFE (Teflon®) (2-mm thick) on the bench. The edge of the sheet must be along the impact side of the bench's seat pan.
- Place a sheet of 514 x 514 mm PTFE (Teflon®) (2-mm thick) between the seatback and the dummy's posterior thorax; the edge of the sheet must be along the impact side of the bench's seatback.
- The probe impact surface has a 70.0 ± 0.25 mm diameter face, and a mass of 3.81 ± 0.02 kg.
- The probe longitudinal axis should be positioned level (0 ± 1º).

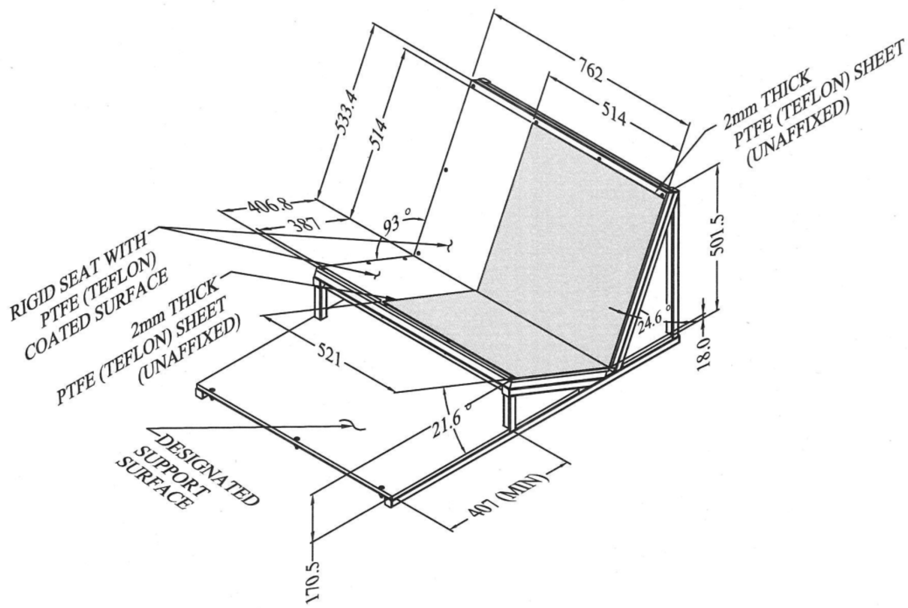


Figure 82. Qualification bench seat specifications for Q3s qualification tests

[23] This is the same bench specified for WorldSID and SID-IIsD qualification procedures.

- To prepare to install the Q3s positioning tool[24] (Figure 83) between the dummy's knees, push the femurs and tibias downward so that the legs make full contact with the test surface.

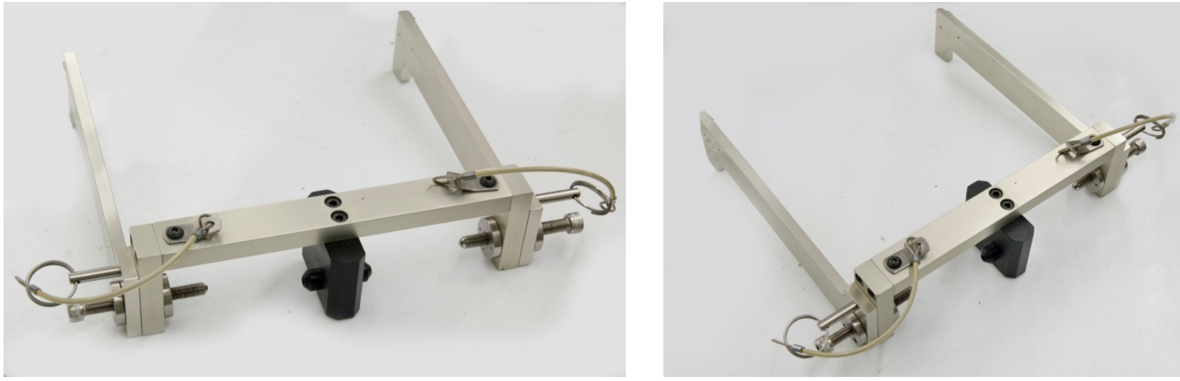


Figure 83. Q3s positioning device for Q3s

- Ensure that the instrumentation umbilical exits the dummy from the non-impact side of the pelvis. In addition, fastening the hook and loop closure which connects the thoracic part of the jacket to the pelvis portion with a small overlap allows for easier adjustment of the jacket (Figure 84).

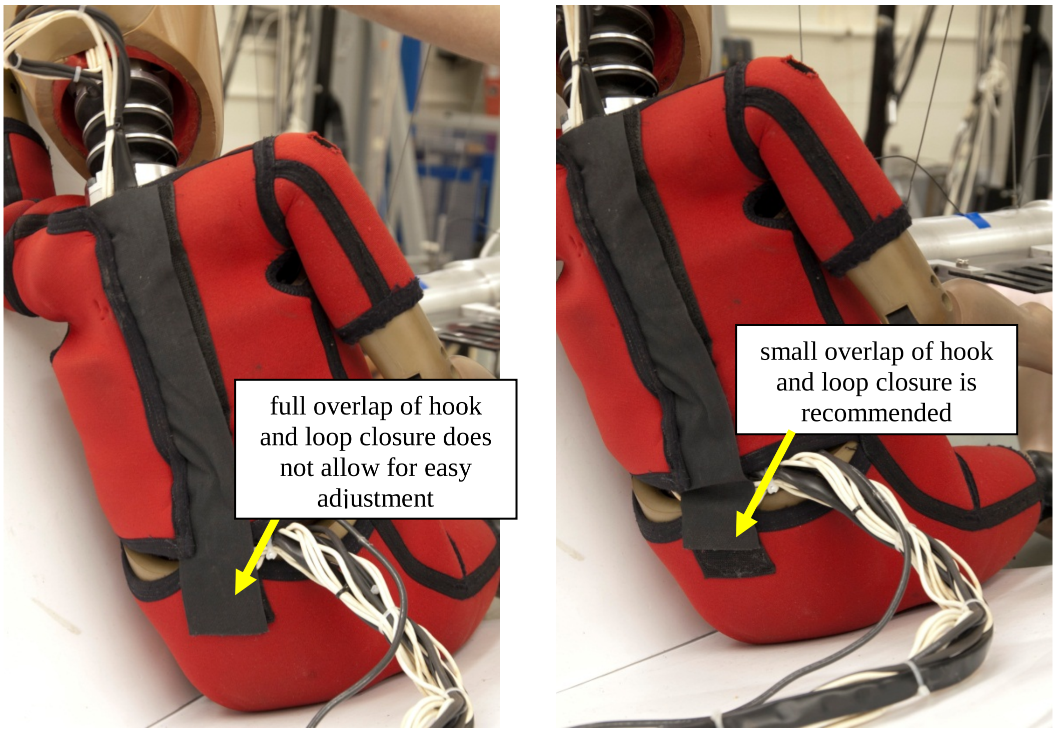
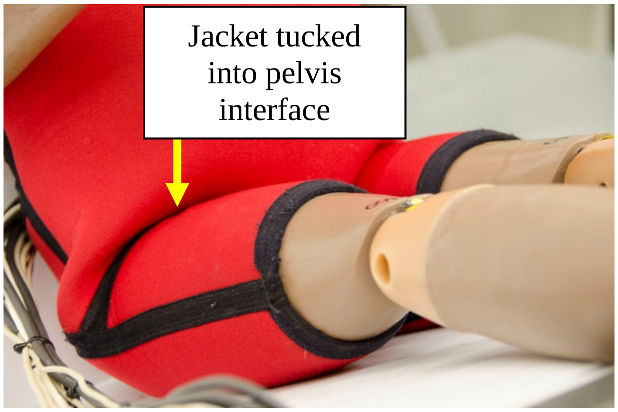


Figure 84. Proper umbilical placement and jacket closure

[24] "*Q3s Positioning Tool*", First Technology Safety Systems, Drawing # 020-9000, June 22, 2010.

- Ensure that the jacket is not tucked into the pelvis/femur interface during the setup procedures (Figure 85). If it is, pull the suit upwards near the shoulders.



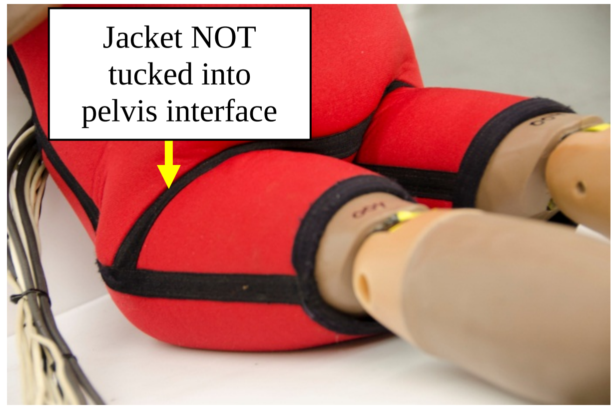


Figure 85. Ensure that jacket is not tucked into pelvis/femur interface

- For this procedure, the pins on either side of Q3s positioning device should both be installed (Figure 86).

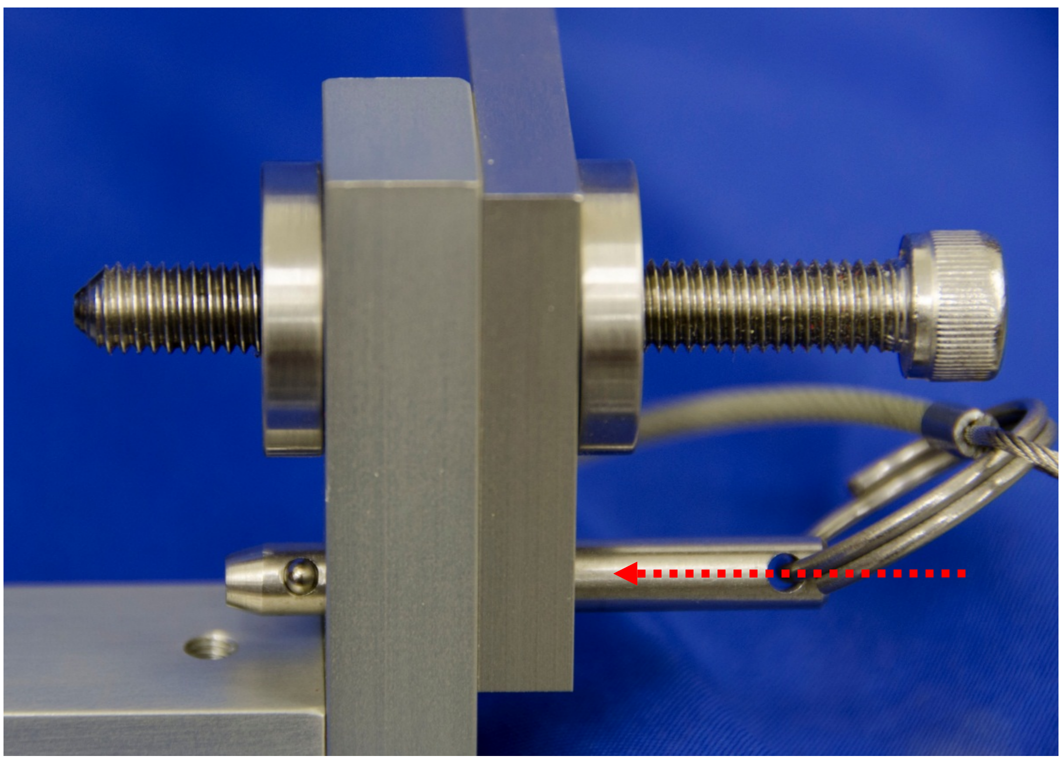


Figure 86. Insert pins into Q3s positioning device

- Be sure the bolts on the positioning tool are correctly seated into the knee (Figure 87).

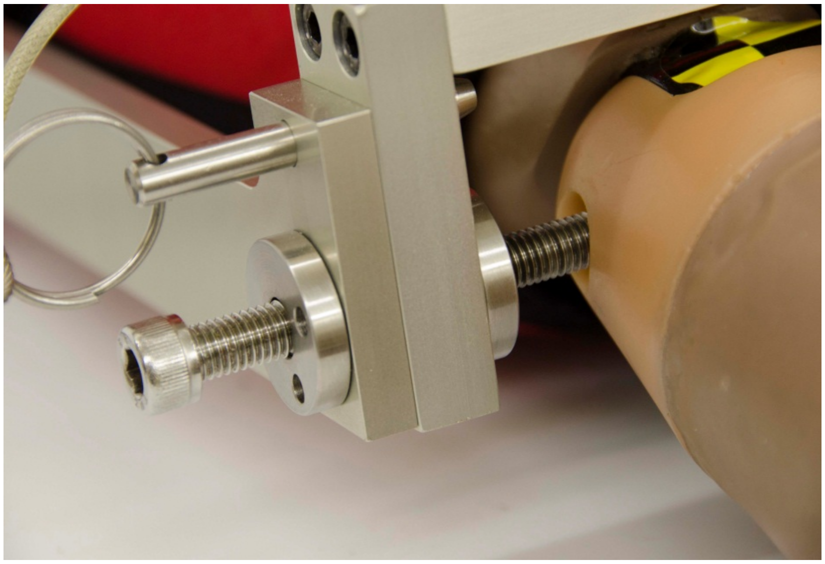


Figure 87. Position bolts into the knee

- Pull the feet apart while hand-tightening either left or right bolt (Figure 88) until the inner side of the knee *just touches* the center spacer of the positioning tool (Figure 89).

Figure 88. Pull feet apart while tightening bolt on positioning tool

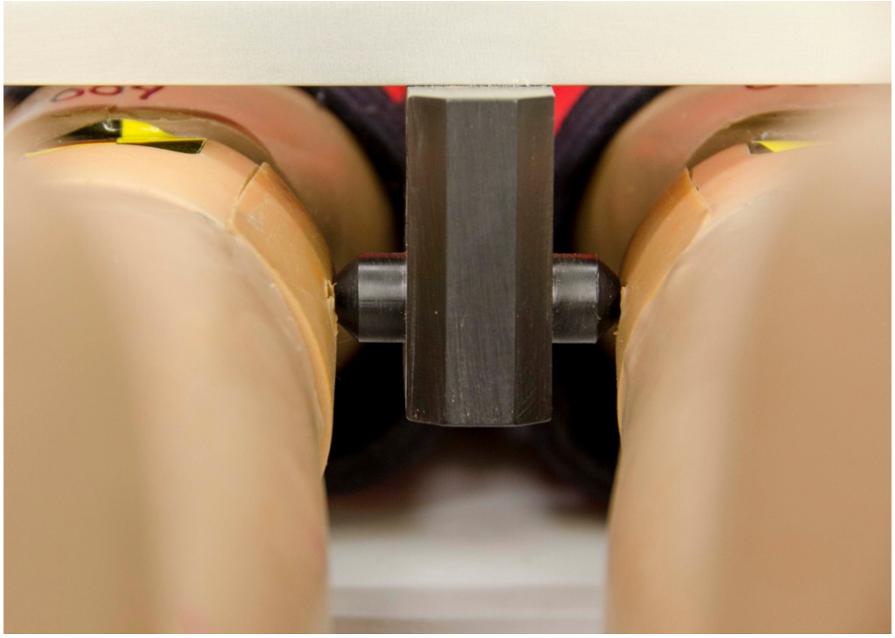


Figure 89. Knees just touching the inner spacing bar on the positioning device

- Push the dummy's chest toward the seatback, so that the ribs make full contact with the seatback. If the optional tilt sensor is installed, the sensor should indicate 24.6 ± 1º.
- Push the feet towards the seatback to position the pelvis.
- Adjust the pelvis position so that both left and right extensions of the Q3s positioning device are equidistant from the seatback (Figure 90). This "squares" the dummy with the seat.

Figure 90. Squaring the dummy to the seat using the Q3s positioning tool

- Adjust the bench position (roughly) so that the probe contacts the shoulder near the impact point. When the pendulum probe is at its lowest position during travel, it should be just touching the shoulder. Using the lateral laser device will aid in the process.
- Square the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 90). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the shoulder positioning at the probe.
- Raise the impact arm to reveal the thorax. Carefully pull down the jacket at the hole under the arm (Figure 91).

Figure 91. Positioning probe to impact point on thorax

- Pull back the probe and insert a small pointer into the center of the probe (Figure 92). This will allow access to the proper area of impact (the portion of the arm corresponding to an impact between the IRTRACC bolts). Align the pointer with the center point between the IRTRACC bolts (Figure 93). The lateral laser will also aid in this process.

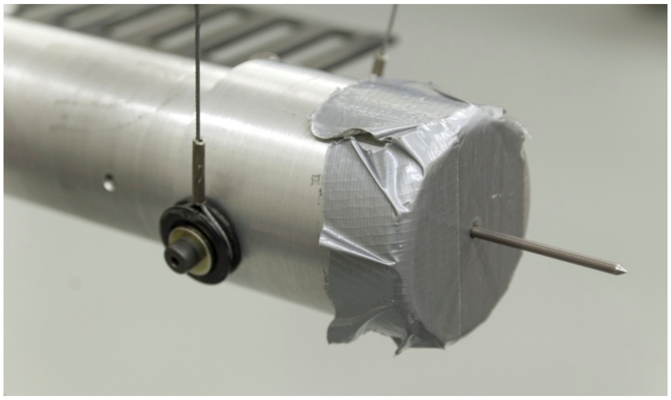


Figure 92. Pointer inserted into center of probe

Figure 93. Align pointer between IRTRACC bolts

- Reposition the arm so that the upper arm is perpendicular to the lower arm; move the arm down so that it is in the probe impact area. Square the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 94). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the thorax positioning at the probe.

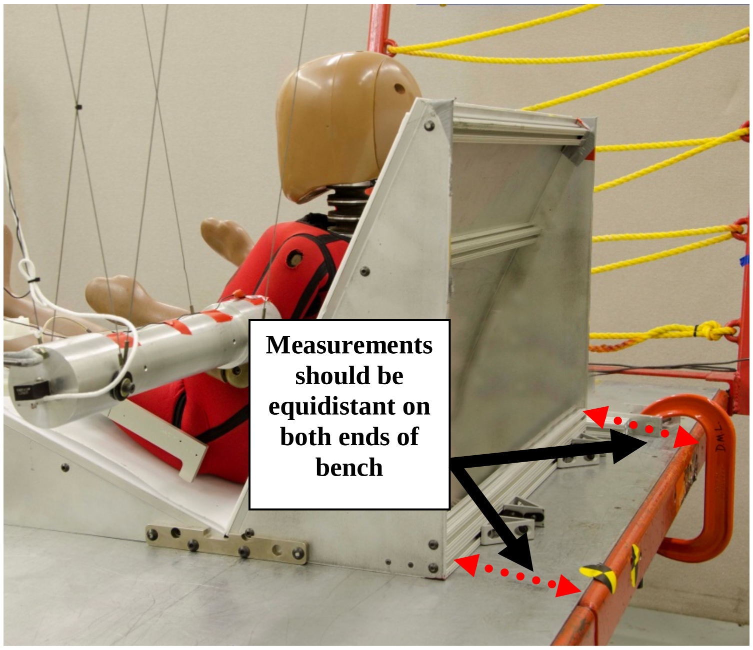


Figure 94. Checking that the bench is aligned

- Move the arm inwards (medially) until initial contact occurs between the sleeve and the portion of the suit covering the thorax (Figure 95).

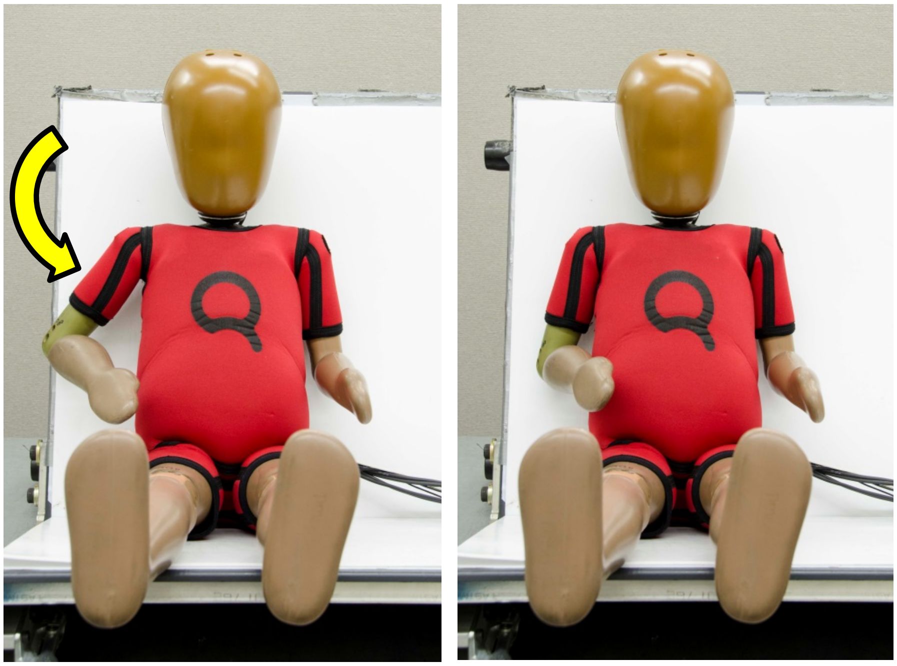


Figure 95. Setting the arm medially for thorax with arm tests

- Assure that the lower arm is parallel to the sagittal plane (Figure 96).

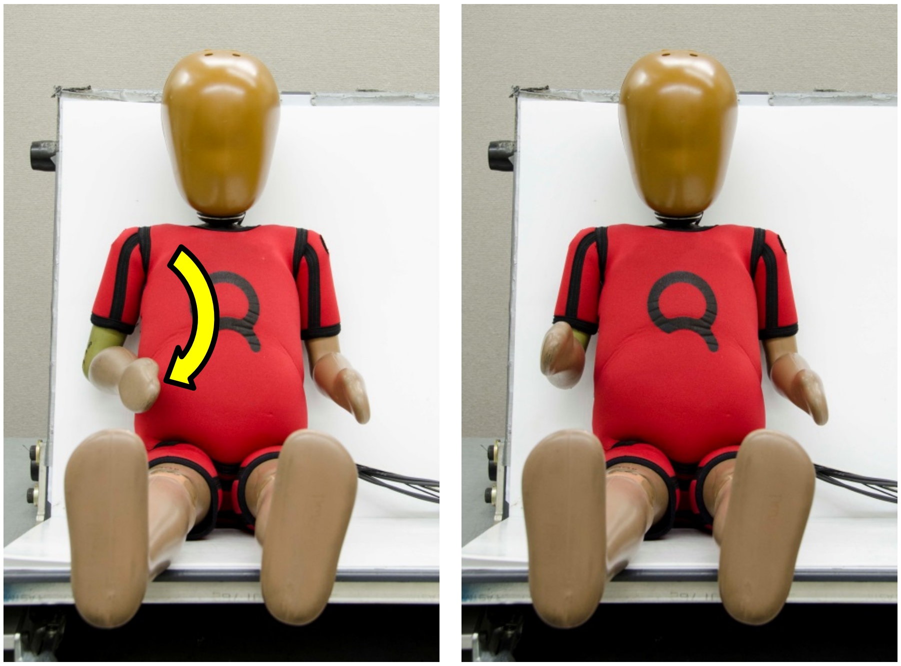


Figure 96. Setting the arm parallel to sagittal plane for thorax with armtests

- Pull the probe away from the dummy and carefully pull up the sleeve of the jacket to reveal the reference line. Reposition the impact arm so that the pointer aligns with the reference centerline of the arm (Figure 97). Remove the pointer after the arm impact point is set. Pull the sleeve back down onto the arm.

Figure 97. Setting arm to contact position

- To ensure that the dummy is seated upright (not leaning laterally), using a laser device positioned in front of the dummy, align the laser between the feet and along the dummy's midsagittal plane (Figure 96). Align the laser between the feet and along the centerline of the Q3s positioning tool. Placing a measuring tape between the feet to ensure the dummy is upright may be useful. As an alternative, if the optional tilt sensor device is installed in the spinebox, ensure that the lateral positioning of the dummy is 0 ± 1º. Adjust the dummy as necessary to achieve these results.

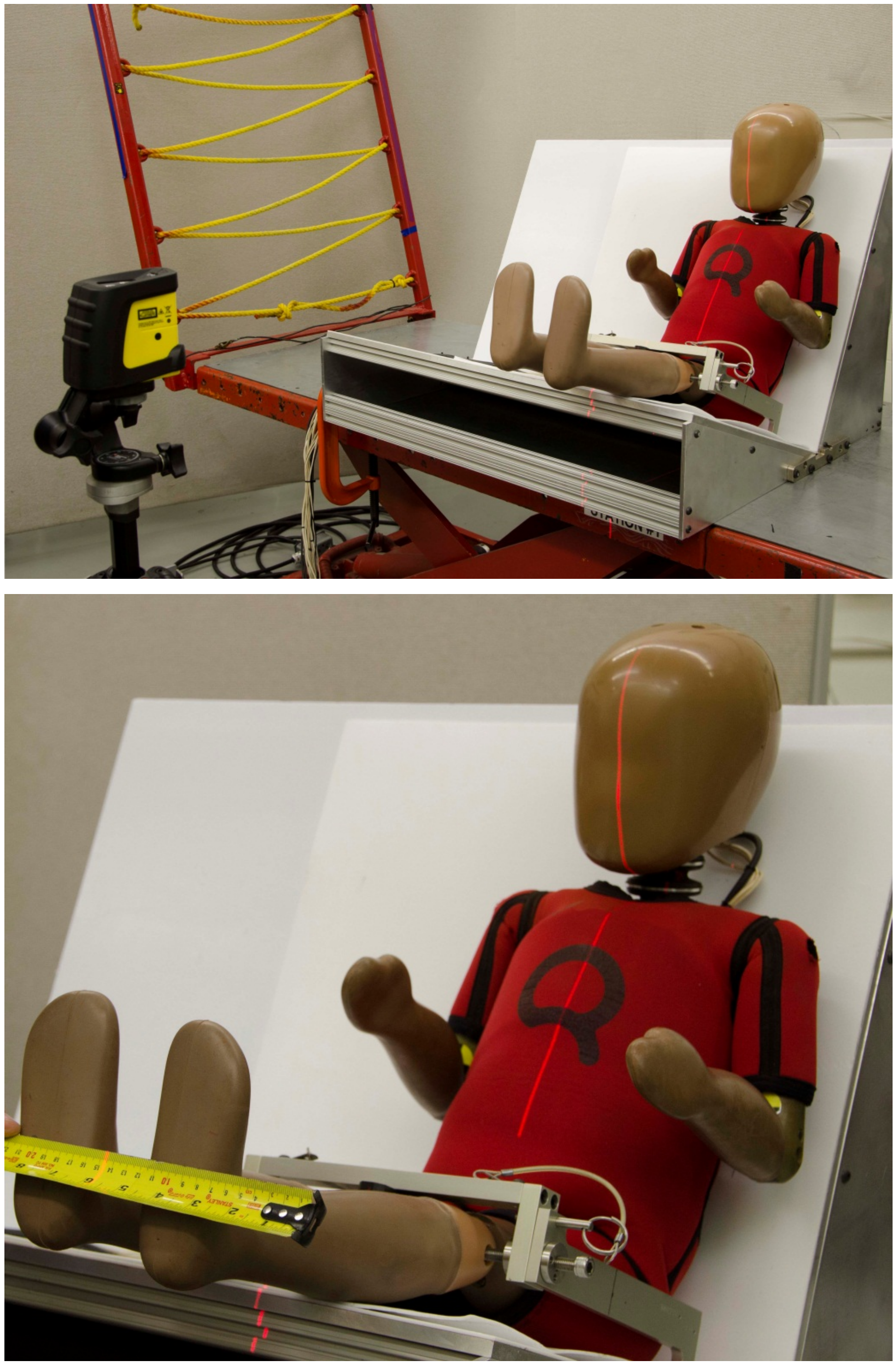


Figure 98. Use laser to align dummy laterally

- Move the seat as needed to achieve desired results. Align the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 94). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the arm impact positioning at the probe.
- Recheck that the dummy has maintained an upright position using the front laser or the optional tilt sensor device (Figure 96). The front laser may need to be repositioned along the midsaggital plane if the bench was moved in the previous step.
- Secure the bench to the support surface using a clamp or any suitable method.
- Remove the Q3s positioning device.
- Figure 97 shows the final setup for the dummy.

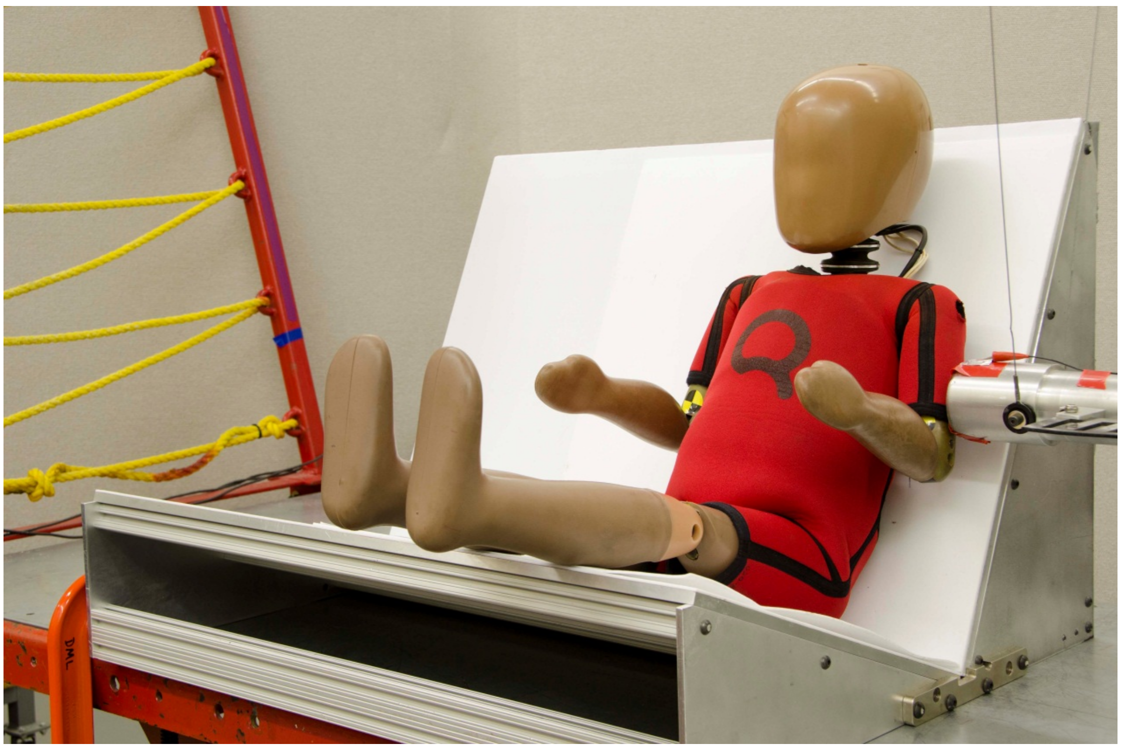


Figure 99. Final setup for Q3s thorax with arm qualification test

4.4. **Test Procedure**

- The test probe should have a mass of 3.81 ± 0.02 kg [25] with a 70.0 ± 0.25 mm face diameter, and a 6.4 - 12.7 mm radius.
- Mount an accelerometer on the test probe with its sensitive axis in line with the longitudinal centerline of the test probe.
- Release the test probe within the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% specifications so that it achieves a velocity between 4.9 – 5.1 m/s at the instant of contact with the dummy.
- At the instant of contact, the probe should be horizontal (± 1º), and the centerline of the probe should be within 2 mm of the centerline of the arm reference line corresponding to the center of the IRTRACC bolts.
- The data acquisition system should conform to SAE Recommended Practice J211 (July 2007).
- The probe acceleration is collected and filtered using a Channel Class 180 phaseless filter.
- The thorax displacement (IRTRACC) is collected and filtered[26] using a Channel Class 180 phaseless filter.
- Time zero is defined as the time of contact between the impact probe and the arm. All channels should be at a zero level at this point.
- Calculate probe force using the filtered probe acceleration[27]:
  - $F_{probe} = (m_{probe})x(a_{probe})$
- The peak lateral thorax displacement and peak probe force shall lie within the proper specifications:
  - Peak lateral thorax displacement: 22.5 – 27.5 mm
  - Peak probe force: 1360 – 1695 N
- Wait at least 30 minutes between consecutive thorax with arm impact tests on the same arm.

[25] Mass includes probe mass and all rigidly attached hardware, plus 1/3 of supporting cable weight.
[26] Filtering should be performed only after the IRTRACC data has been calculated into displacement.
[27] Mass should be measured in kg and acceleration should be measured in m/s^2.

5. Q3S THORAX WITHOUT ARM QUALIFICATION TESTS

5.1. Required Instrumentation

- Thorax IR-TRACC displacement device
- Test probe accelerometer
- Speed trap

5.2. Optional Instrumentation

- Dual axis tilt sensor installed in spine box

5.3. Pre-Test Preparation

- With the pendulum in its lowest resting position, draw a reference line along the bench support surface along the path of the pendulum; using a line laser device[28] (set for vertical) positioned on a tripod (Figure 98) will aid in this process.
- Align the laser vertically along the back of the probe, along the top of the centerline of the probe (Figure 99), and along the probe path reference line on the support surface. Leave the laser in this position for the duration of the setup.

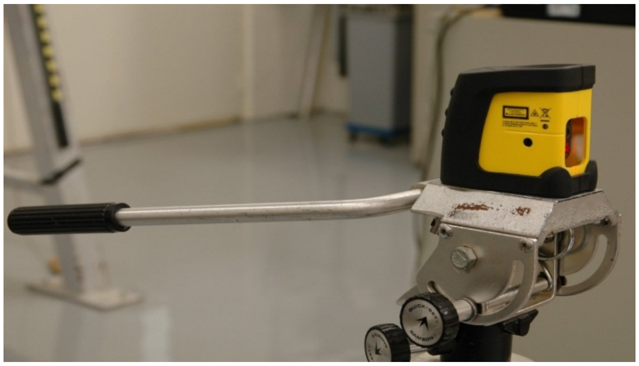


Figure 100. Laser line device set on tripod

[28] For ease of setup, a laser line device is utilized in this procedure. However, any method which achieves the same result is acceptable if such a device is unavailable.

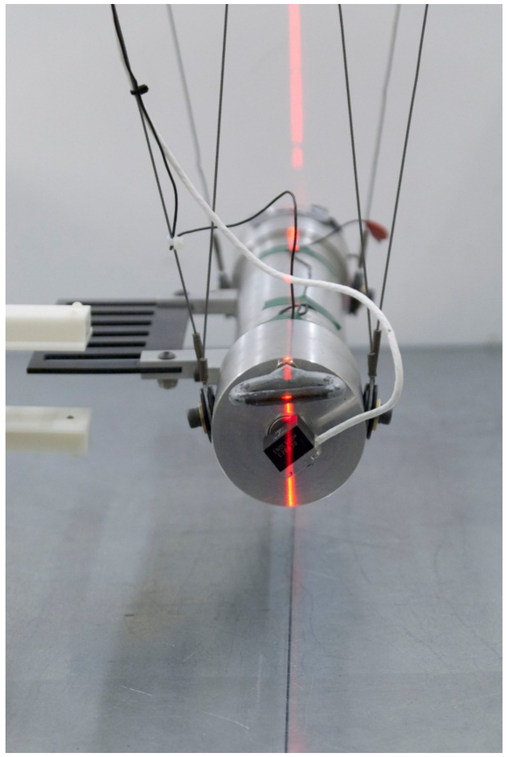


Figure 101. Align laser with probe centerline and pendulum path reference line on support surface

- Unfasten the upper portion of the suit jacket and electrically ground the dummy using a cable between a metal component of the dummy and the ground such as that shown in Figure 100.

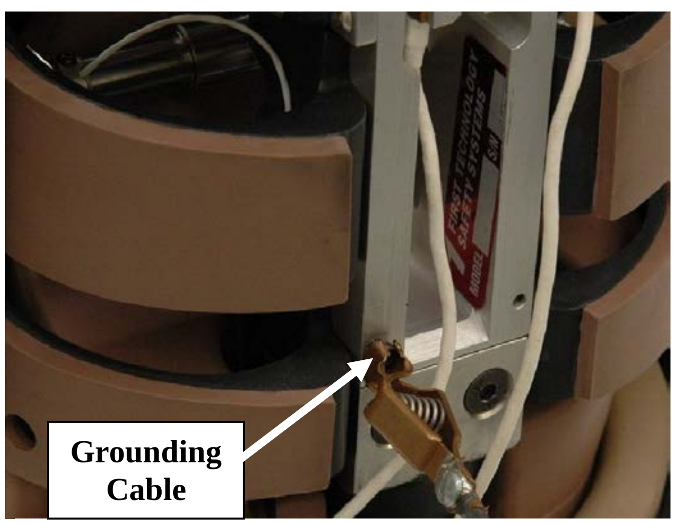


Figure 102. Grounding the dummy

- The dummy wears only the jacket for this procedure. No additional clothing or shoes are placed on the dummy.
- Place the qualification bench[29] (Figure 101) in the probe's impact area so that the dummy can be impacted in the thorax.
- Seat the dummy on a sheet of 387 x 521 mm PTFE (Teflon®) (2-mm thick) on the bench. The edge of the sheet must be along the impact side of the bench's seat pan.
- Place a sheet of 514 x 514 mm PTFE (Teflon®) (2-mm thick) between the seatback and the dummy's posterior thorax; the edge of the sheet must be along the impact side of the bench's seatback.
- The probe impact surface has a 70.0 ± 0.25 mm diameter face, and a mass of 3.81 ± 0.02 kg.
- The probe longitudinal axis should be positioned level (0 ± 1º).

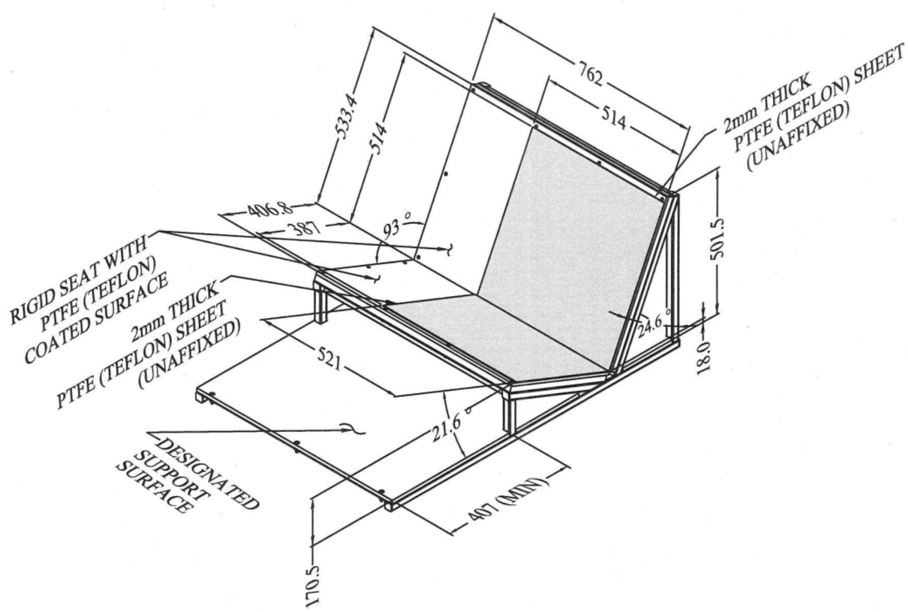


Figure 103. Qualification bench seat specifications for Q3s qualification tests

[29] This is the same bench specified for WorldSID and SID-IIsD qualification procedures.

- Remove the arm on the impact side, reinstall the jacket, and tape the sleeve of the suit to the dummy, assuring that it will clear the cables from the impact probe (Figure 102). The non-impact arm is positioned with the upper arm and lower arm perpendicular as shown in Figure 102.

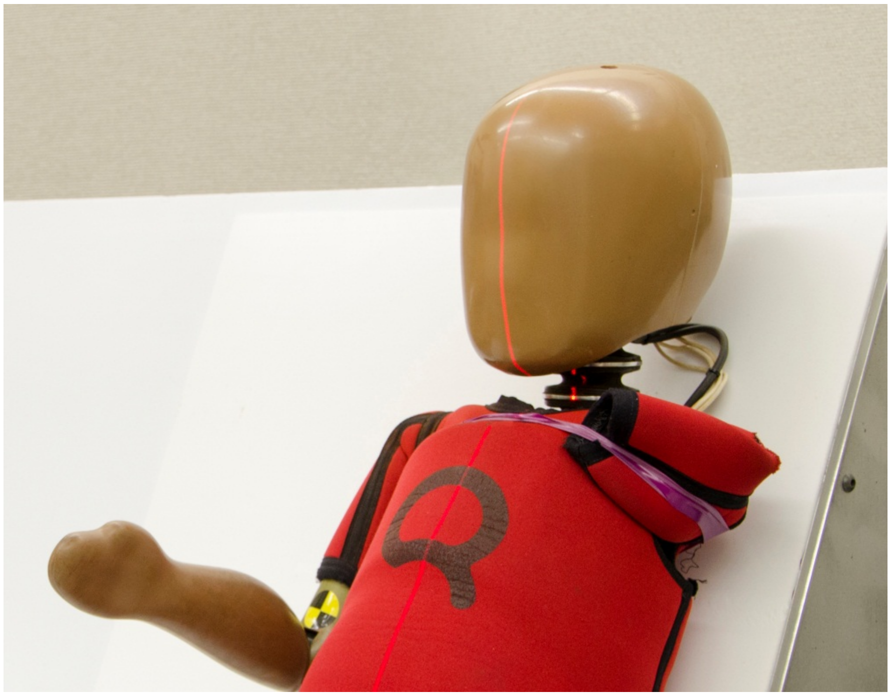


Figure 104. Remove the arm and tape the sleeve on the impact side

- To prepare to install the Q3s positioning tool[30] (Figure 103) between the dummy's knees, push the femurs and tibias downward so that the legs make full contact with the test surface.

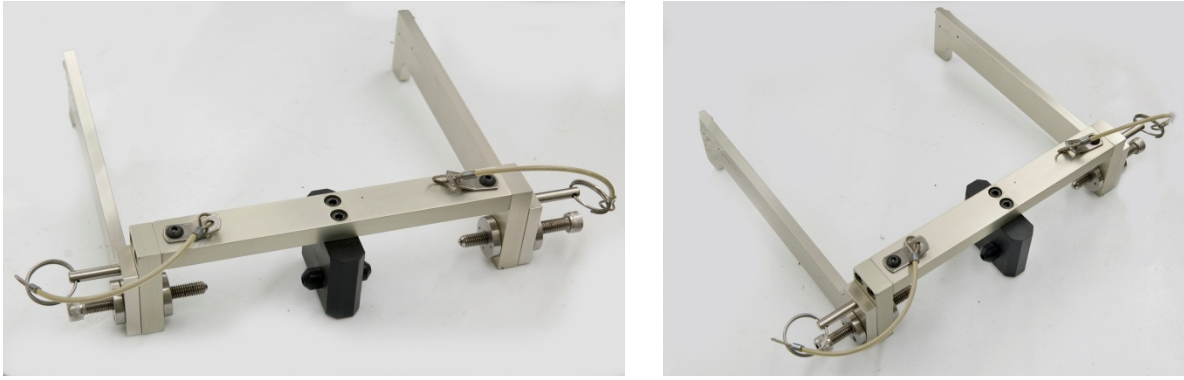


Figure 105. Q3s positioning device for Q3s

[30] "*Q3s Positioning Tool"*, First Technology Safety Systems, Drawing # 020-9000, June 22, 2010.

- Ensure that the instrumentation umbilical exits the dummy from the non-impact side of the pelvis. In addition, fastening the hook and loop closure which connects the thoracic part of the jacket to the pelvis portion with a small overlap allows for easier adjustment of the jacket (Figure 104).

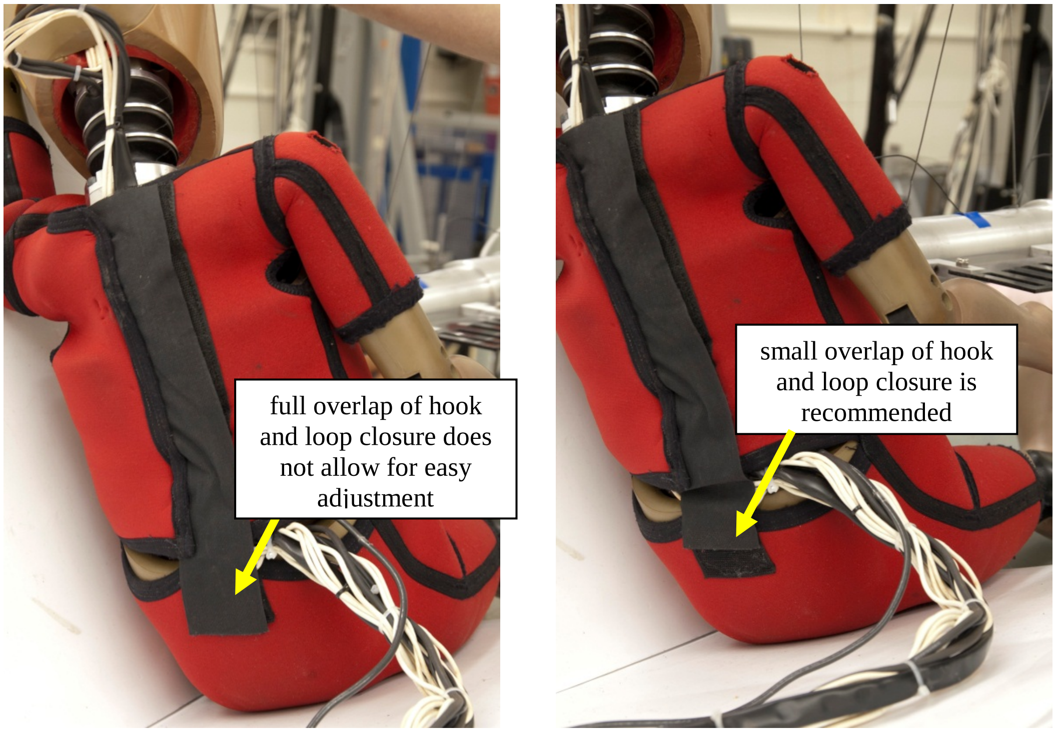


Figure 106. Proper umbilical placement and jacket closure (shown prior to arm removal)

- Ensure that the jacket is not tucked into the pelvis/femur interface during the setup procedures (Figure 105). If it is, pull the suit upwards near the shoulders.

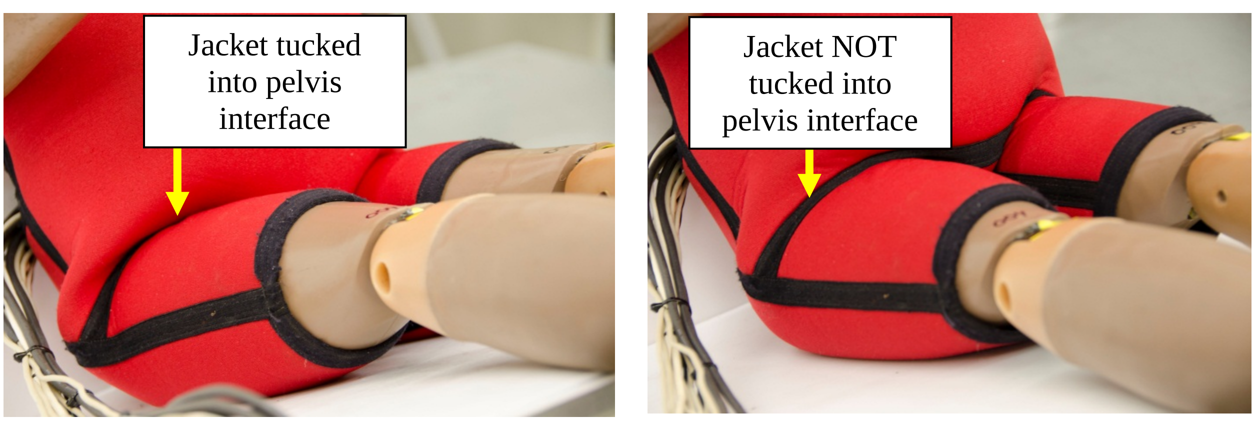


Figure 107. Ensure that jacket is not tucked into pelvis/femur interface

- For this procedure, the pins on either side of Q3s positioning device should both be installed (Figure 106).

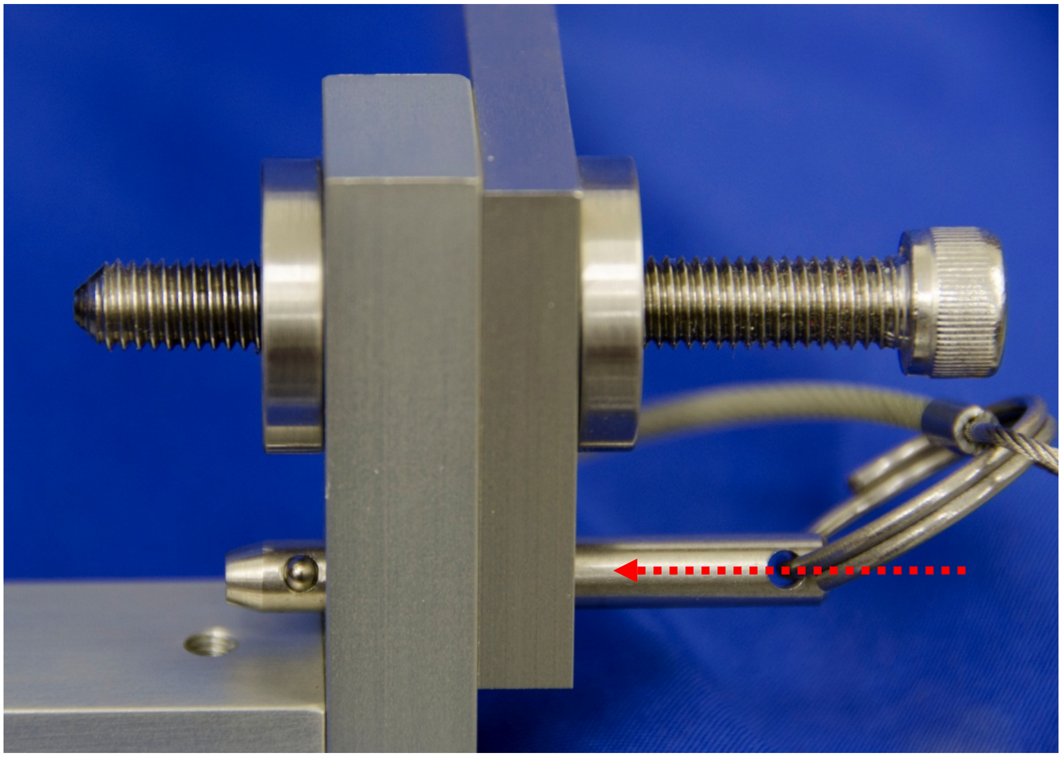


Figure 108. Insert pins into Q3s positioning device

- Be sure the bolts on the positioning tool are correctly seated into the knee (Figure 107).

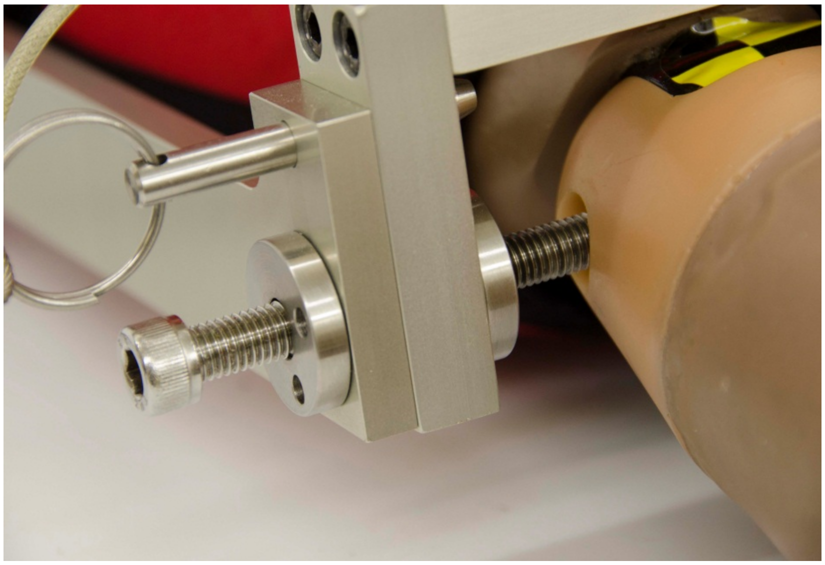


Figure 109. Position bolts into the knee

- Pull the feet apart while hand-tightening either left or right bolt (Figure 108) until the inner side of the knee *just touches* the center spacer of the positioning tool (Figure 109).

Figure 110. Pull feet apart while tightening bolt on positioning tool

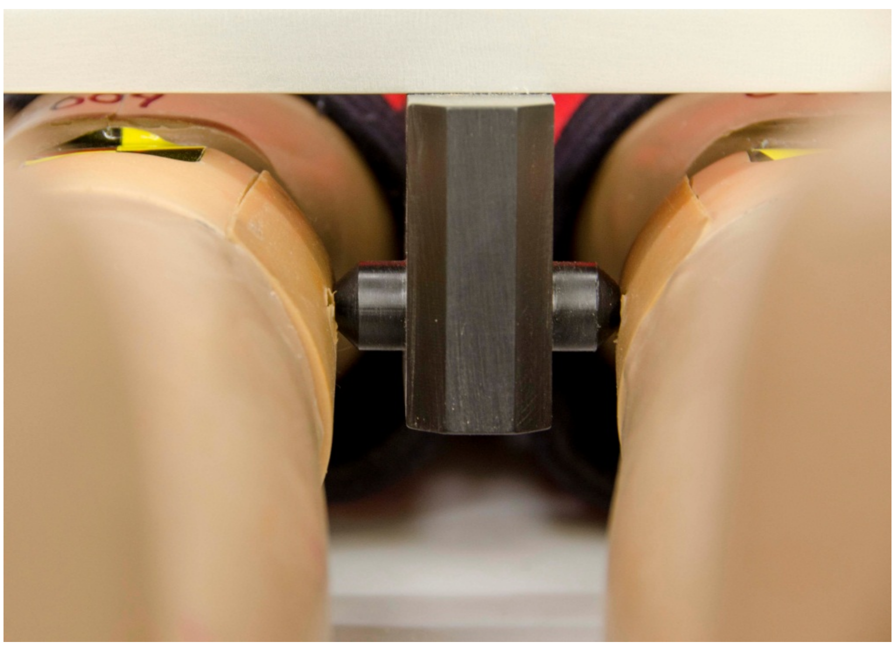


Figure 111. Knees just touching the inner spacing bar on the positioning device

- Push the dummy’s chest toward the seatback, so that the ribs make full contact with the seatback. If the optional tilt sensor is installed, the sensor should indicate 24.6 ± 1º.
- Push the feet towards the seatback to position the pelvis.
- Adjust the pelvis position so that both left and right extensions of the Q3s positioning device are equidistant from the seatback (Figure 110). This “squares” the dummy with the seat.

Figure 112. Squaring the dummy to the seat using the Q3s positioning tool

- Carefully pull down the jacket at the hole under the arm. This will allow access to the proper impact area, the center of the IRTRACC bolts. Adjust the bench position (roughly) so that the probe contacts the thorax near the impact point. When the pendulum probe is at its lowest position during travel, it should be just touching the thorax. Using the lateral laser device will aid in the process.

- Pull back the probe and insert a small pointer into the center of the probe (Figure 111). This will allow access to the proper area of impact (the portion of the thorax corresponding to an impact between the IRTRACC bolts). Align the pointer with the center point between the IRTRACC bolts (Figure 112). The lateral laser will also aid in this process. Remove the pointer from the probe.

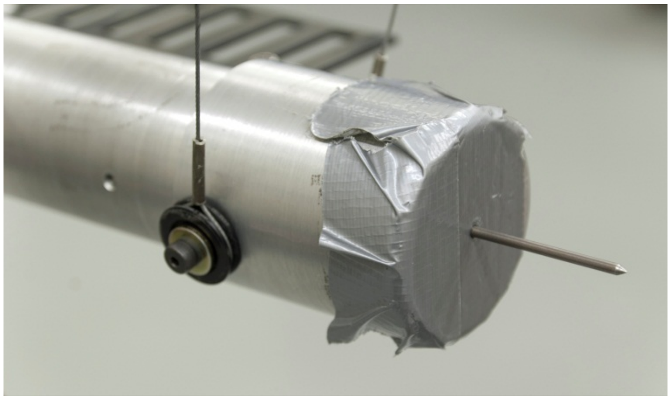


Figure 113. Pointer inserted into center of probe

Figure 114. Align pointer between IRTRACC bolts

- Square the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 113). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the thorax positioning at the probe.

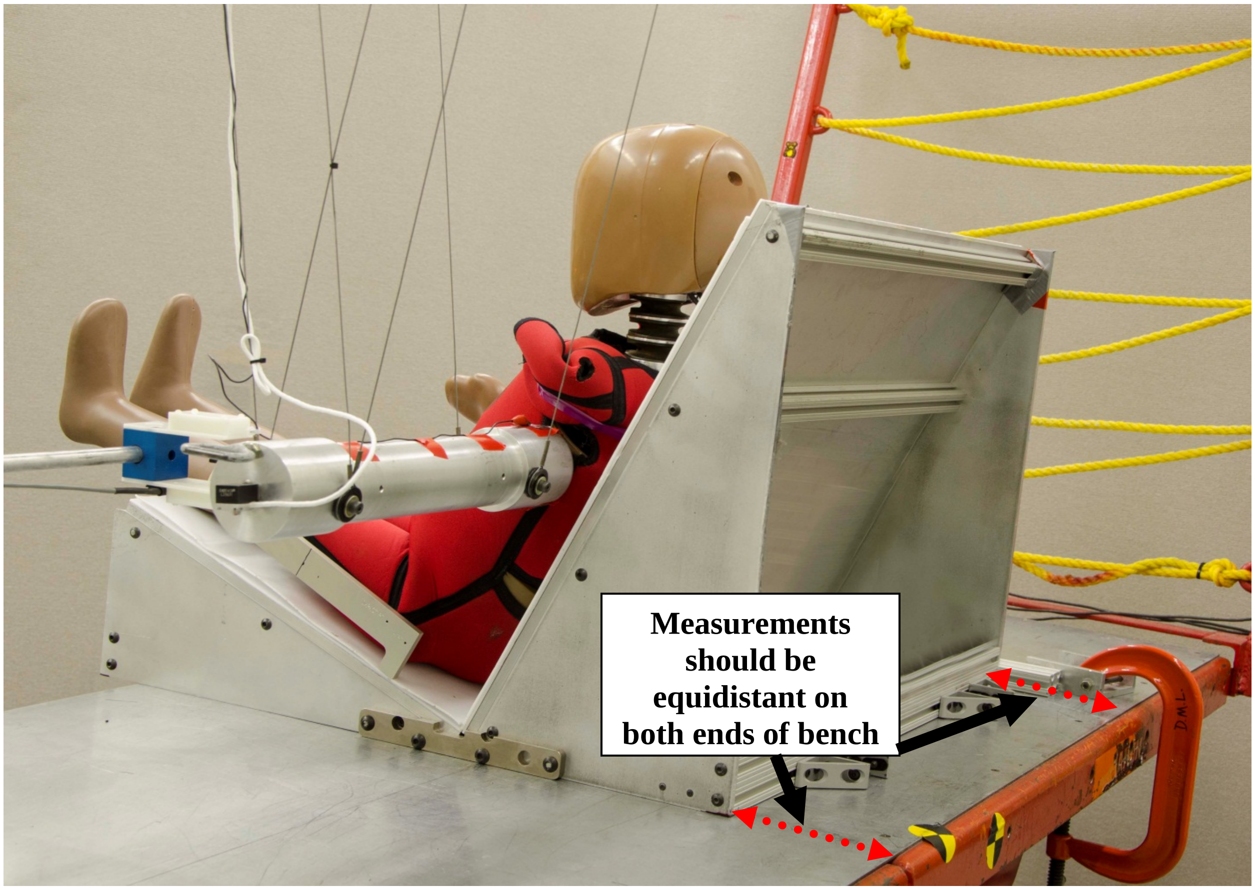


Figure 115. Checking that the bench is square

- To ensure that the dummy is seated upright (not leaning laterally), using a second laser device positioned in front of the dummy, align the laser between the feet and along the dummy's midsagittal plane (Figure 114). Align the laser between the feet and long the centerline of the Q3s positioning tool. Placing a measuring tape between the feet to ensure the dummy is upright may be useful. As an alternative, if the optional tilt sensor device is installed in the spinebox, ensure that the lateral positioning of the dummy is 0 ± 1º. Adjust the dummy as necessary to achieve these results.

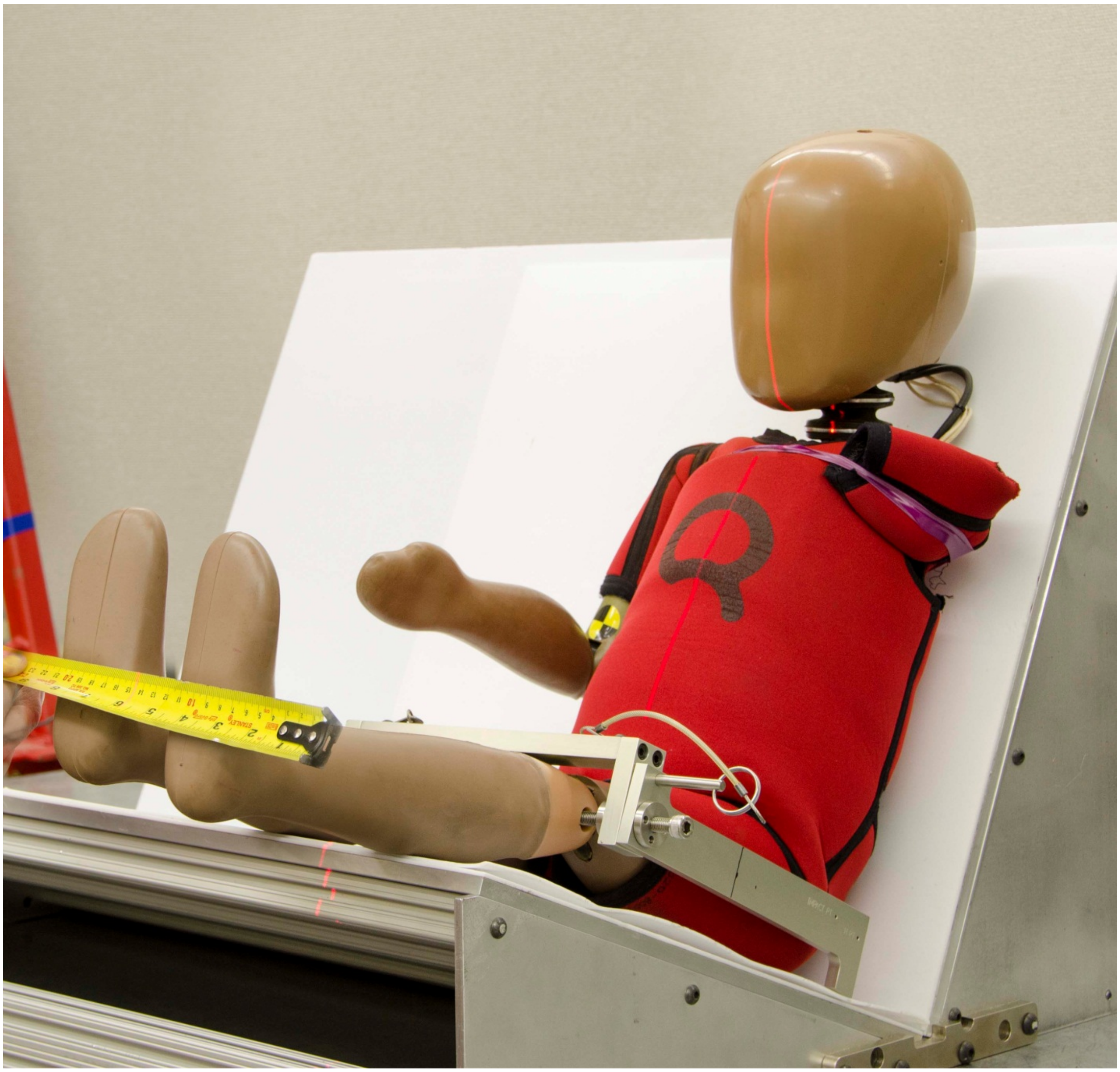


Figure 116. Adjusting the dummy laterally

- Secure the bench to the support surface using a clamp or any suitable method.
- Remove the Q3s positioning device.
- Figure 115 shows the final setup for the dummy.

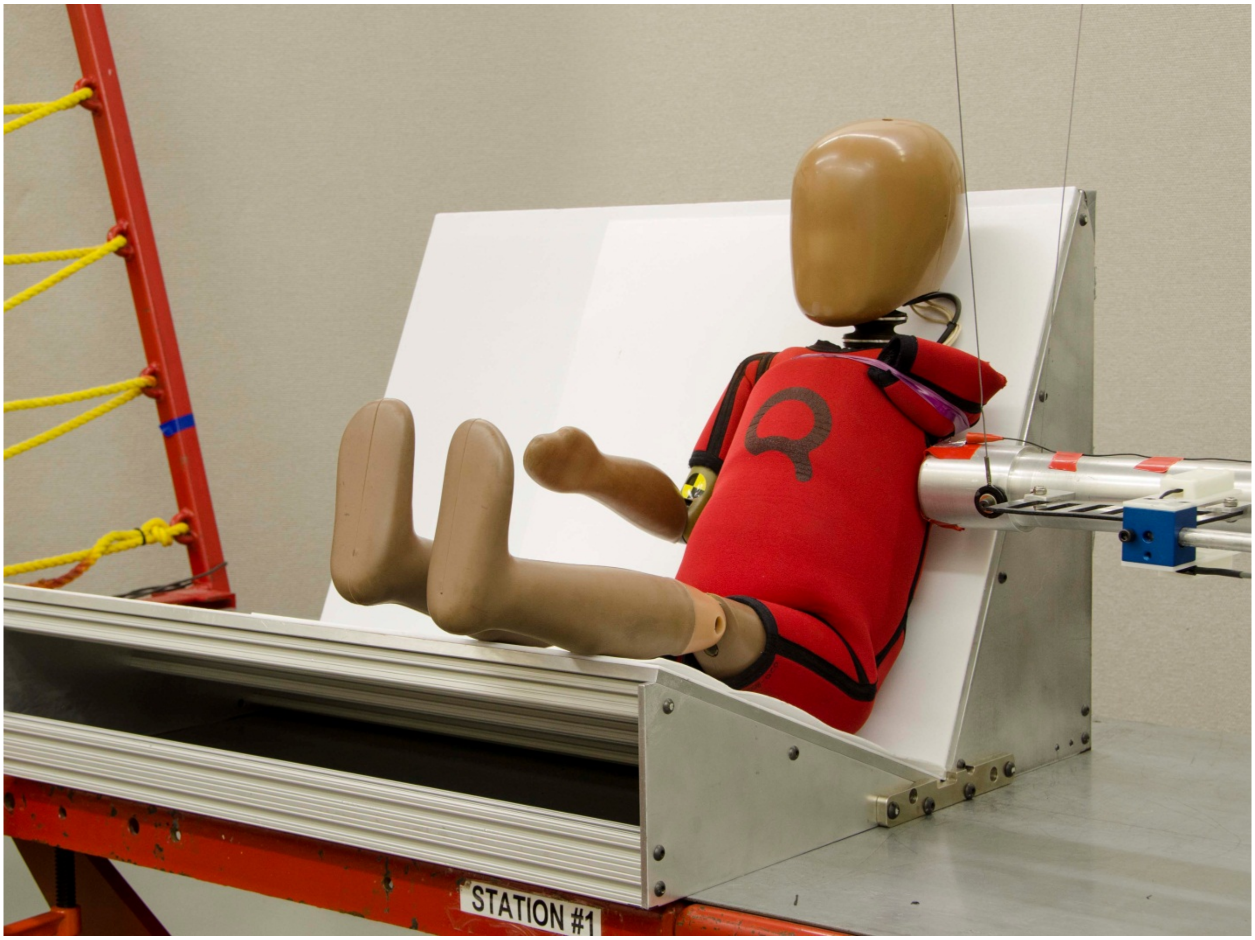


Figure 117. Final setup for thorax without arm qualification test

5.4. **Test Procedure**

- The test probe should have a mass of 3.81 ± 0.02 kg [31] with a 70.0 ± 0.25 mm face diameter, and a 6.4 - 12.7 mm radius.
- Mount an accelerometer on the test probe with its sensitive axis in line with the longitudinal centerline of the test probe.
- Release the test probe within the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% specifications so that it achieves a velocity between 3.2 – 3.4 m/s at the instant of contact with the dummy.
- At the instant of contact, the probe should be horizontal (± 1º), and the centerline of the probe should be within 2 mm of the centerline of the arm reference line corresponding to the center of the IRTRACC bolts.
- The data acquisition system should conform to SAE Recommended Practice J211 (July 2007).
- The probe acceleration is collected and filtered using a Channel Class 180 phaseless filter.
- The thorax displacement (IRTRACC) is collected and filtered[32] using a Channel Class 180 phaseless filter.
- Time zero is defined as the time of contact between the impact probe and the thorax. All channels should be at a zero level at this point.
- Calculate probe force using the filtered probe acceleration[33]:
    - $F_{probe} = (m_{probe})x(a_{probe})$
- The peak lateral thorax displacement and peak probe force shall lie within the proper specifications:
    - Peak lateral thorax displacement: 24.5 – 30.5 mm
    - Peak probe force: 610 – 754 N
- Wait at least 30 minutes between consecutive thorax impact tests on the same side of the thorax.

[31] Mass includes probe mass and all rigidly attached hardware, plus 1/3 of supporting cable weight.
[32] Filtering should be performed only after the IRTRACC data has been calculated into displacement.
[33] Mass should be measured in kg and acceleration should be measured in m/s^2.

6. Q3S PELVIS QUALIFICATION TESTS

6.1. Required Instrumentation

- Test probe accelerometer
- Speed trap

6.2. Optional Instrumentation

- Dual axis tilt sensor installed in spine box

6.3. Pre-Test Preparation

- With the pendulum in its lowest resting position, draw a reference line along the bench support surface along the path of the pendulum; using a line laser device[34] (set for vertical) positioned on a tripod (Figure 116) will aid in this process.
- Align the laser vertically along the back of the probe, along the top of the centerline of the probe (Figure 117), and along the probe path reference line on the support surface. Leave the laser in this position for the duration of the setup.

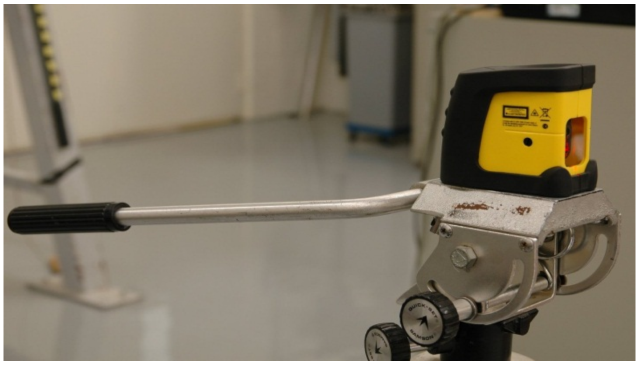


Figure 118. Laser line device set on tripod

[34] For ease of setup, a laser line device is utilized in this procedure. However, any method which achieves the same result is acceptable if such a device is unavailable.

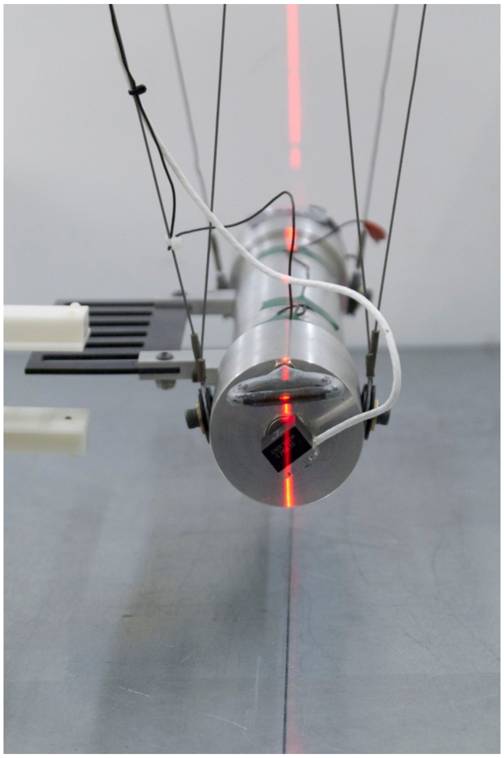


Figure 119. Align laser with probe centerline and pendulum path reference line on support surface

- Unfasten the upper portion of the suit jacket and electrically ground the dummy using a cable between a metal component of the dummy and the ground such as that shown in Figure 118.

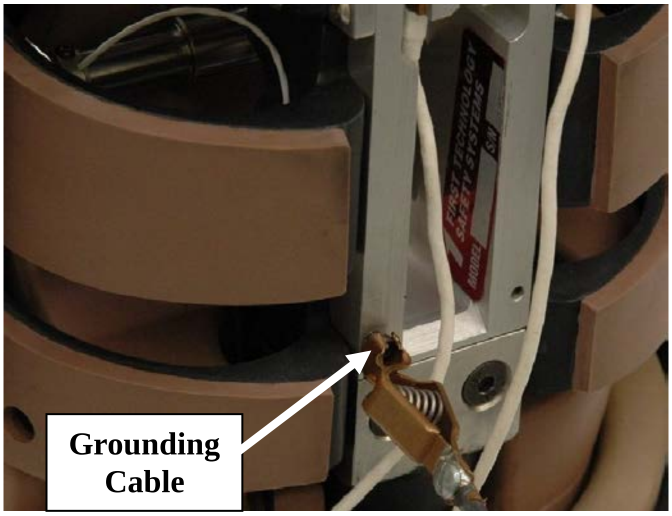


Figure 120. Grounding the dummy

- Reinstall the jacket.
- The dummy wears only the jacket for this procedure. No additional clothing or shoes are placed on the dummy.
- Place the qualification bench[35] (Figure 119) in the probe's impact area so that the dummy can be impacted in the pelvis.
- Seat the dummy on a sheet of 387 x 521 mm PTFE (Teflon®) (2-mm thick) on the bench. The edge of the sheet must be along the impact side of the bench's seat pan.
- Place a sheet of 514 x 514 mm PTFE (Teflon®) (2-mm thick) between the seatback and the dummy's posterior thorax; the edge of the sheet must be along the impact side of the bench's seatback.
- The probe impact surface has a 70.0 ± 0.25 mm diameter face, and a mass of 3.81 ± 0.02 kg.
- The probe longitudinal axis should be positioned level (0 ± 1º).

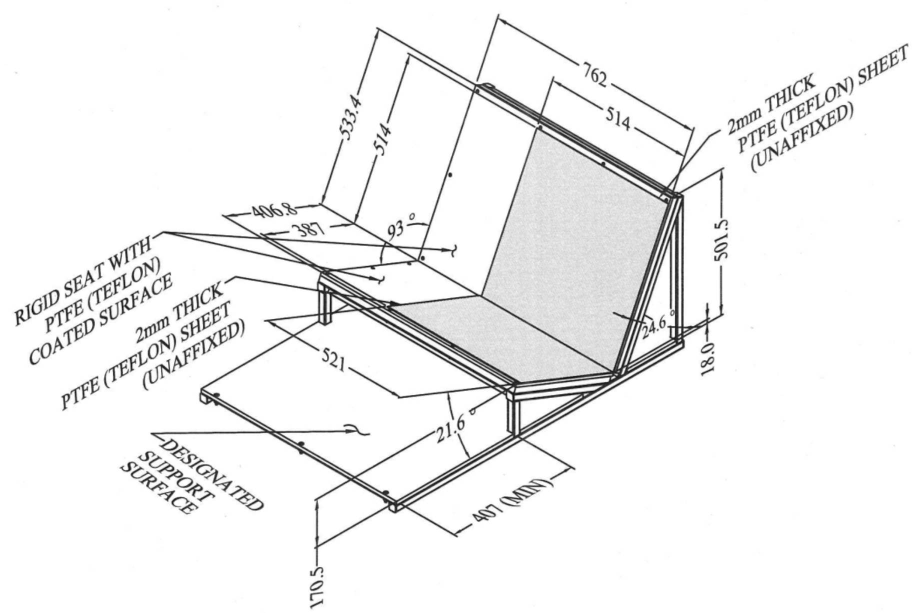


Figure 121. Qualification bench seat specifications for Q3s qualification tests

[35] This is the same bench specified for WorldSID and SID-IIsD qualification procedures.

- To prepare to install the Q3s positioning tool[36] (Figure 120) between the dummy's knees, push the femurs and tibias downward so that the legs make full contact with the test surface. When installed on the dummy, the (impact side) edge of the positioning tool should be flush or no more than 10mm inboard of the edge of the Teflon® sheet; the edge of the sheet must be along the impact side of the bench's seat pan.

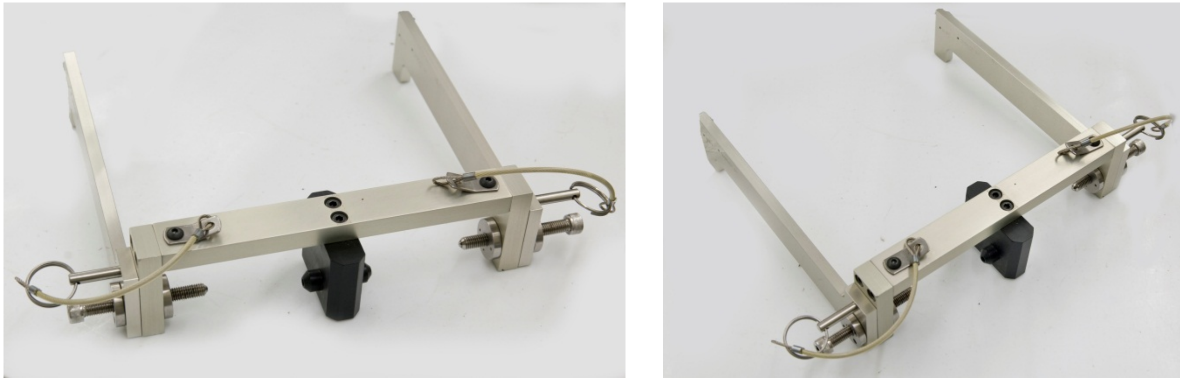


Figure 122. Q3s positioning device for Q3s

- Ensure that the instrumentation umbilical exits the dummy from the non-impact side of the pelvis. In addition, fastening the hook and loop closure which connects the thoracic part of the jacket to the pelvis portion with a small overlap allows for easier adjustment of the jacket (Figure 121).

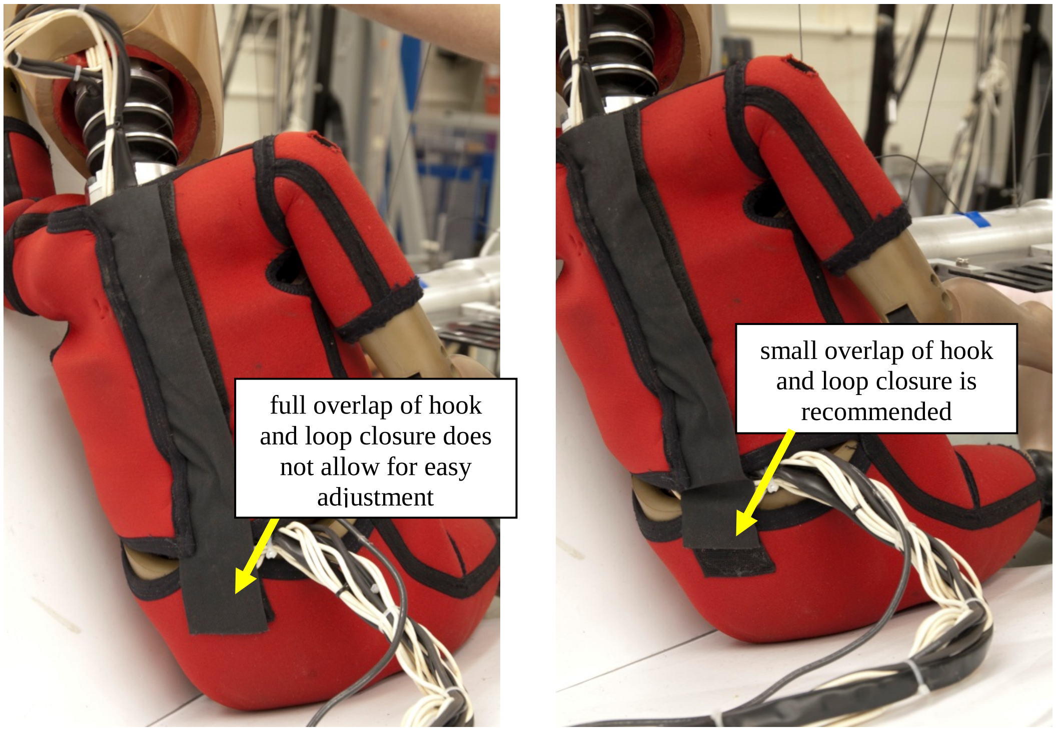


Figure 123. Proper umbilical placement and jacket closure

[36] "*Q3s Positioning Tool*", First Technology Safety Systems, Drawing # 020-9000, June 22, 2010.

- Ensure that the jacket is not tucked into the pelvis/femur interface during the setup procedures (Figure 122). If it is, pull the suit upwards near the shoulders.

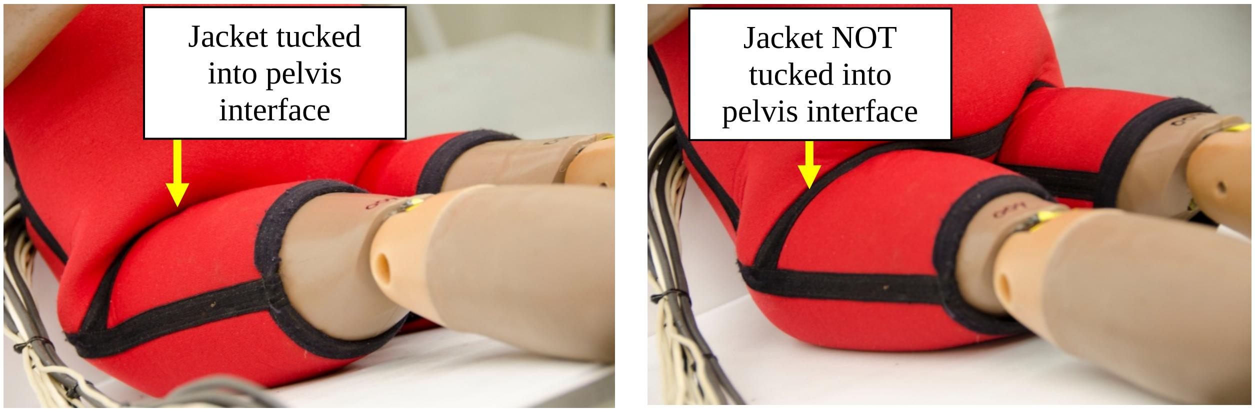


Figure 124. Ensure that jacket is not tucked into pelvis/femur interface

- For this procedure, *initially only*, the pins on either side of Q3s positioning device should both be installed (Figure 123).

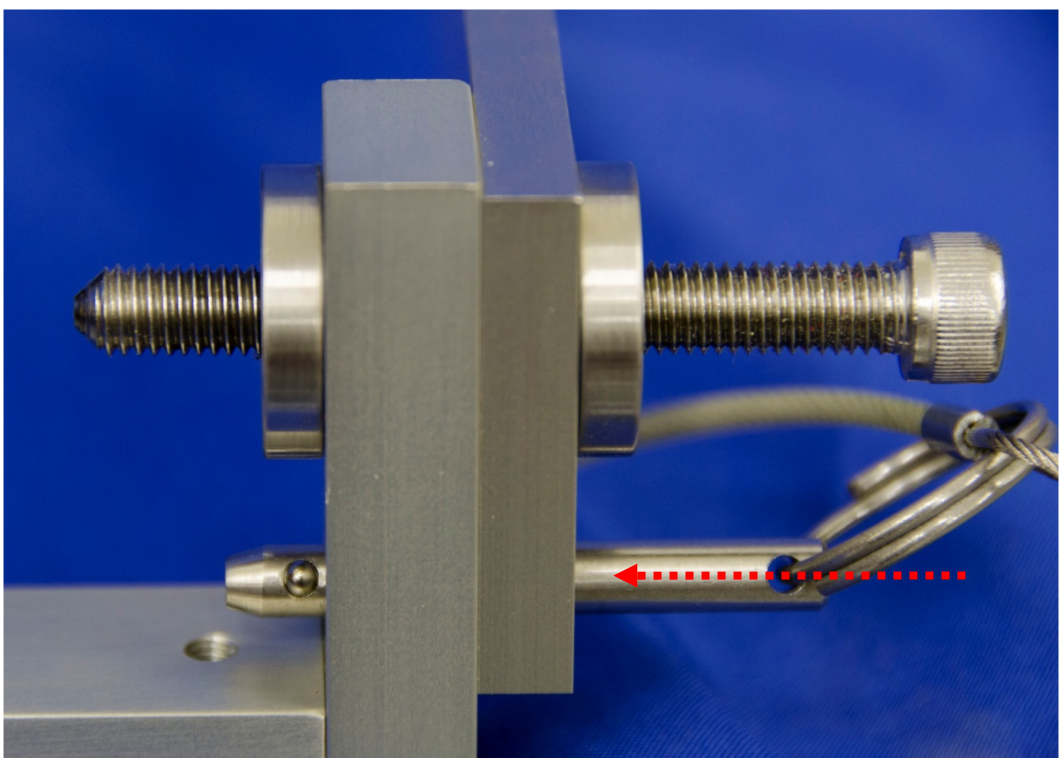


Figure 125. Insert pins into Q3s positioning device

- Be sure the bolts on the positioning tool are correctly seated into the knee (Figure 124).

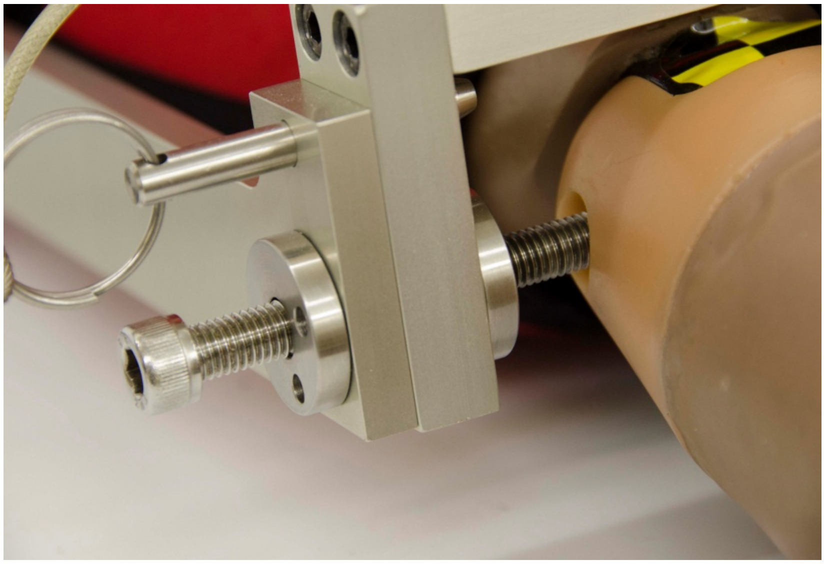


Figure 126. Position bolts into the knee

- Tape the impact side arm of the dummy to the head, assuring that it will clear the cables from the impact probe (Figure 125). The non-impact arm is positioned with the upper arm and lower arm perpendicular as shown in Figure 125.

Figure 127. Tape the impact side arm to the head for pelvis tests

- Pull the feet apart while hand-tightening either left or right bolt (Figure 126) until the inner side of the knee *just touches* the center spacer of the positioning tool (Figure 127).

Figure 128. Pull feet apart while tightening bolt on positioning tool

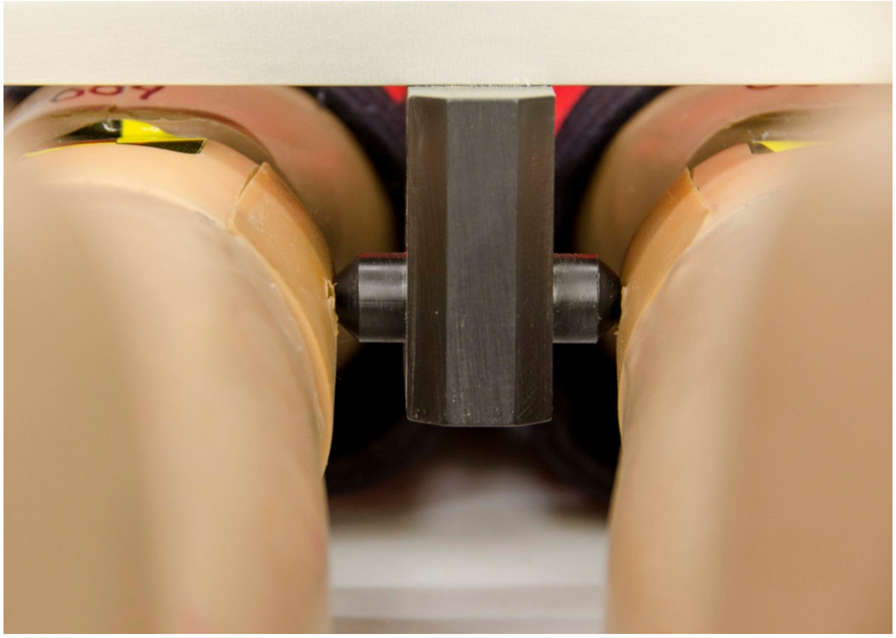


Figure 129. Knees just touching the inner spacing bar on the positioning device

- Push the dummy’s chest toward the seatback, so that the ribs make full contact with the seatback. If the optional tilt sensor is installed, the sensor should indicate 24.6 ± 1º.
- Push the feet towards the seatback to position the pelvis.
- Adjust the pelvis position so that both left and right extensions of the Q3s positioning device are equidistant from the seatback (Figure 128). This “squares” the dummy with the seat.

Figure 130. Squaring the dummy to the seat using the Q3s positioning tool

- Remove both pins on the Q3s positioning tool.
- Adjust the bench position (roughly) so that the probe contacts the pelvis near the impact point. When the pendulum probe is at its lowest position during travel, it should be just touching the pelvis. Since the pin is removed from the Q3s positioning device on the impact side, swing the extension bar upwards and forward out of the way to access an approximate impact site (Figure 129).
- Pull the probe back, swing the positioning arm towards the seat back, and re-check that the dummy is square in the seat (Figure 128).

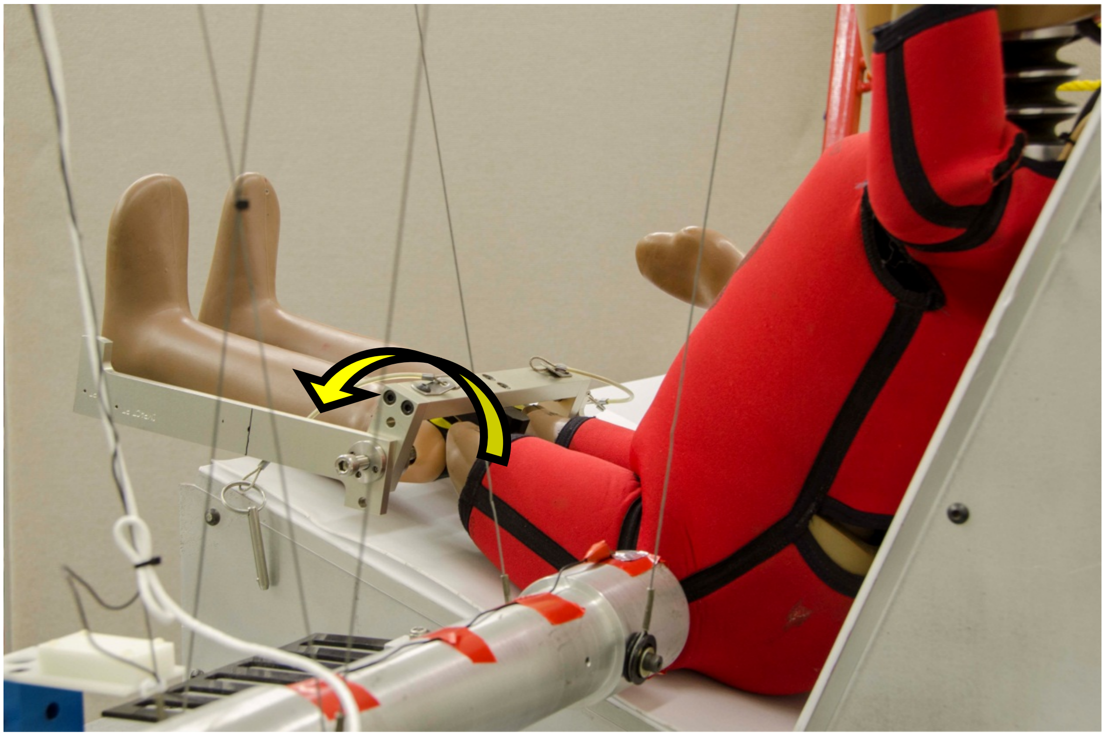


Figure 131. Setting approximate pelvis impact position

- Pull back the probe and insert a small pointer into the center of the probe (Figure 130).

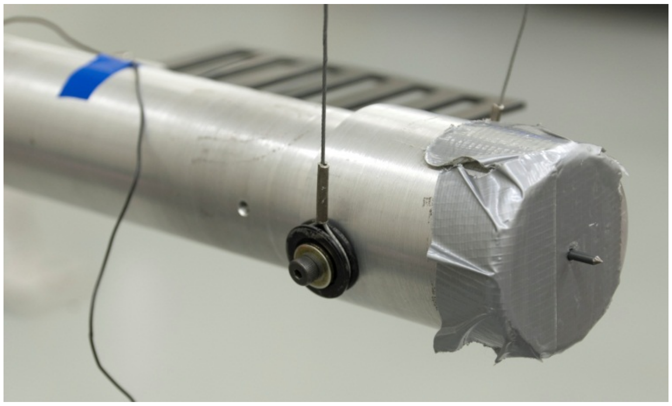


Figure 132. Pointer inserted into center of probe

- Align the pointer with the pelvis impact point hole on the Q3s positioning tool (Figure 131).

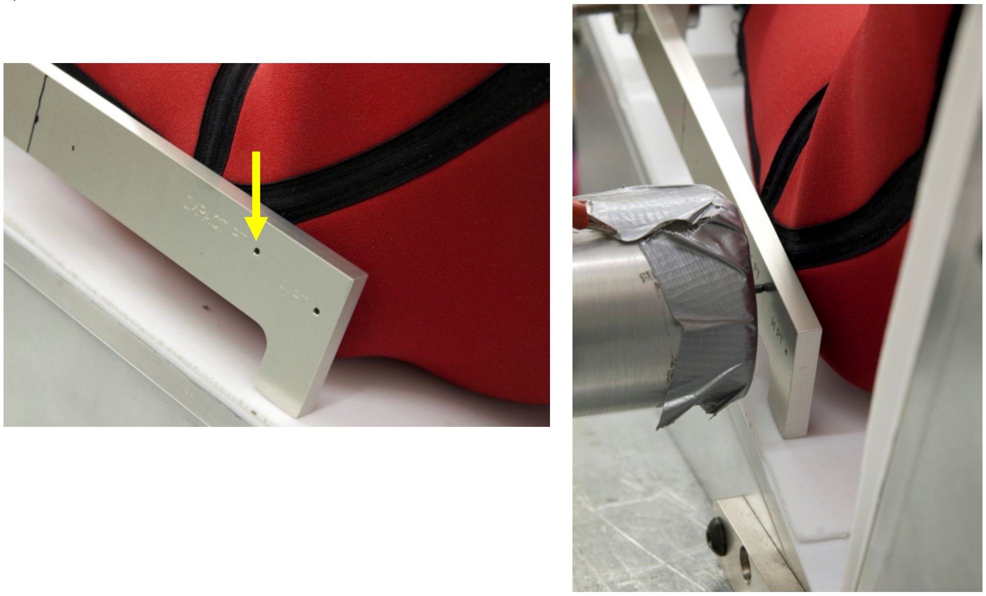


Figure 133. Positioning probe for pelvis impact using pointer

- Square the bench by measuring the distance of a reference edge along the back of the bench which is parallel to the line of impact, such as the edge of the table (Figure 132). Perform this measurement at both ends of the bench. Slightly adjust bench until it is parallel to the line of impact so that both measurements are equidistant (± 1 mm) to the reference, taking care to maintain the pelvis positioning at the probe.

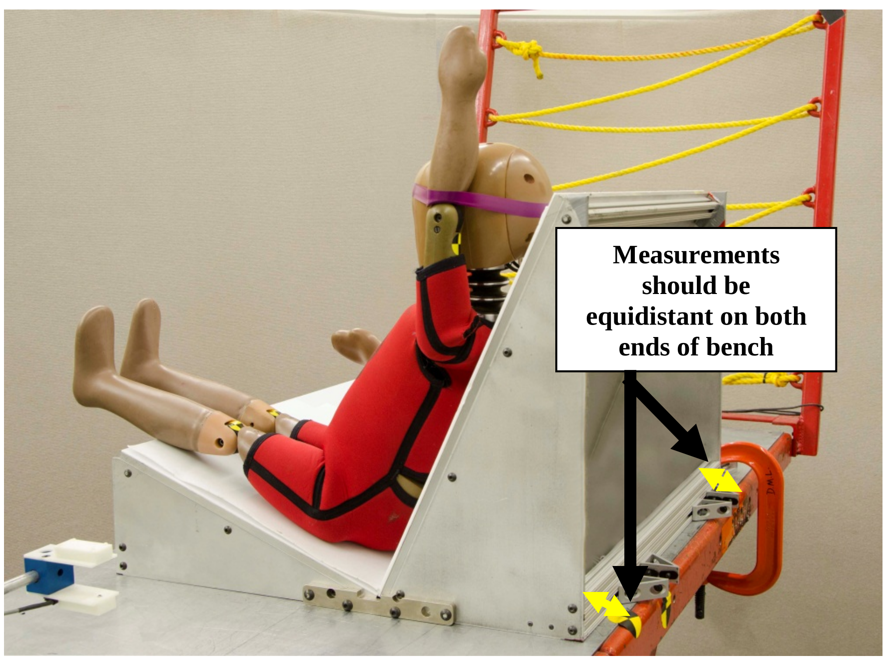


Figure 134. Checking that the bench is square

- Remove the pointer after the pelvis impact point is set.
- To ensure that the dummy is seated upright (not leaning laterally), using a second laser device positioned in front of the dummy, align the laser between the feet and along the dummy's midsagittal plane (Figure 133). Align the laser between the feet and long the centerline of the Q3s positioning tool. As an alternative, if the optional tilt sensor device is installed in the spinebox, ensure that the lateral positioning of the dummy is 0 ± 1º. Adjust the dummy as necessary to achieve these results.

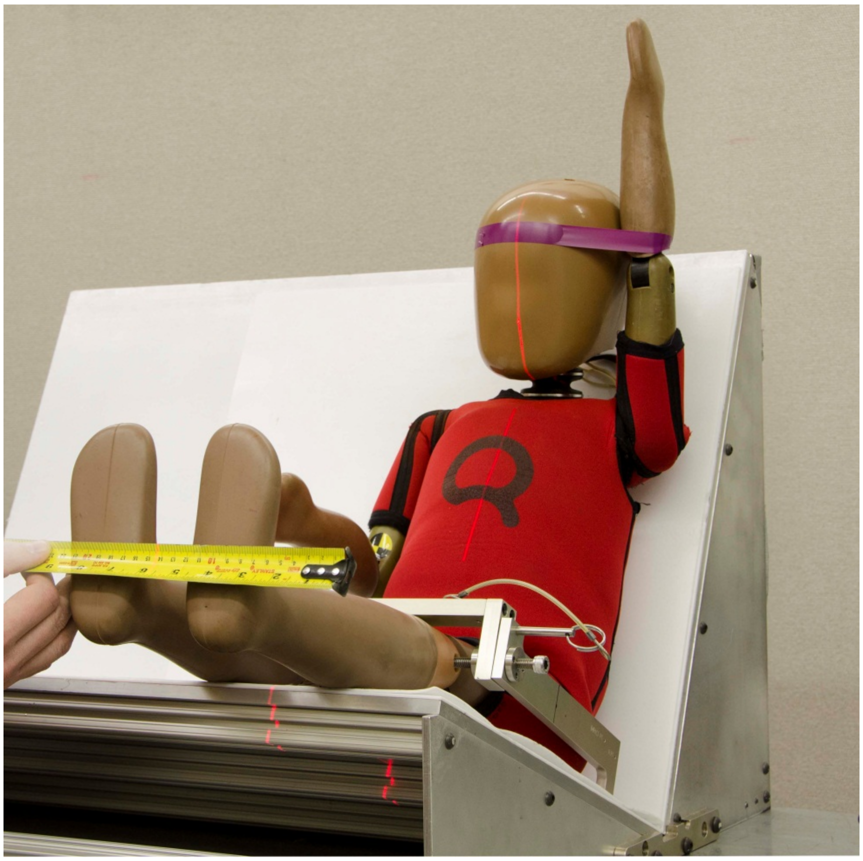


Figure 135. Adjusting the dummy laterally

- Secure the bench to the support surface using a clamp or any suitable method.
- Remove the Q3s positioning device.
- Figure 134 shows the final setup for the dummy.

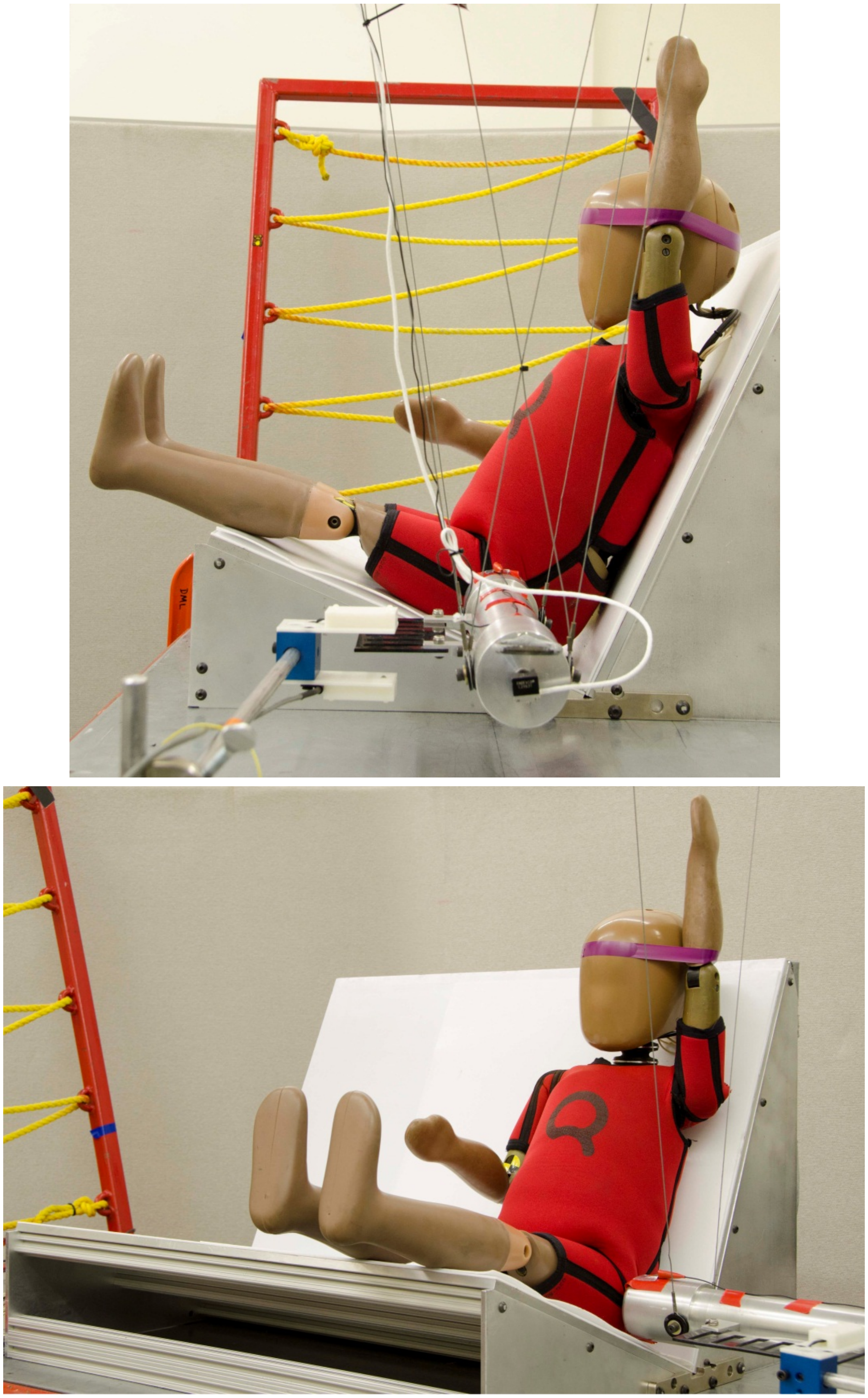


Figure 136. Final setup for Q3s pelvis Qualification test

6.4. **Test Procedure**

- The test probe should have a mass of 3.81 ± 0.02 kg [37] with a 70.0 ± 0.25 mm face diameter, and a 6.4 - 12.7 mm radius.
- Mount an accelerometer on the test probe with its sensitive axis in line with the longitudinal centerline of the test probe.
- Release the test probe within the 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% specifications so that it achieves a velocity between 3.9 – 4.1 m/s at the instant of contact with the dummy.
- At the instant of contact, the probe should be horizontal (± 1º), and the centerline of the probe should be within 2 mm of the center of the pelvis impact point.
- The data acquisition system should conform to SAE Recommended Practice J211 (July 2007).
- The probe acceleration is collected and filtered using a Channel Class 180 phaseless filter.
- Time zero is defined as the time of contact between the impact probe and the pelvis. All channels should be at a zero level at this point.
- Calculate probe force using the filtered probe acceleration[38]:
    - $F_{probe} = (m_{probe})x(a_{probe})$
- The peak probe force shall lie within the proper specifications:
    - Peak probe force: 1587 – 1901 N
- Wait at least 30 minutes between consecutive pelvic impact tests on the same side of the pelvis.

[37] Mass includes probe mass and all rigidly attached hardware, plus 1/3 of supporting cable weight.
[38] Mass should be measured in kg and acceleration should be measured in m/s^2.

7. Q3S LUMBAR SPINE QUALIFICATION PROCEDURES

7.1. Q3S LUMBAR SPINE FLEXION QUALIFICATION PROCEDURES

7.1.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis lumbar load cell
- Two angular rate sensors (ARS)

7.1.2. Pre-Test Preparation

- Soak the lumbar spine assembly in a controlled environment at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the lumbar spine for deformation, tears or breaks in the rubber. Replace the lumbar if deformation or damage is observed.
- Install the interface plate to the bottom of the pendulum using four (4) M6 x 15 SHCS (Figure 135 and Figure 136).
- Install accelerometer to the pendulum (Figure 136).

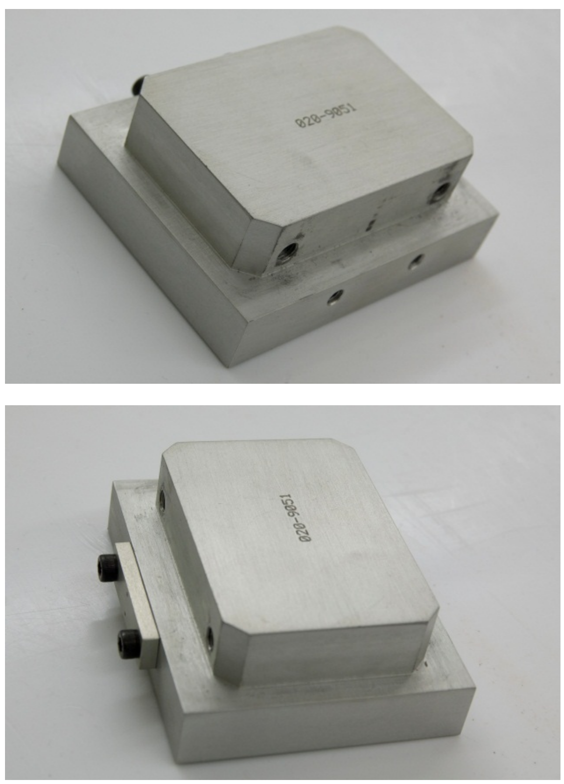


Figure 137. Interface plate for test pendulum

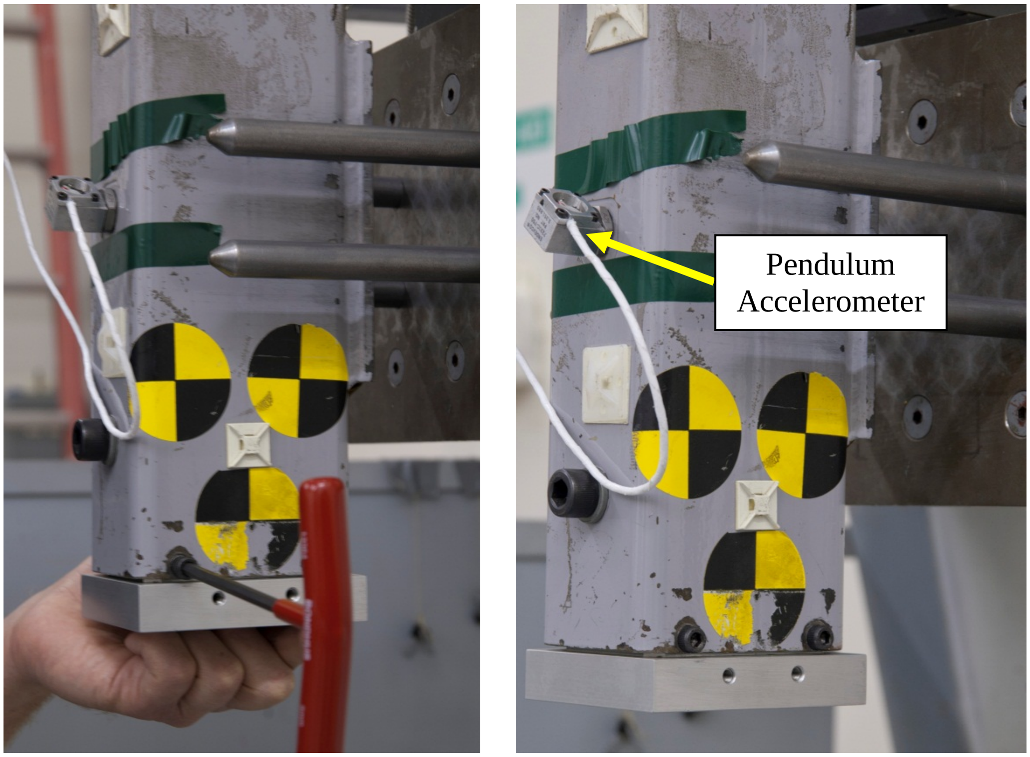


Figure 138. Install pendulum interface plate and pendulum accelerometer

- Install the Angular Rate Sensor (ARS)[39] to the pendulum interface plate using two M1.4 x 8 SHCS so that it measures rotational velocity about the Y′ axis (Figure 137 and Figure 146).

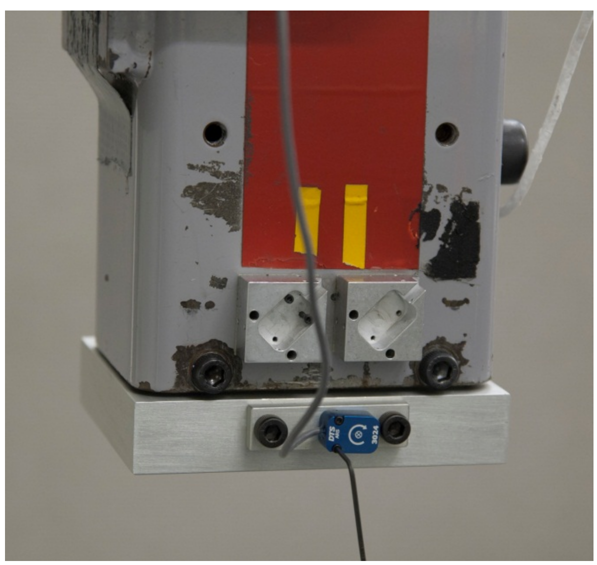
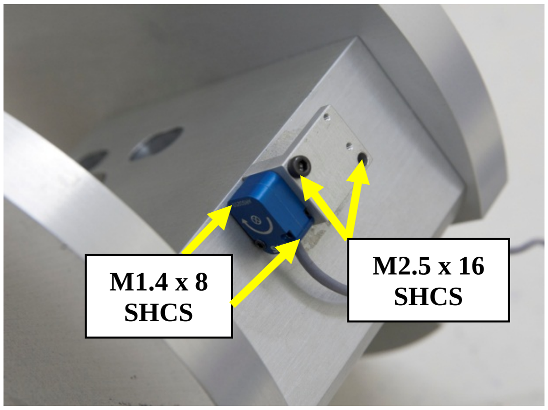


Figure 139. Install ARS to pendulum

[39] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Install the Angular Rate Sensor (ARS)[40] to its mount using two M1.4 x 8 SHCS so that it measures rotational velocity about the (headform) Y axis. Then install this assembly to the front of the headform (Figure 138 and Figure 139).



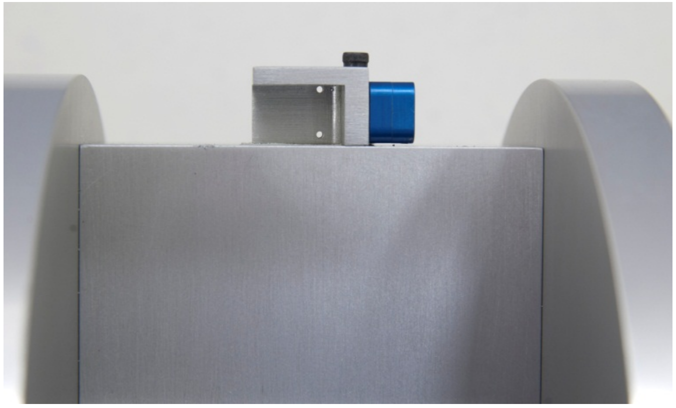


Figure 140. Install ARS to mount then to front of headform

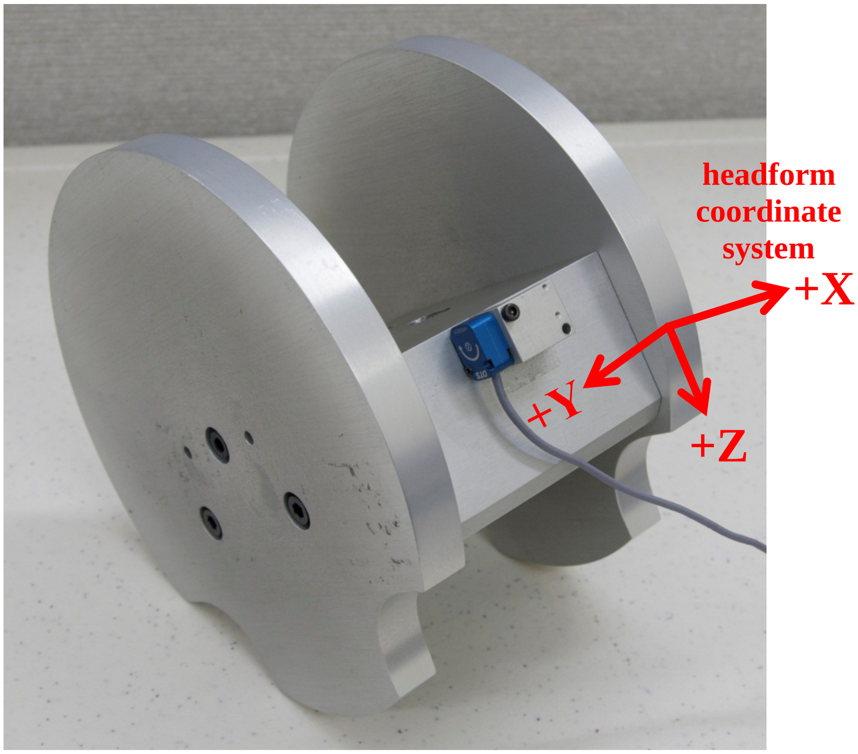


Figure 141. ARS installed to headform for lumbar flexion tests

[40] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Align and insert the alignment pin on the lumbar interface (Figure 140) to the back of the headform (Figure 141).

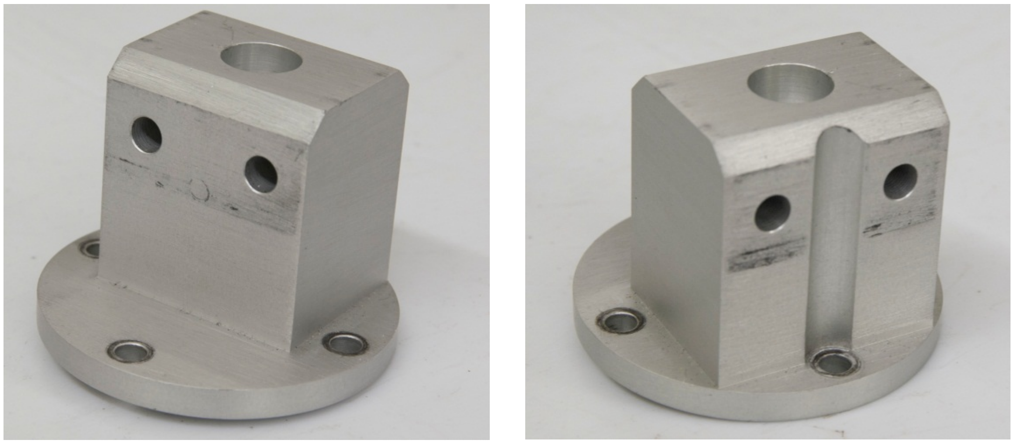


Figure 142. Lumbar interface

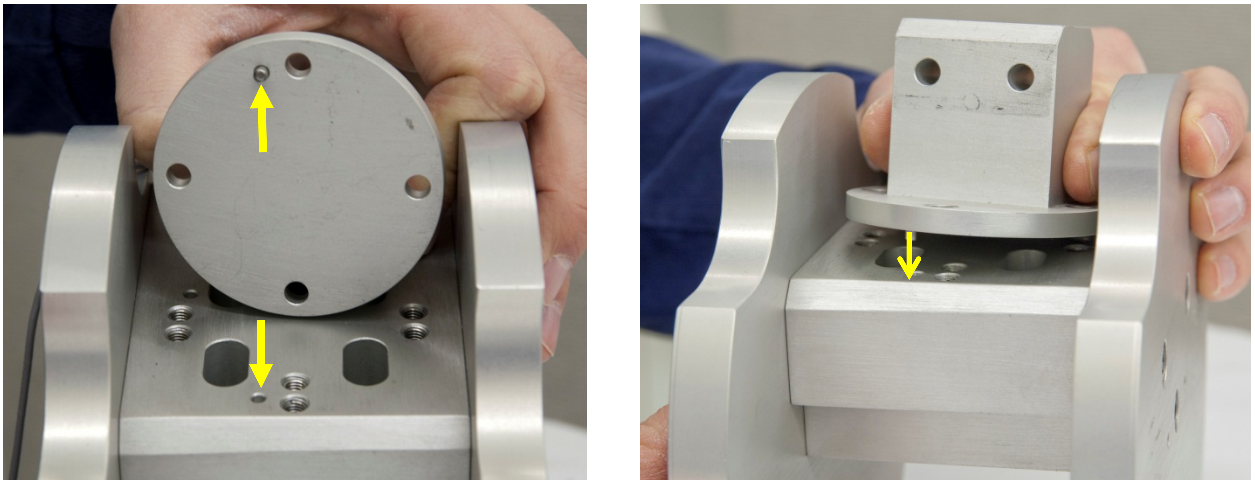


Figure 143. Aligning the lumbar interface to the headform

- Attach the lumbar interface to the headform using four M5 x 12 SHCS (Figure 142).

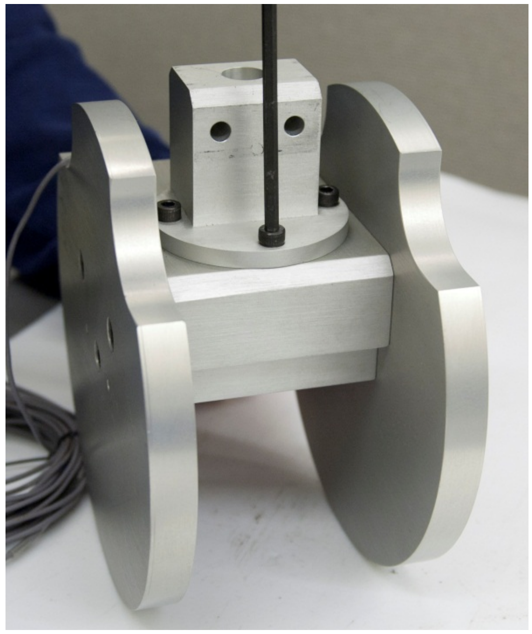


Figure 144. Install lumbar interface to headform

- Mount the lumbar load cell to the lumbar spine using four M5 x 12 SHCS (Figure 143). The load cell wiring should protrude from the back of the lumbar spine.[41]

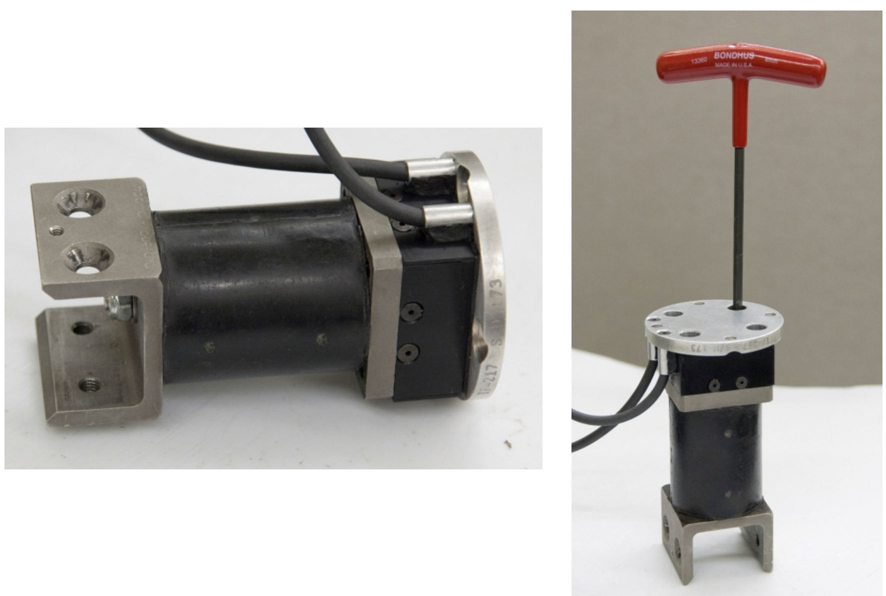


Figure 145. Installing lumbar load cell to lumbar spine

[41] The chamfered counter-bored holes indicate the back of the lumbar spine.

- Mount the lumbar load cell to the pendulum interface using four M5 x 12 FHCS (Figure 144). The back of the lumbar spine should be on the side opposite of the impact surface of the pendulum.

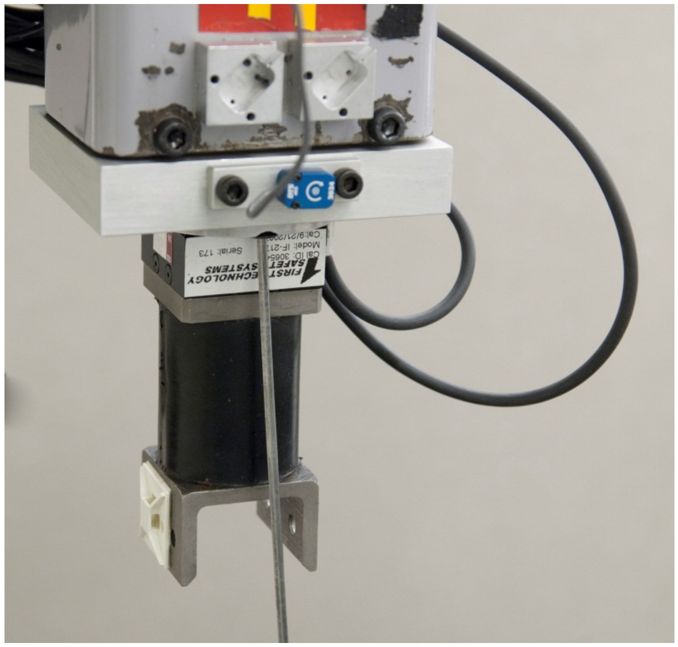


Figure 146. Mount lumbar load cell to pendulum

- Mount the headform to the lumbar spine using two lumbar spine mounting screws[42] (Figure 145). Be certain these screws are tight so that the headform does not slip in the mount.

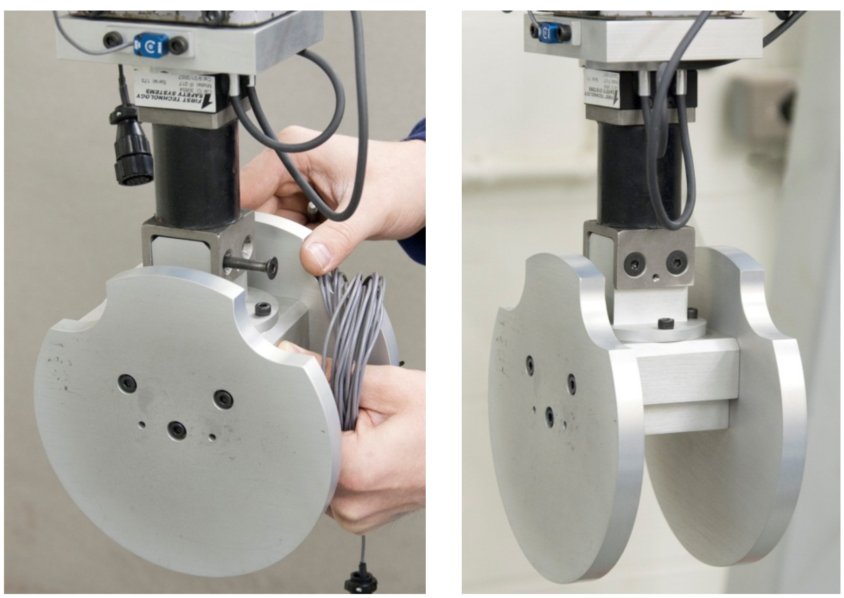


Figure 147. Installing headform to lumbar spine

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[42] These are specialty screws, Part 020-9902, drawing 020-9060.

- Shows the final setup for the Q3s lumbar spine flexion qualification tests (Figure 146).
- Install the proper size hexcell to meet the pulse requirements specified in Table 5.

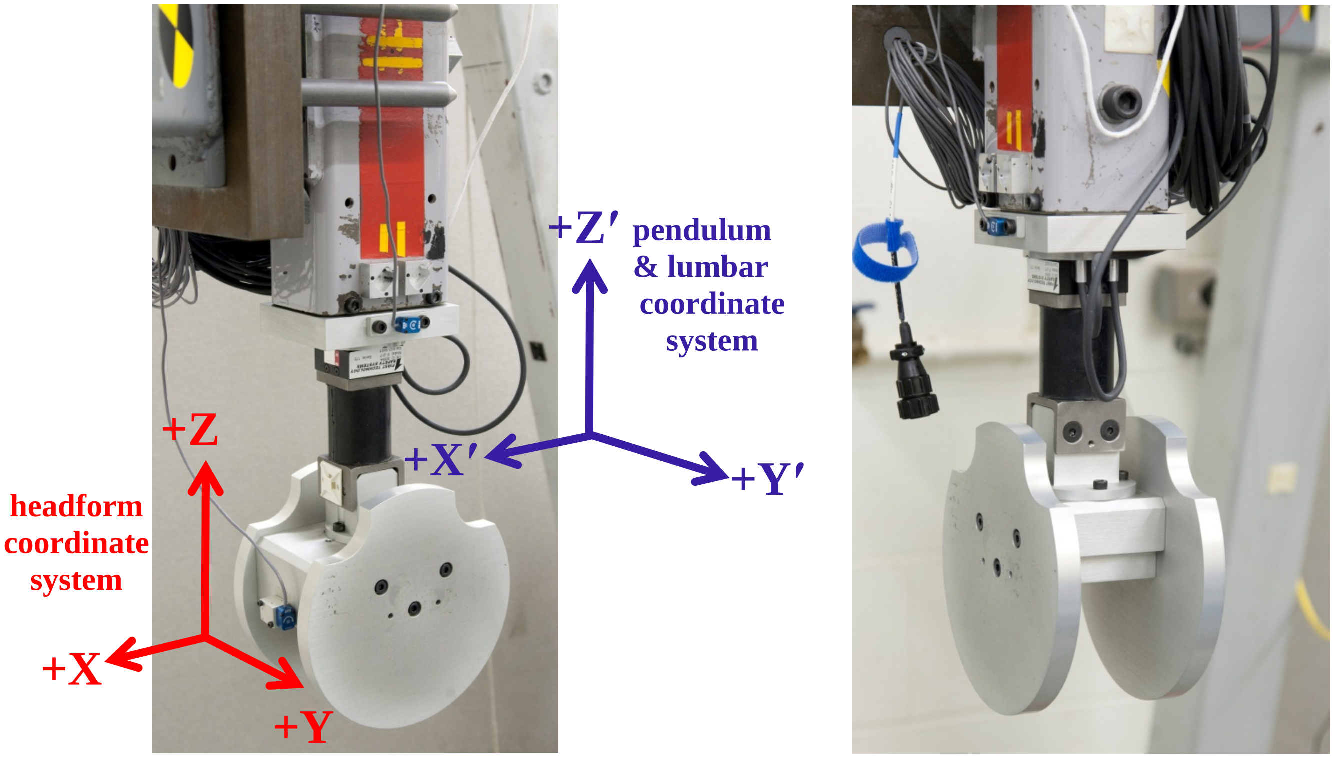

Figure 148. Final setup for the Q3s lumbar spine flexion qualification test

7.1.3. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb.
- All channels are at the zero level when the pendulum is vertical.
- Post-test offset removal of the data signals shall be performed only on the pendulum acceleration and moment signals.
- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 4.3 – 4.5 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 5.

Table 5. Q3s Lumbar Spine Flexion Pulse Parameters

Parameter		units	Spec. Limits lower	Spec. Limits upper
impact speed		m/s	4.3	4.5
pendulum pulse	@10 ms	m/s	1.3	1.7
pendulum pulse	@20 ms	m/s	2.7	3.7
pendulum pulse	@30 ms	m/s	4.1	4.9

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The ARS is filtered using a Channel Class 60 phaseless filter.
- The lumbar moment about the Y′-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- Determine the headform rotation using the following formula[43]:
  - Headform Rotation = $\int(\text{Headform Angular Rate})_y - (\text{Pendulum Angular Rate})_{y'}\, dt$
- The peak rotation, peak moment, and rotation decay time to zero shall lie within the proper specifications:
  - Peak headform rotation: 47.0 – 58.5°
  - Peak moment[44] (My′): 78.2 – 96.2 Nm
  - Headform rotation decay time to 0° from peak angle: 49 – 59 ms

[43] Perform this calculation *after* filtering the ARS sensors. Begin integration at time zero.
[44] Maximum moment measured during the time interval while the rotation is within the specified corridor.

7.2. Q3S LUMBAR SPINE LATERAL FLEXION QUALIFICATION PROCEDURES

7.2.1. Required Instrumentation

- Speed trap
- Pendulum accelerometer
- Six-axis lumbar load cell
- Two angular rate sensors (ARS)

7.2.2. Pre-Test Preparation

- Soak the lumbar spine assembly in a controlled environment at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70% for at least four hours prior to a test.
- Inspect the lumbar spine for deformation, tears or breaks in the rubber. Replace the lumbar if deformation or damage is observed.
- Install the interface plate to the bottom of the pendulum using four (4) M6 x 15 SHCS (Figure 147 and Figure 148)
- Install accelerometer to the pendulum (Figure 148).

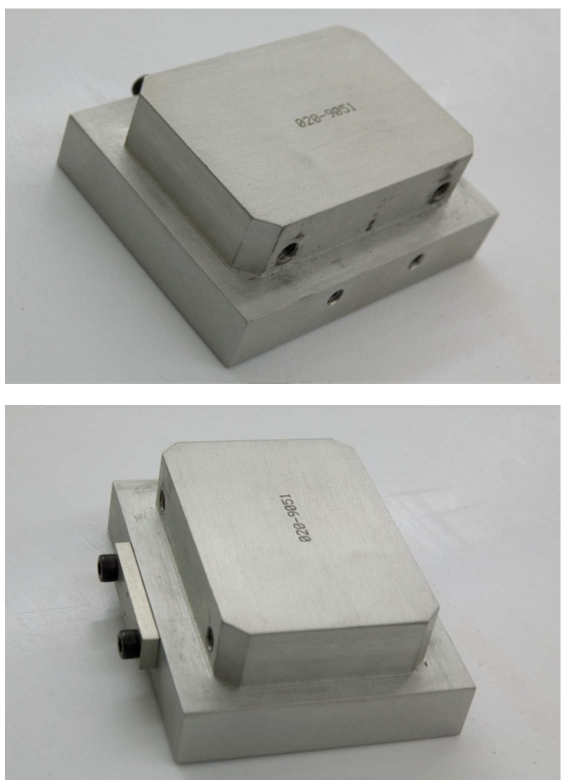

Figure 149. Interface plate for test pendulum

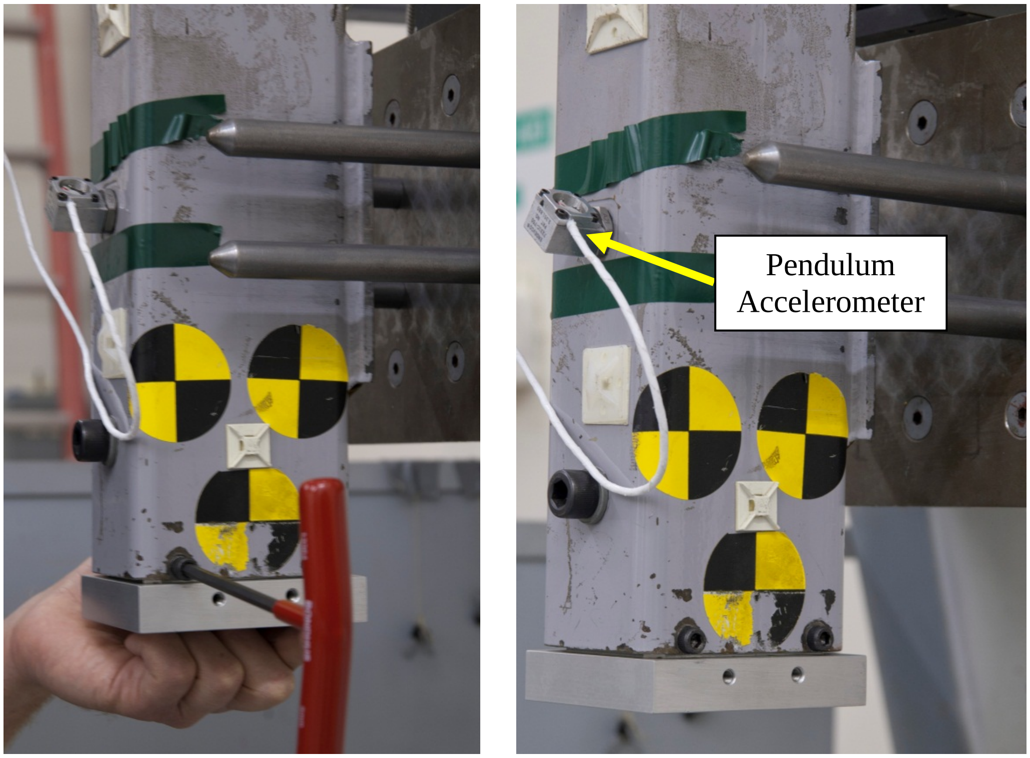

Figure 150. Install pendulum interface plate and pendulum accelerometer

- Install the Angular Rate Sensor (ARS)[45] to the pendulum interface plate using two M1.4 x 8 SHCS so that it measures rotational velocity about the Y′ axis (Figure 149).

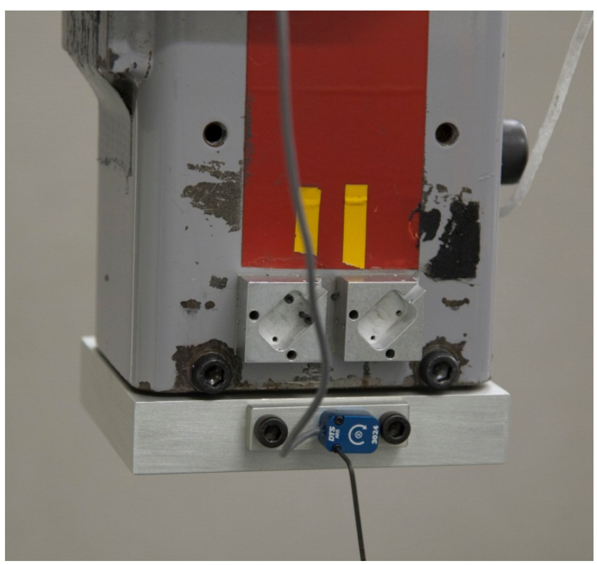

Figure 151. Install ARS to pendulum

[45] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Install the Angular Rate Sensor (ARS)[46] to its mount using two M1.4 x 8 SHCS so that it measures rotational velocity about the X axis. Then install this assembly to the front of the headform (Figure 150 and Figure 151).

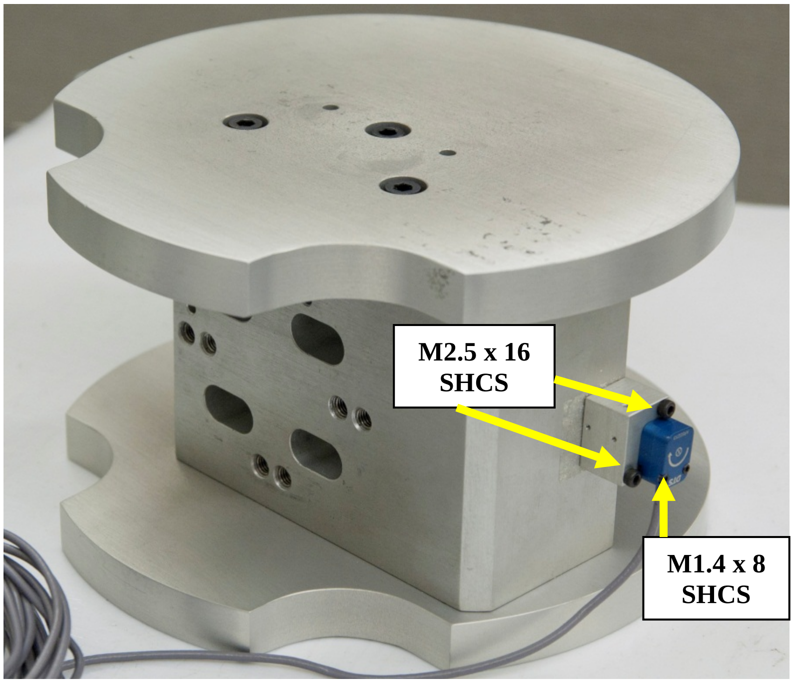

Figure 152. Install ARS to mount then to front of headform

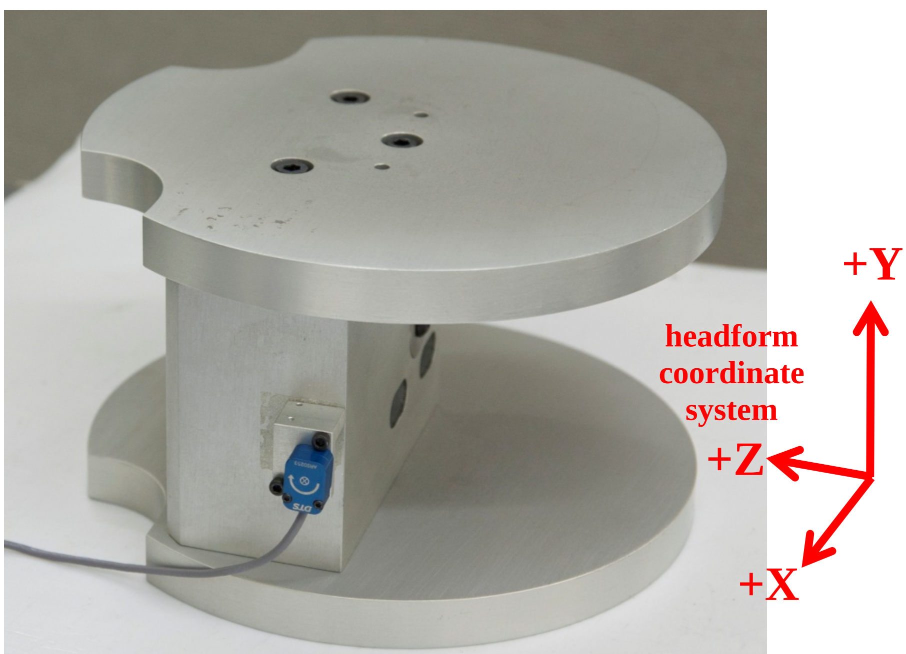

Figure 153. ARS installed to headform for lumbar lateral tests

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[46] Install the Angular Rate Sensor (ARS) SA572-S58 for this application.

- Align and insert the alignment pin on the lumbar interface (Figure 152) to the back of the headform (Figure 153).

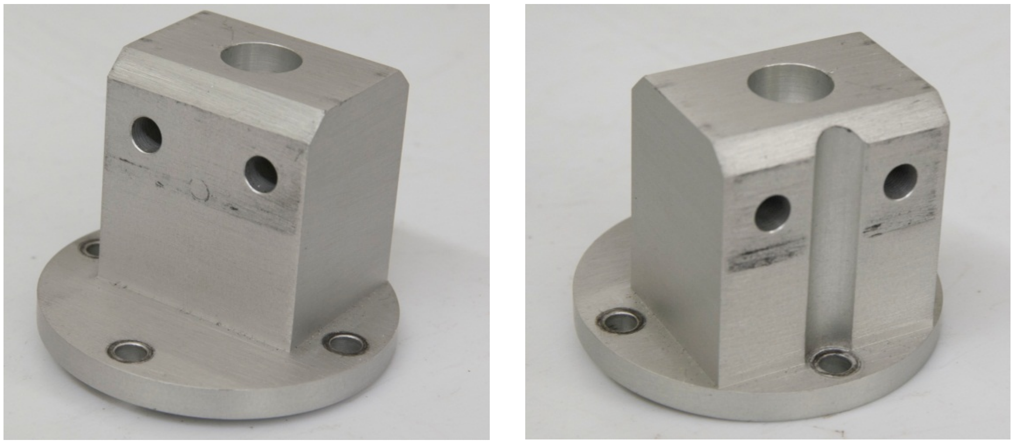

Figure 154. Lumbar interface

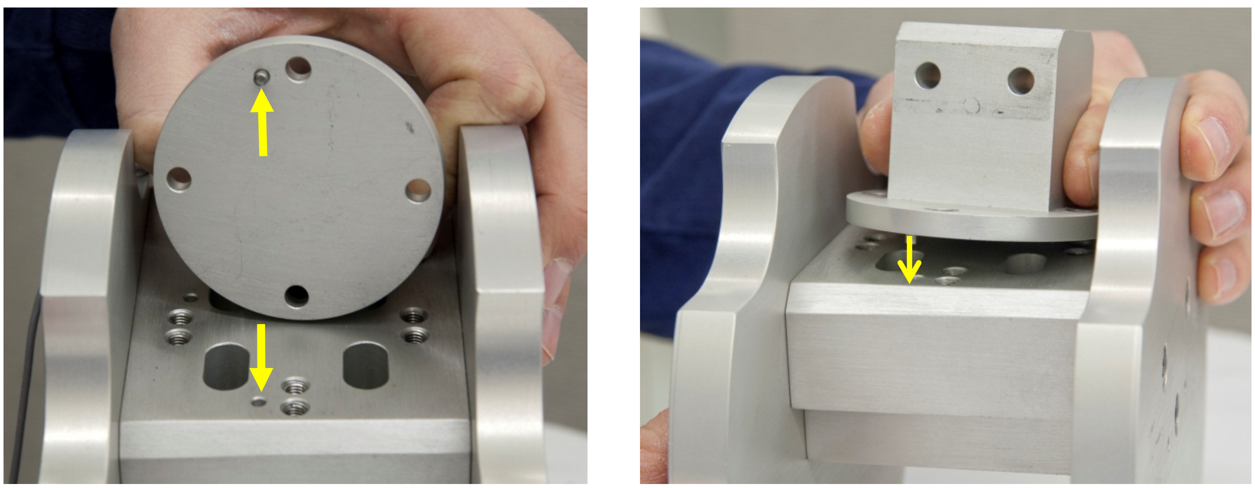

Figure 155. Aligning the lumbar interface to the headform

- Attach the lumbar interface to the headform using four M5 x 12 SHCS (Figure 154).

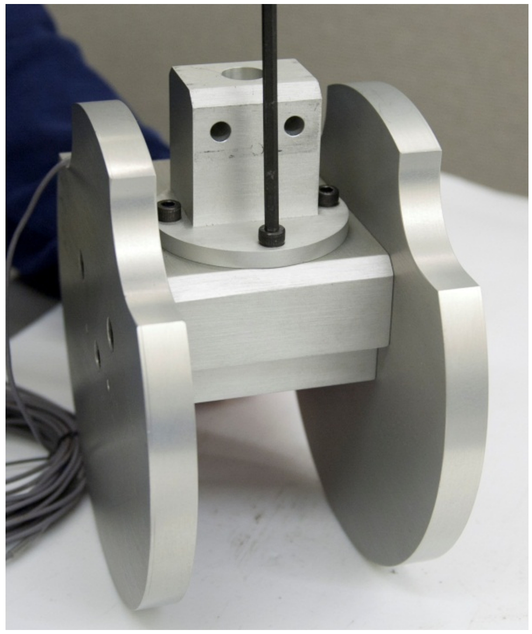

Figure 156. Install lumbar interface to headform

- Mount the lumbar load cell to the lumbar spine using four M5 x 12 SHCS (Figure 155). The load cell wiring should protrude from the back of the lumbar spine.[47]

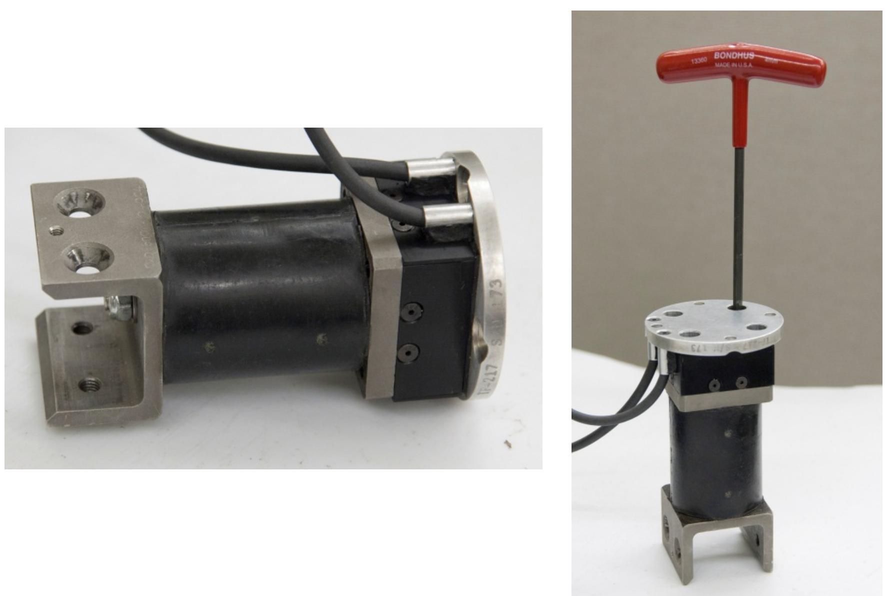

Figure 157. Installing lumbar load cell to lumbar spine

[47] The chamfered counter-bored holes indicate the back of the lumbar spine.

- Mount the lumbar load cell to the pendulum interface using four M5 x 12 FHCS (Figure 156). The left side of the lumbar should be closest to the hexcell for left side lateral tests[48].

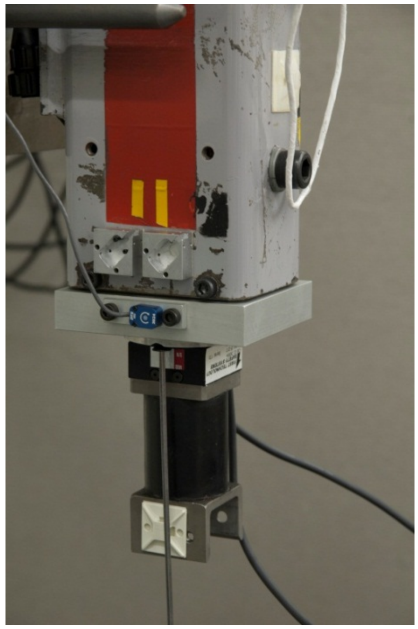

Figure 158. Mount lumbar load cell to pendulum

- Mount the headform to the lumbar spine using two lumbar spine mounting screws[49] (Figure 157). Be certain these screws are tight so that the headform does not slip in the mount. Note that the headform is positioned 90 degrees with respect to arc of the pendulum swing. This configuration is unique to this particular test. The headform is positioned edgewise in the other qualification tests (neck frontal, neck lateral, lumbar frontal).

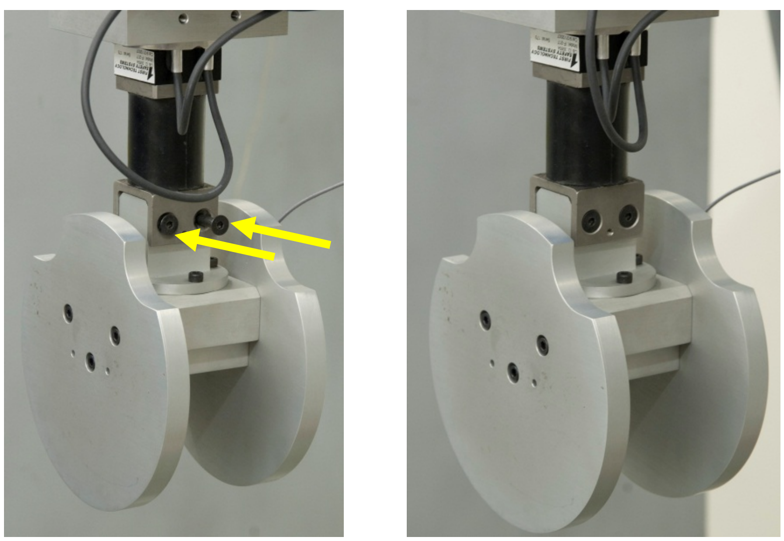

Figure 159. Mount headform to the lumbar spine

[48] The right side of the lumbar is closest to hexcell for right side lateral tests.
[49] These are specialty screws, Part 020-9902, drawing 020-9060.

- Tape the ARS wiring to the headform, allowing sufficient slack. Figure 158 shows the final setup for the Q3s lumbar spine lateral qualification tests.
- Install the proper size hexcell to meet the pulse requirements specified in Table 6.

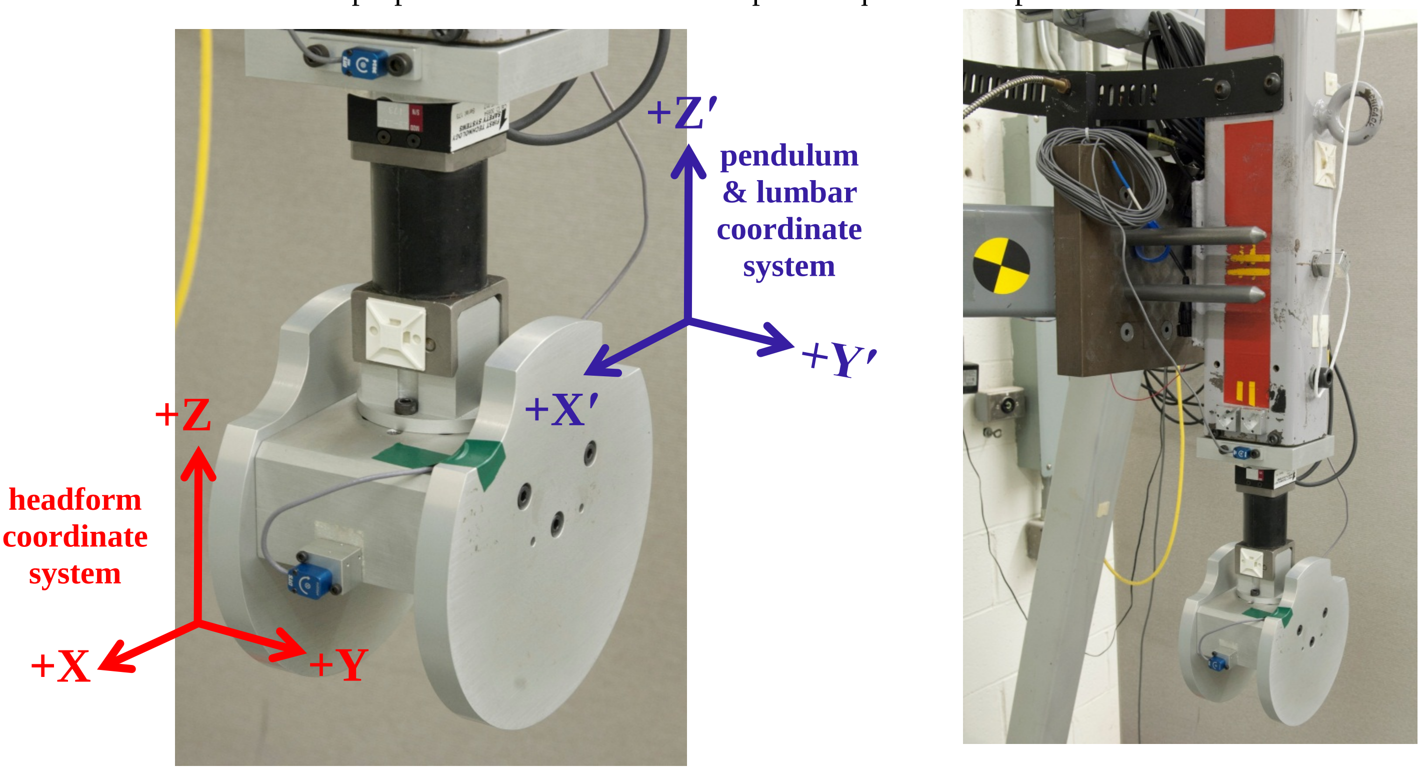

Figure 160. Final setup for the Q3s lumbar spine lateral qualification test

7.2.3. Test Procedures

- The neck pendulum has a mass as specified in Figure 22, 49 CFR 572.33.
- Mount an accelerometer on the pendulum at the location specified in Figure 22, 49 CFR 572.33.
- Test shall be performed at 69 - 72°F (20.5 - 22.2°C) and relative humidity of 10 - 70%.
- Time zero is defined as the time of contact between the pendulum striker plate and the honeycomb.
- All channels are at the zero level when the pendulum is vertical.
- Post-test offset removal of the data signals shall be performed only on the pendulum acceleration and moment signals.
- Raise the pendulum and allow it to fall freely such that it achieves an impact velocity between 4.3 – 4.5 m/s at the time of contact with the arresting block and meets the required pulse specifications included in Table 6.

Table 6. Q3s Lumbar Spine Lateral Pulse Parameters

Parameter		units	Spec. Limits	
			lower	upper
impact speed		m/s	4.3	4.5
pendulum pulse	@10 ms	m/s	1.3	1.7
	@20 ms	m/s	2.7	3.7
	@30 ms	m/s	4.0	4.8

- The data acquisition system conforms to SAE Recommended Practice J211 (July 2007).
- The pendulum acceleration is filtered using a Channel Class 180 phaseless filter.
- The ARS is filtered using a Channel Class 60 phaseless filter.
- The lumbar moment about the X′-axis is filtered using Channel Class 600 phaseless filter.
- Determine the change in pendulum deceleration by integrating the pendulum acceleration beginning at time zero.
- Determine the headform rotation using the following formula[50]:
  - Headform Rotation = $\int(\text{Headform Angular Rate})_x - (\text{Pendulum Angular Rate})_{x'}\, dt$
- The peak rotation, peak moment, and headform rotation decay time to zero time shall lie within the proper specifications:
  - Peak headform rotation: 46.1 – 58.2°
  - Peak moment[51] (Mx′): 79.4 – 98.1 Nm
  - Headform rotation decay time to 0° from peak angle: 48 – 59 ms

[50] Perform this calculation *after* filtering the ARS sensors. Begin integration at time zero.
[51] Maximum moment measured during the time interval while the rotation is within the specified corridor.