THOR 5th Percentile Female (THOR-05F)

Qualification Procedures and Requirements

July 2025

TABLE OF CONTENTS

1 ORDER OF OPERATIONS

The order of operations is shown in Figure 1-1. First, the component tests (group 1) are carried out on the sub-assemblies (head and neck assembly, knee assembly, and lower leg assembly). These tests (A, B, and C) can be carried out in parallel. After the component tests are completed, the dummy is fully assembled, and the full body qualification tests are conducted (group 2). Table 1-1 summarizes the test velocities and impactor probes used in each test.

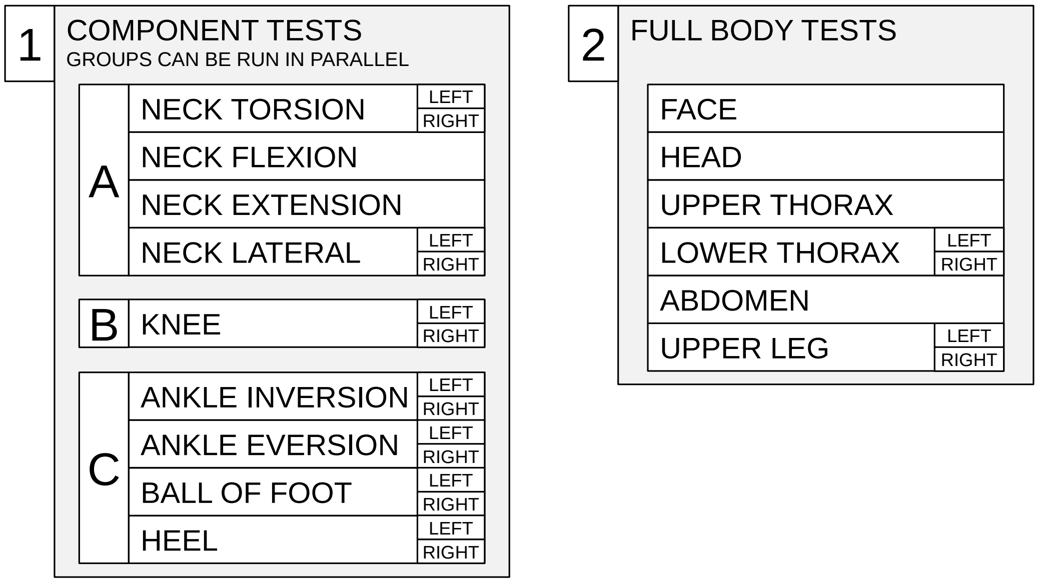


Figure 1-1. Order of operations for qualification procedures.

Table 1-1. Qualification Test Matrix

Body Region	Test	Impact Velocity m/s [± 0.05 m/s]	Impactor Mass kg [± 0.02 kg]	Impactor Face mm [± 0.25 mm]
Head	Head Impact Test	2.00	19.2	152.4 disk
	Face Impact Test	6.73	10.7	152.4 disk
Neck	Neck Left Torsion	3.40		Neck Pendulum
	Neck Right Torsion	3.40		
	Neck Frontal Flexion	5.00		
	Neck Frontal Extension	5.00		
	Neck Left Lateral Flexion	3.40		
	Neck Right Lateral Flexion	3.40		
Thorax	Upper Thorax Impact	4.30	13.97	152.4 disk
	Left Thorax Impact	4.30	13.97	152.4 disk
	Right Thorax Impact	4.30	13.97	152.4 disk
Abdomen	Abdomen Impact	6.10	16.0	140x50 rectangle
Femur/Knee	Left Upper Leg Impact	3.65	7.26	76.2 disk
	Right Upper Leg Impact	3.65	7.26	76.2 disk
	Left Knee Impact	2.15	7.26	76.2 disk
	Right Knee Impact	2.15	7.26	76.2 disk
Lower Extremity	Left Ankle Inversion	2.00	3.00	NHTSA Dynamic Impactor
	Right Ankle Inversion	2.00	3.00	
	Left Ankle Eversion	2.00	3.00	
	Right Ankle Eversion	2.00	3.00	
	Left Ball of Foot Impact	2.00	7.45	
	Right Ball of Foot Impact	2.00	7.45	
	Left Heel Impact	4.00	3.00	
	Right Heel Impact	4.00	3.00	

2 GENERAL PROCEDURE NOTES, DATA COLLECTION CONVENTIONS, AND CALCULATIONS

All photographs and illustrations in this document are provided for reference only.

2.1 Acronyms

The following acronyms used throughout this manual include:

FASTENER ABBREVIATIONS:

BHCS	**B**utton **H**ead **C**ap **S**crew
BHSS	**B**utton **H**ead **S**houlder **S**crew
FHCS	**F**lat **H**ead **C**ap **S**crew
SHCS	**S**ocket **H**ead **C**ap **S**crew
SHSS	**S**ocket **H**ead **S**houlder **S**crew
SSSNP	**S**ocket **S**et **S**crew **N**ylon **P**oint

OTHER ABBREVIATIONS:

AM	**A**s **M**easured
ARS	**A**ngular **R**ate **S**ensor
ATD	**A**nthropomorphic **T**est **D**evice
AMVO	**A**nthropometry of **M**otor **V**ehicle **O**ccupants
CFC	**C**hannel **F**requency **C**lass
CFR	**C**ode of **F**ederal **R**egulations
CM	**C**alculated **M**easure
CG	**C**enter of **G**ravity
IR-TRACC	**I**nfra-**R**ed **T**elescoping **R**od for the **A**ssessment of **C**hest **C**ompression
ISO	**I**nternational **O**rganization for **S**tandardization
LS	**L**umbar **S**pine
LTS	**L**ower **T**horacic **S**pine
NHTSA	**N**ational **H**ighway **T**raffic **S**afety **A**dministration
OC	**O**ccipital **C**ondyle
PADI	**P**rocedures for **A**ssembly, **D**isassembly, and **I**nspection
ROM	**R**ange **O**f **M**otion
SAE	**S**ociety of **A**utomotive **E**ngineers
THOR-05F	**THOR 5**th Percentile **F**emale
UTS	**U**pper **T**horacic **S**pine

2.2 Bolt Torque Values

For the test fixtures and THOR-05F assemblies described in this manual, unless otherwise specified, use 10% of the specified torque requirement for the assembly tolerance. For example, a bolt specified for a torque of 12.0 N-m would be tightened to 12.0 ± 1.2 N-m.

2.3 Sign conventions

The sign conventions of signals are defined in "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

2.4 Signal conditioning

Filtering of data channels is applied using CFC definitions in accordance with Appendix C of the March 1995 update to SAE J211-1 (Section 2.6(a)1).

2.5 Signal naming conventions

In data processing steps prescribed herein, standard signal names are used to identify particular signals. Standard codes are also used to identify signal characteristics, such as axes and polarities. The signal naming convention follows ISO-MME (Section 2.6 (a)1) and the characteristic codes are identified in NHTSA's Version 5 Test Reference Guide. Names and codes are applied herein only to provide clarity. Any signal naming and coding convention may be used.

2.6 Normative Documents

(a) SAE International, 400 Commonwealth Drive, Warrendale, PA, 15096.

1) SAE Recommended Practice J211-1, Instrumentation for impact test – Part 1: Electronic Instrumentation, August 2022.
2) SAE Information Report J1733, Sign Convention for Vehicle Crash Testing.
3) SAE Information Report J2570, Performance specifications for anthropomorphic test device transducers.
4) SAE Recommended Practice J2876_201505, Low Speed Knee Slider Test Procedure for the Hybrid III 50th Male Dummy.

(b) 49 CFR Part 572

1) §572.133, Subpart O, Hybrid III 5th Percentile Female Test Dummy, Alpha Version, Neck Assembly and Test Procedure.
2) §572.137, Subpart O, Hybrid III 5th Percentile Female Test Dummy, Alpha Version, Test conditions and instrumentation.

(c) www.Regulations.gov

1) THOR-05F NHTSA Drawing Package, Document ID NHTSA-2025-In Progress.
2) THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI), Document ID NHTSA-2025-In Progress.

(d) https://one.nhtsa.gov/Research/Databases-and-Software/NHTSA-Test-Reference-Guides

1) Version 5 Test Reference Guide, Volume II : Biomechanical Tests (Revision) November, 2014.

2.7 Impact Force Calculation

In test procedures in which the response to be evaluated requires calculation of impact force at the contact interface, measurement from a single linear accelerometer along the line of impact is used to calculate impact force using the following equations:

$$F_{IMP}(t) = m_{IMP} \cdot a_{IMP}(t)$$

where

$F_{IMP}(t) =$ calculated force time-history at contact interface

$m_{IMP} =$ mass of the impactor

$a_{IMP}(t) =$ measured acceleration time-history of impactor

2.8 Measured Channels

Throughout these procedures, sensor channels denoted AM in the respective Required Measurements Table are subsequently used in the qualification specifications. Where calculations are necessary to achieve a qualification specification, this calculation is detailed in the Data Processing section and listed as a CM in the respective Required Measurement Channels table for a given test mode.

3 ATD ADJUSTMENT

3.1 Lumbar Spine Pitch Change Mechanism

The lumbar spine pitch change mechanism connects the upper (thoracic) and lower (lumbar) spine segments. It allows adjustment of the spine angle in 3 degree increments. There are four settings marked on the lumbar spine pitch change assembly (474-3220-A), representing erect, neutral, slouched, and super-slouched postures (Figure 3-2). The default position is the slouched posture, which is the setting used herein for qualification purposes, with the exception of the face qualification which utilizes the erect posture. The slouched posture most closely resembles the AMVO[1] seated posture for a 5th percentile female occupant.

To adjust the lumbar spine pitch change mechanism angle, follow the steps below.

3.1.1 Unzip the zippers on the right shoulder and the right side of the jacket and remove the jacket.

---

[1] Schneider, L.W., Robbins, D.H., Pflug, M.A., Snyder, R. G., "Development of Anthropometrically Based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family; Volume 1-Procedures, Summary Findings and Appendices, "U.S. Department of Transportation, DOT-HS-806-715, 1985.

3.1.2 Locate the M12 X 1.75 X 45 mm SHCS on the right side of the lower spine, as indicated in Figure 3-1.

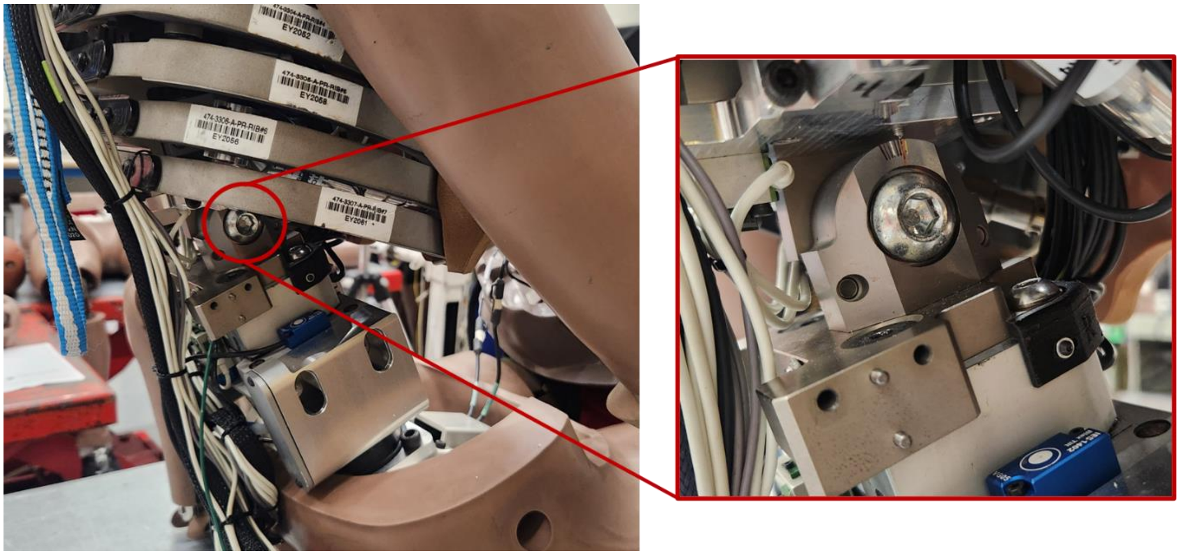
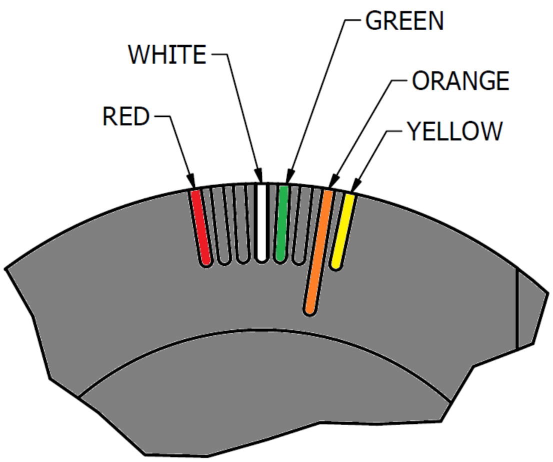


Figure 3-1. Lumbar spine pitch change mechanism adjustment SHCS (M12).

3.1.3 Loosen the M12 X 1.75 X 45 mm SHCS at least two complete turns (720 degrees) to disengage the sprockets.

3.1.4 Manipulate the upper portion of the spine to achieve the desired posture setting, as shown in Figure 3-2.



POSTURE CHART		
POSTURE	COLOR	ANGLE
ERECT	RED	-9°
NEUTRAL	WHITE	0°
45° SEAT BACK	GREEN	3°
SLOUCHED (UMTRI AMVO POSTURE)	ORANGE	9°
SUPER SLOUCHED	YELLOW	12°

Figure 3-2. Lumbar spine pitch change assembly (474-3069) posture settings.

3.1.5 Re-tighten the M12 x 1.75 x 45 mm SHCS and torque to 68.0 N-m.

3.2 Neck Pitch Change Mechanism

The neck pitch change mechanism (474-3050) connects the lower neck load cell to the upper spine assembly (474-3240). It allows adjustment of the angle of the base of the neck in 3 degree increments. There are three scribe lines marked on the left sprocket, which is fixed to the UTS, and one scribe line settings marked on right sprocket, which rotates with the neck. A neutral setting is achieved by aligning the fixed scribe line with the superior scribe line on the left sprocket, as shown in Figure 3-3. The default position is the neutral posture, which is the setting used herein for qualification purposes. The neutral posture most closely resembles the AMVO seated posture for a 5th percentile female occupant.

To adjust the angle of the neck pitch change mechanism, follow the steps below.

3.2.1 Unzip the zippers on the right and left shoulders and sides of the jacket, and remove the jacket.

3.2.2 Locate the M6 X 1 X 12 LG. SHCS on the front side of the upper thoracic spine, as indicated in Figure 3-3. On a fully assembled dummy, the SHCS can be accessed by inserting an M5 T-handle ball-end hex wrench through the Chest Flesh (474-3730-A) in the front of the dummy (Figure 3-4).

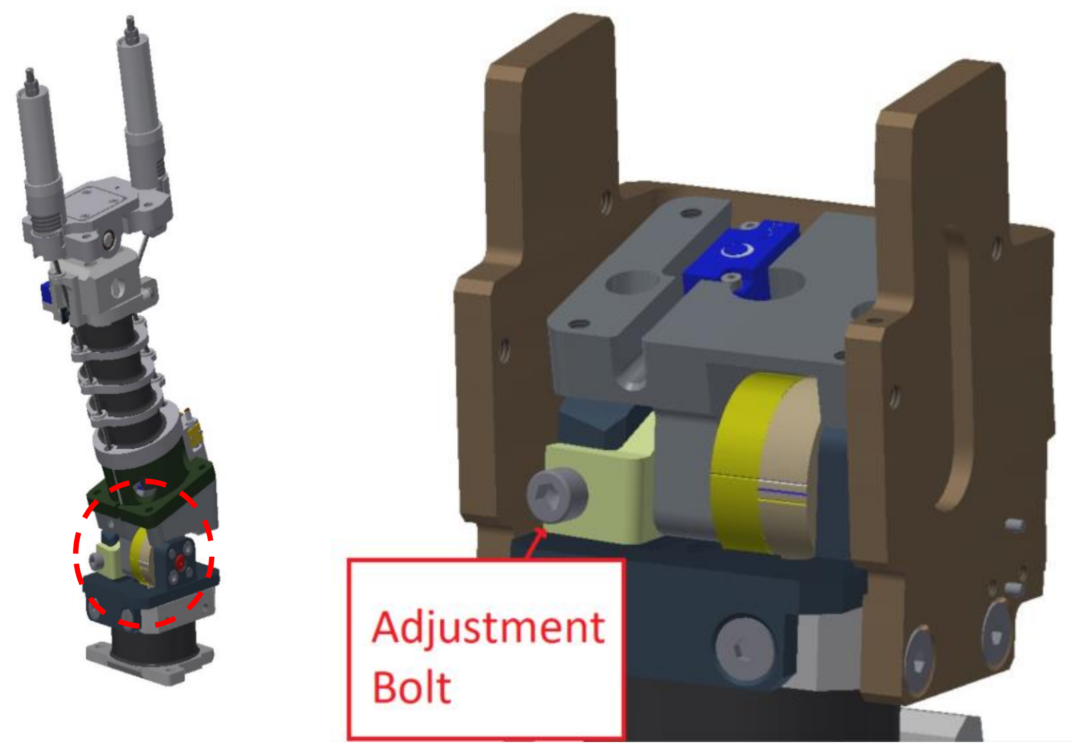


Figure 3-3. Neck pitch change assembly (474-3050) posture setting (diagram shows "neutral" position).

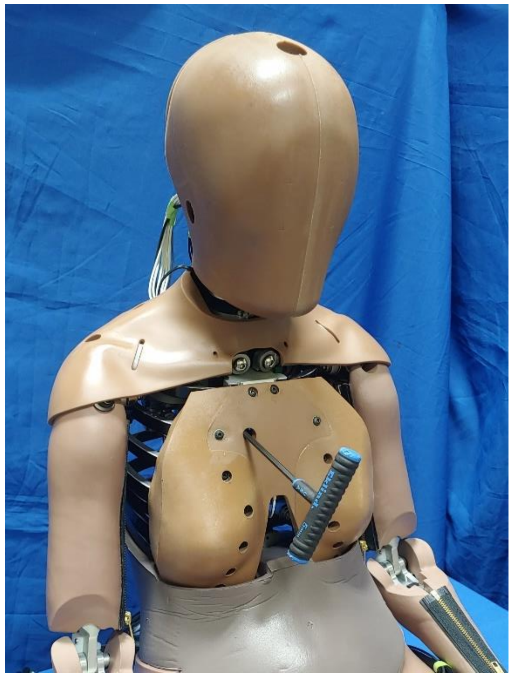


Figure 3-4. Access to the neck pitch change mechanism through the chest flesh.

3.2.3 Loosen the Modified M6 X 1 X 12 LG. SHCS bolt to loosen the Adjustment Wedge (474-3052) and disengage the sprockets (Figure 3-5).

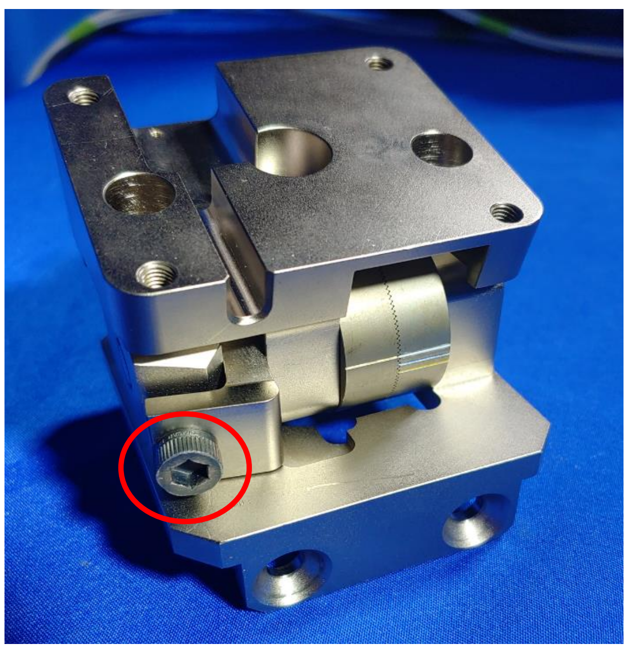


Figure 3-5. Adjustment wedge bolt

3.2.4 Manipulate the neck to achieve the desired posture setting (Table 3-1). The default position ("neutral" as shown in Figure 3-3 right, and Figure 3-6) is achieved by aligning the superior scribe line on the sprocket attached to the neck with the scribe line on the fixed sprocket.

Table 3-1. Neck Pitch Adjustment

Color	White	Blue	Yellow
Posture	Neutral	Forward Posture 2	Forward Posture 1
Angle	0°	6°	12°

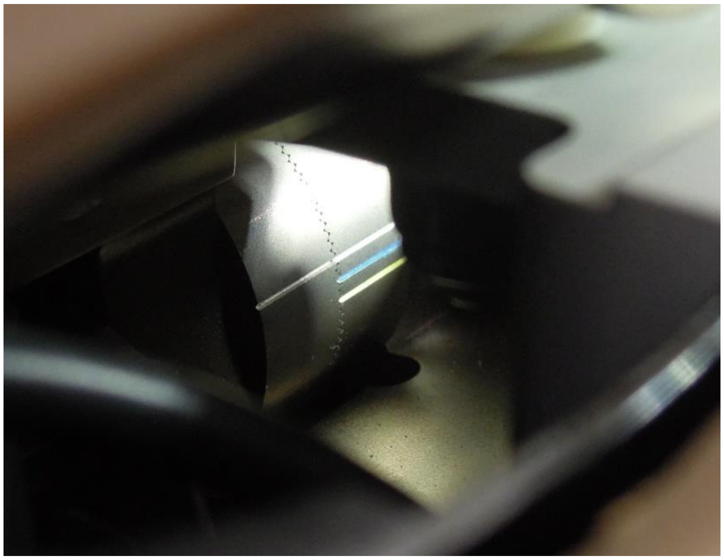


Figure 3-6. View of neck pitch change joint scribe lines through ribcage (set at neutral)

3.2.5 Re-tighten the M6 X 1 X 12 LG. SHCS and torque to 50.8 N-m.

3.3 Arm and Shoulder Joint Torque Settings

3.3.1 To adjust the upper arm Y-axis joint, roatate the upper arm up (forward about the y-axis) until horizontal; bend the lower arm and hand back about the y-axis, towards the face (Figure 3-7). Adjust the M6 nut in the arm pit area so that the arm drops slowly after release (Figure 3-8).

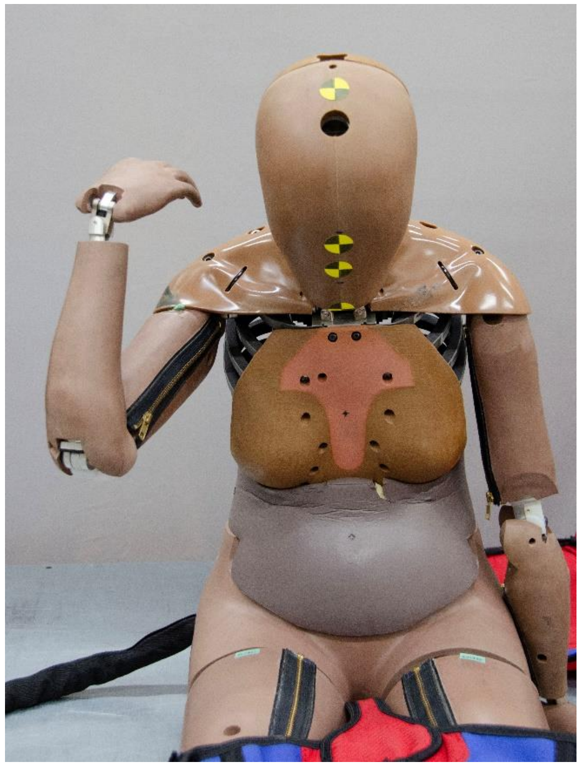


Figure 3-7. Position upper arm for Y-axis joint adjustment

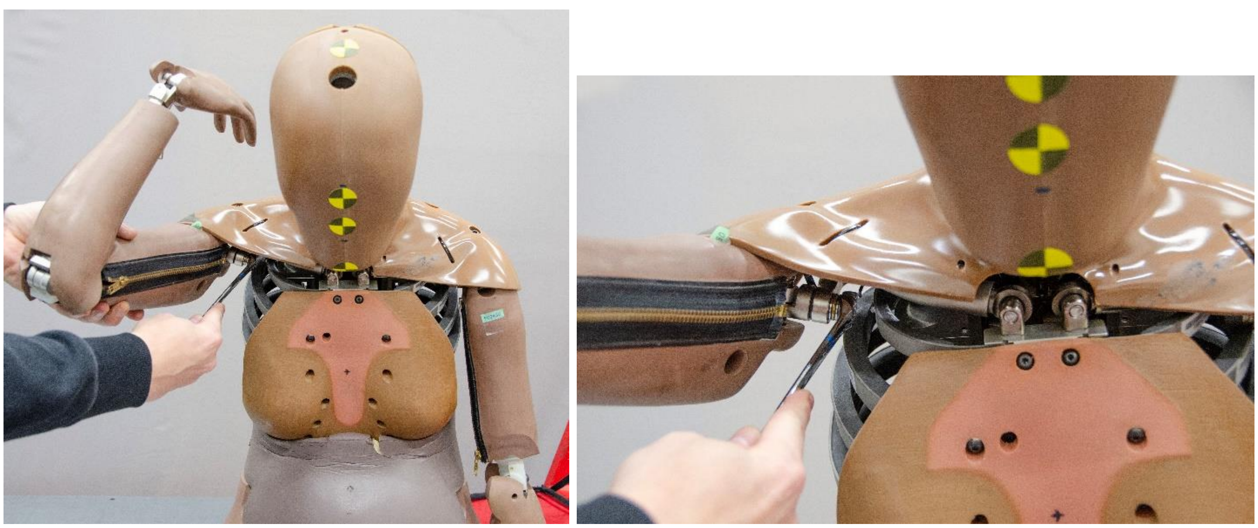


Figure 3-8. Adjust upper arm Y-axis joint with M6 nut

3.3.2 To adjust the upper arm X-axis joint, rotate the upper arm laterally, away from the torso until it is approximately horizontal; rotate the lower arm vertically upwards at the elbow. Bend the hand back towards the head (Figure 3-9). Adjust the friction on the shoulder bolt by tightening or loosening the bolt as appropriate (Figure 3-10). The friction is properly adjusted when the upper arm drops slowly from horizontal after release. Note that the shoulder can also lift during this motion; ensure that it is not lifting by pushing down on the shoulder so it remains on the stop.

Figure 3-9. Position upper arm for X-axis joint adjustment

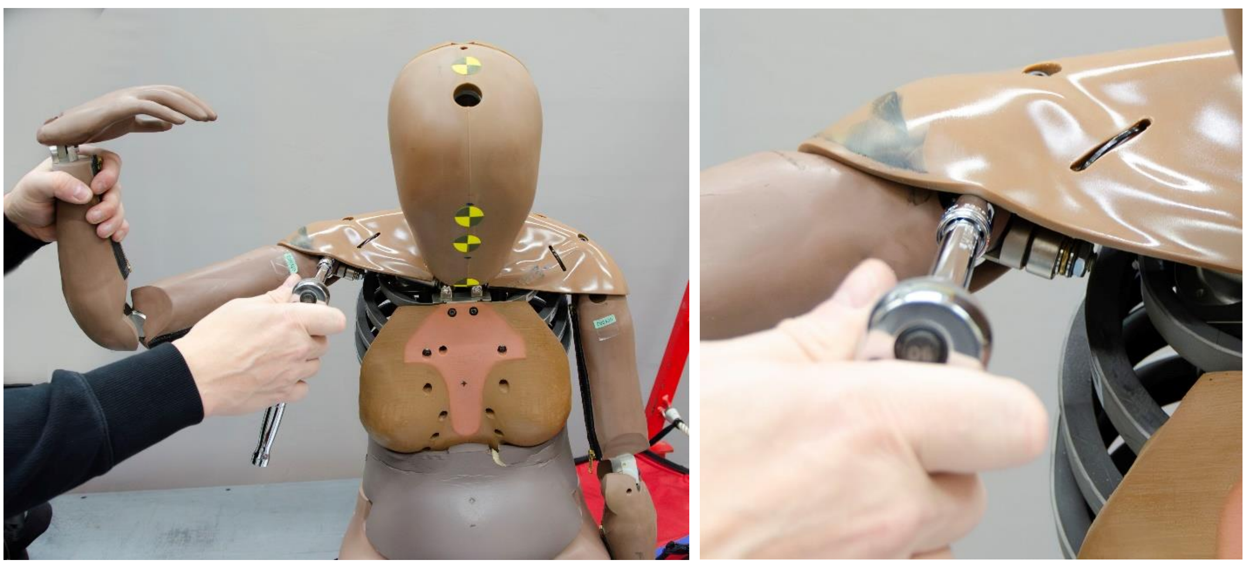


Figure 3-10. Adjust upper arm X-axis joint

3.3.3 To adjust the lower arm Z-axis friction (moment along upper arm shaft), first remove the upper arm skin (484-6120) (Figure 3-11); position the upper arm horizontally away from the torso, with the lower arm and hand horizontally forward (~90° angle). Adjust the upper arm z-axis friction by tightening or loosening, as appropriate, the bolt on the back top of the upper arm near the elbow. Adjust the friction such that the lower arm and hand drop slowly after release.

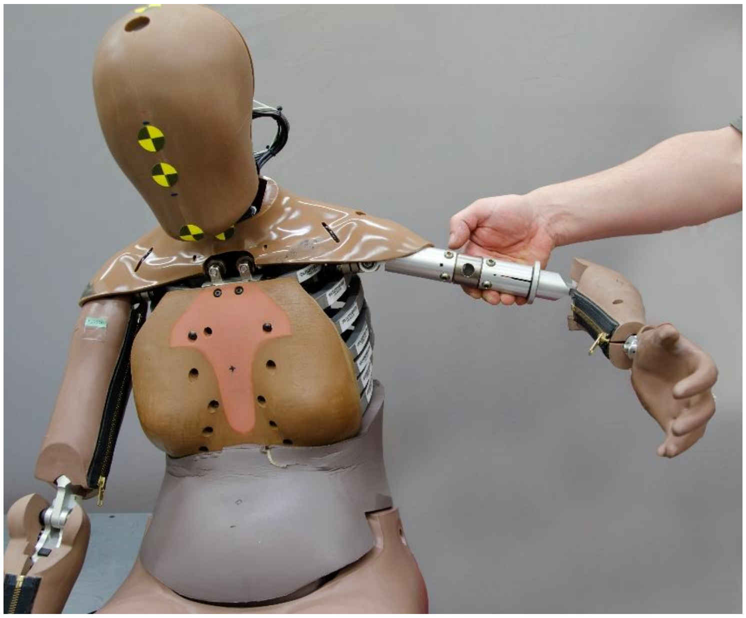


Figure 3-11. Remove upper arm skin and position arm for setting z-axis joint

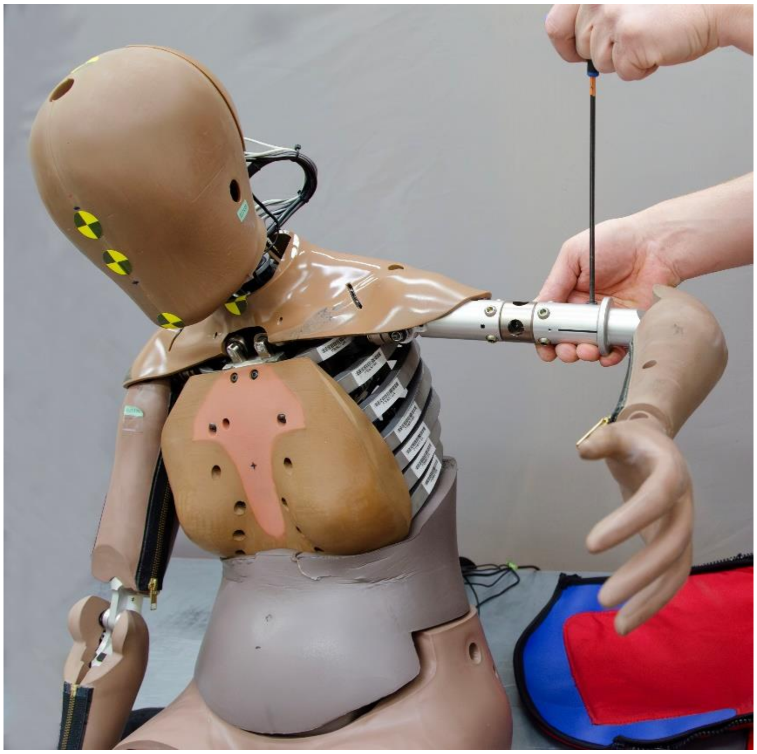


Figure 3-12. Adjust upper arm Z-axis friction joint

3.3.4 To set the wrist friction joint, position the hand with the palm up (Figure 3-13). Adjust the torque of the M5 x 0.8 x 25 mm SHCS at the wrist joint such that the hand remains in this position under its own mass but falls once any additional mass or force is added. Using an allen wrench and a box wrench on the opposite end of the SHCS will prevent the entire bolt from turning while adjusting. Repeat for other hand.

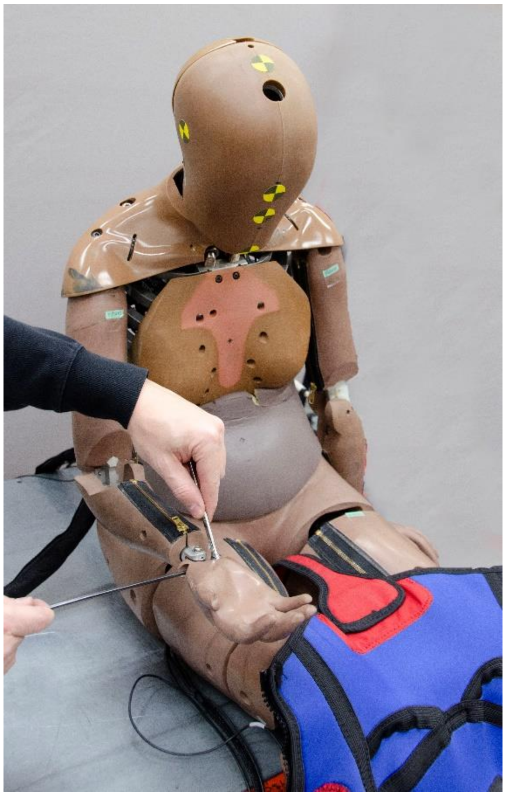


Figure 3-13. Adjust wrist friction joint

3.3.5 Position the lower arm as shown in Figure 3-14**.** Adjust the torque of the M10 x 20 mm SHSS at the elbow joint such that the lower arm remains in this position under its own mass but falls once any additional mass or force is added. Repeat for other elbow.

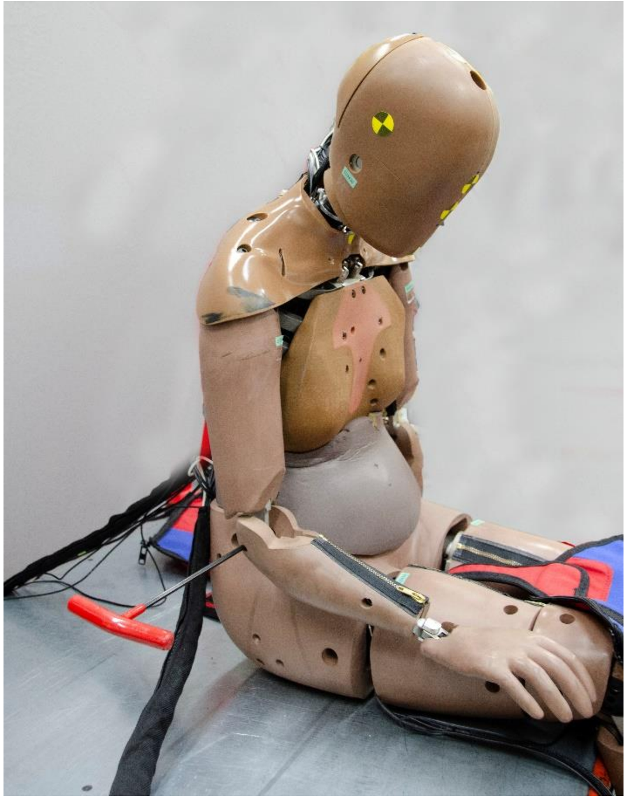


Figure 3-14. Setting elbow joint torque

3.4 Hip Joint Torque Settings

3.4.1 To set the hip joint torque, adjust the torque of the Pelvic Plunger Assembly (474-4315) on the Femur Mounting Socket (474-4003) inside the pelvis flesh (Figure 3-15). Adjust the torque of pelvis plunger such that the femur remains in position under its own mass, but falls once any additional mass or force is added. The Pelvic Plunger Assembly is best accessed through the superior opening of the pelvis flesh, next to the abdomen foam (Figure 3-16).

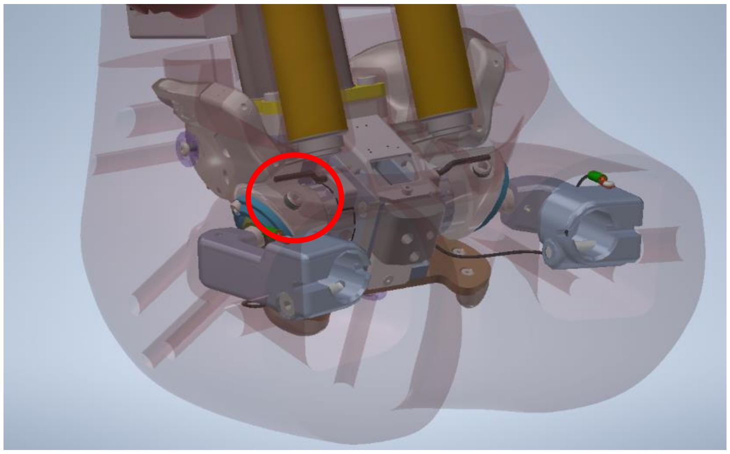


Figure 3-15. Pelvis assembly showing pelvic plunger assembly (circled)

Figure 3-16. Adjust hip joint torque

3.5 Knee Joint Torque Settings

3.5.1 To adjust the knee joint torque setting, seat the dummy with the leg outsretched. Adjust the torque of the M8 x10 SHSS in the center of the inboard left knee and outboard right knee so that the lower leg remains in this position under its own mass but falls once any additional mass or force is added (Figure 3-17).

Figure 3-17. Screw access for setting (left) knee joint torque

3.6 Ankle Rotary Potentiometer Zeroing Procedure

Before conducting any of the lower limb dynamic impact tests, determine the outputs of the individual ankle potentiometers when the ankle is held in a known orientation referred to as the **zero position**: zero degrees plantar-/dorsi-flexion (Y-axis), zero degrees inversion/eversion (X-axis), and zero degrees internal/external rotation (Z-axis). The zero position potentiometer rotational displacement values (in degrees) are later used to determine the angular position of the foot relative to the tibia.

Materials: THOR-05F lower leg assembly (474-5500-1/2), THOR-05F lower leg zero bracket (TH-1603-0671-PR), leg mounting bracket mounted to a rigid surface.

Procedure:

3.6.1 During ankle potentiometer installation (see Section 10.3 in the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)"), ensure that the potentiometers are installed so that they will not pass through the electrical dead band at any point in the ankle's range of motion. When installing the potentiometers, rotate the shaft until the potentiometer output voltage is approximately 0 volts so that the potentiometer is near mid-range. Note: Y-axis potentiometer is installed on the same side as the eversion bumper.

3.6.2 Remove the tibia skin (474-5520), the two M5 X 0.8 X12 BHCS which attach the shin guard (474-5518) to the lower leg assembly (474-5500-1/2) (Figure 3-18).

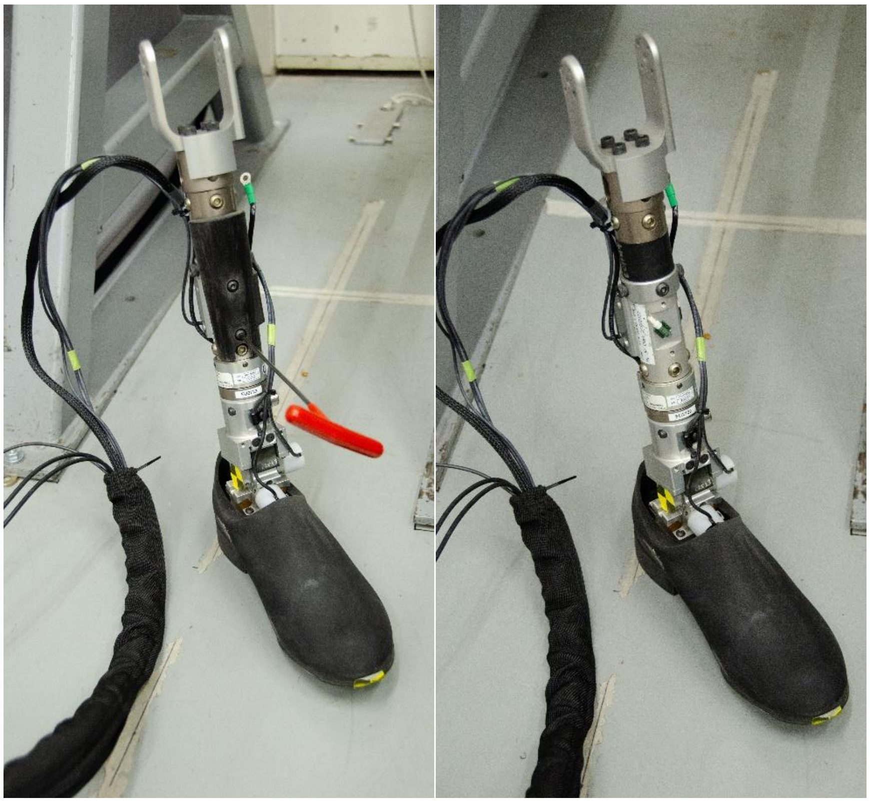


Figure 3-18. Remove shin guard

3.6.3 Remove the four M6 X 1 X 16 SHCS which attach the knee clevis (474-5517) to the lower leg assembly (474-5500-1,2) (Figure 3-19).

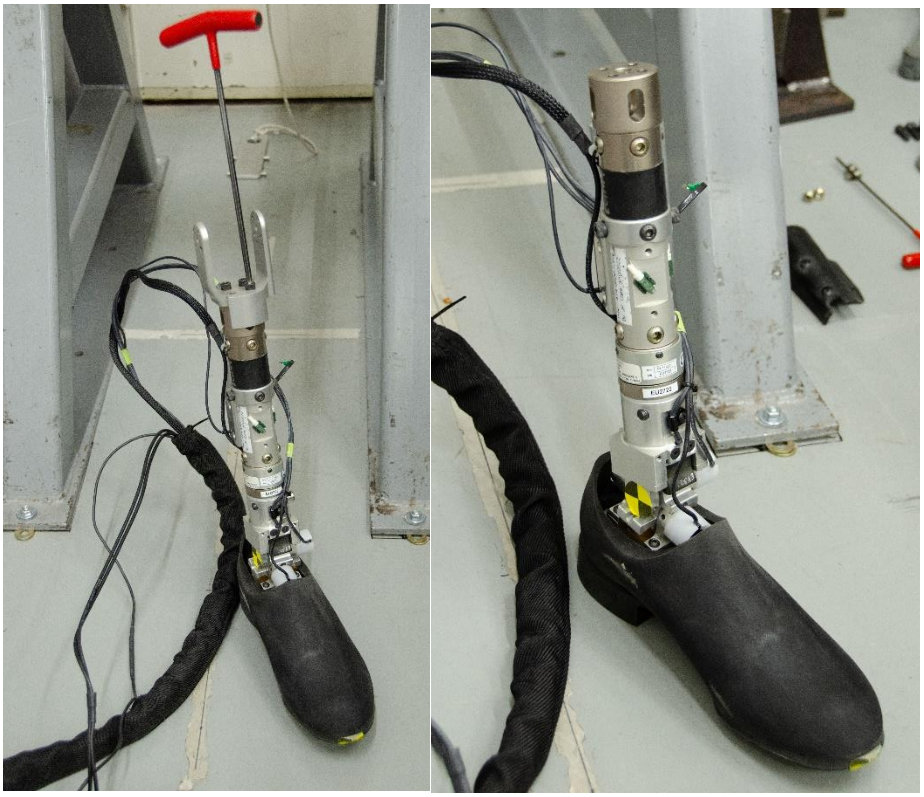


Figure 3-19. Remove knee clevis

3.6.4 Remove the four M4 X 0.7 X 12 LHCS (two per side) which attach the Lower Achilles spring housing (474-5504) to the rear of the lower tibia shaft (474-5540) (Figure 3-20).

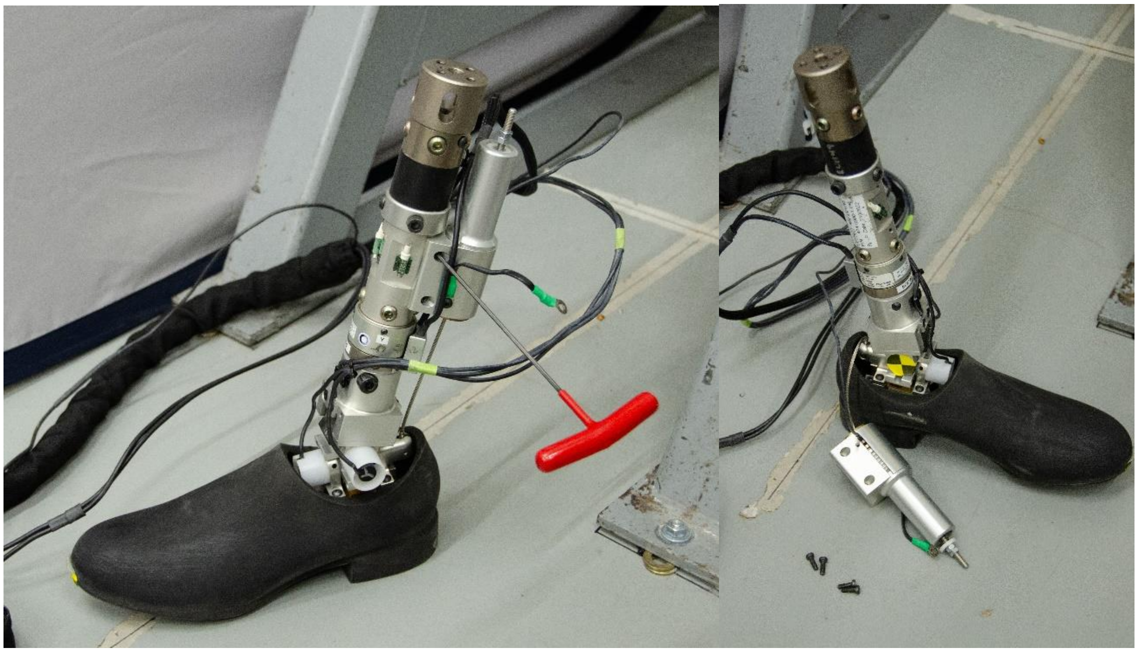


Figure 3-20. Remove Lower Achilles spring housing

3.6.5 Remove the four M4 x 0.7 x 16 SHCS which attach the molded shoe (474-5903) to the ankle (Figure 3-21).

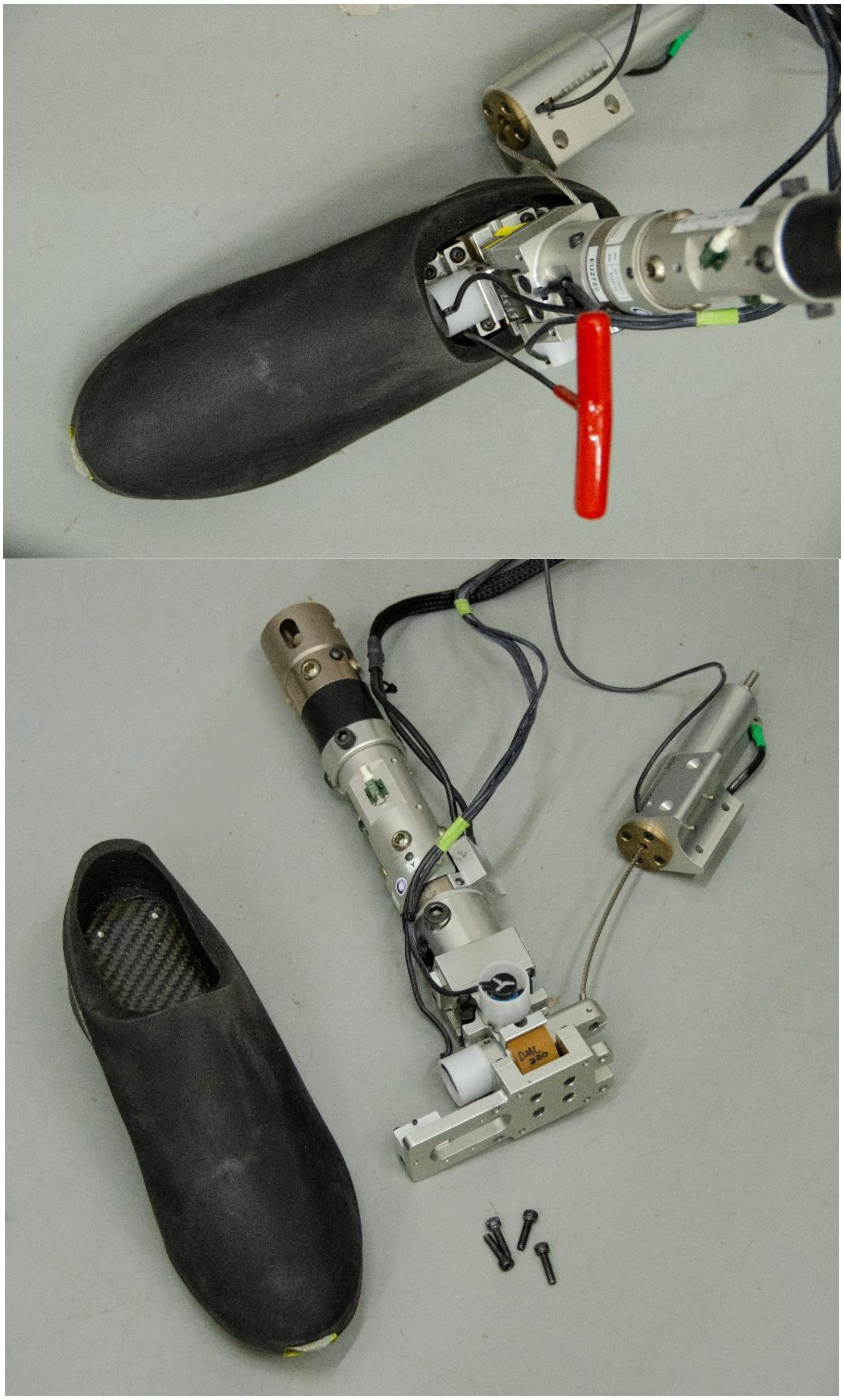


Figure 3-21. Remove the molded shoe

3.6.6 Remove the Tibia Compliant Element Assembly (474-5508) and Upper Tibia Load Cell (SA572-S103) by removing one M6 X 1 X 10 LG. FHCS, one M6 X 1 X 10 LG. BHCS, and two Tibia Plunger Pins (Modified M6 SHCS) (Figure 3-22).

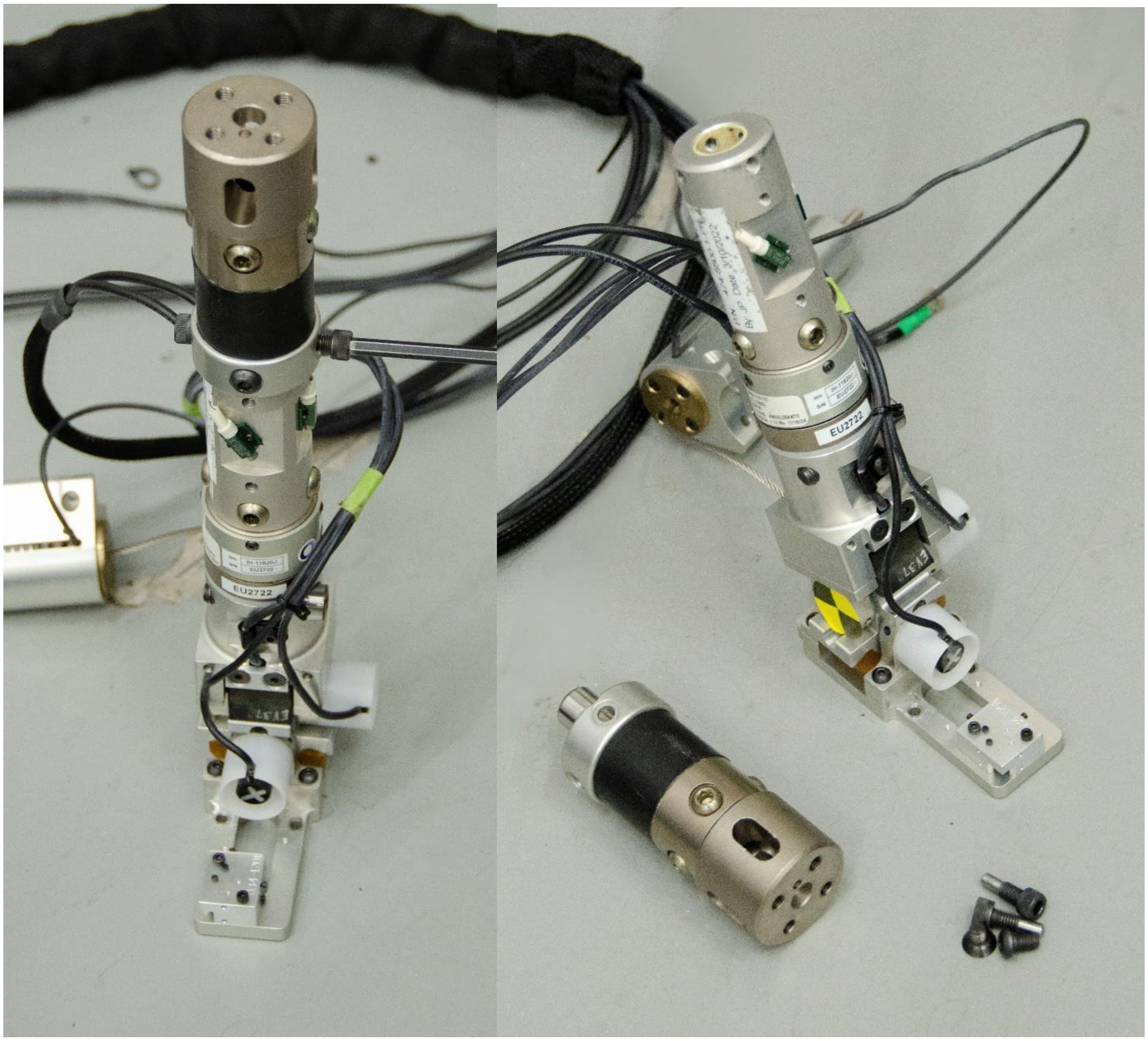


Figure 3-22. Remove the Tibia Compliant Element Assembly and Upper Tibia Load Cell

3.6.7 Uninstall the Modified BHSS M6 Thread bolts (W50-61042) on the left and right sides of the Lower Tibia Shaft (Left) (474-5540) (Figure 3-23).

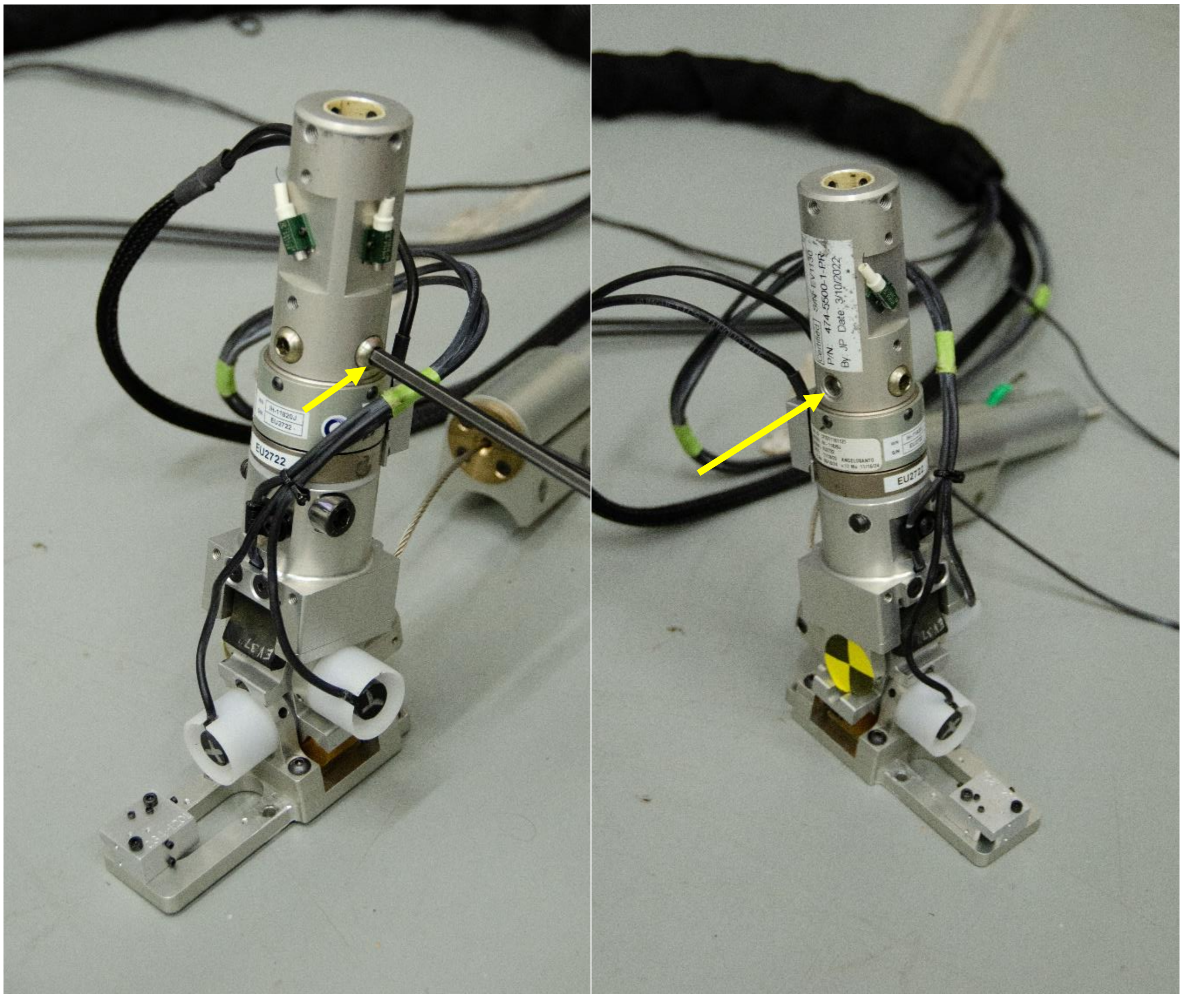


Figure 3-23. Remove bolts from left and right sides of lower tibia shaft

3.6.8 The THOR-05F lower leg zero bracket (TH-1603-0671-PR) is shown in Figure 3-24. Attach the THOR-05F lower leg zero bracket to the lower ankle plate (474-5806) using four M4 x 25mm SHSS (Figure 3-25). Ensure that the toe is pointing into the zero bracket cutout.

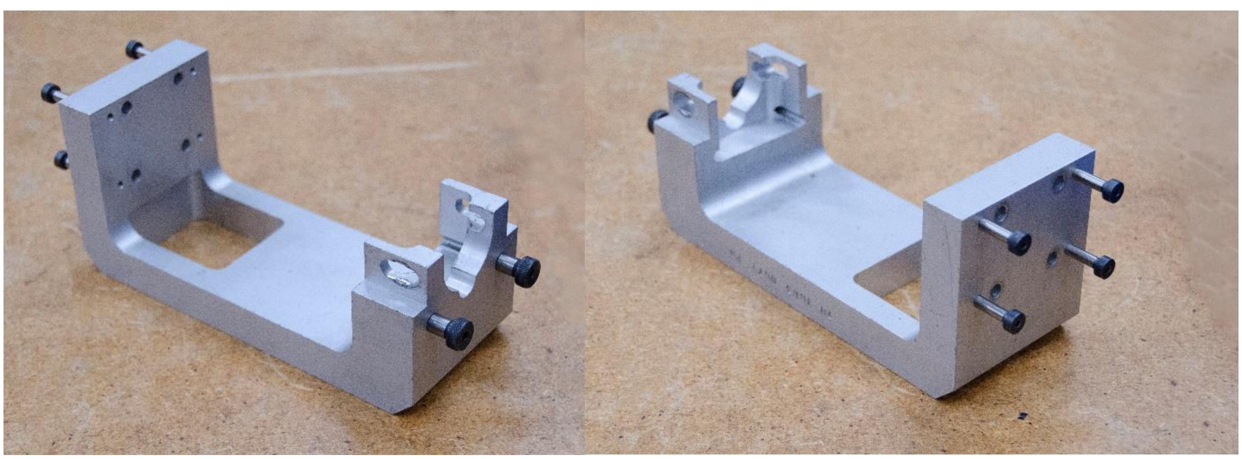


Figure 3-24. THOR-05F lower leg zero bracket

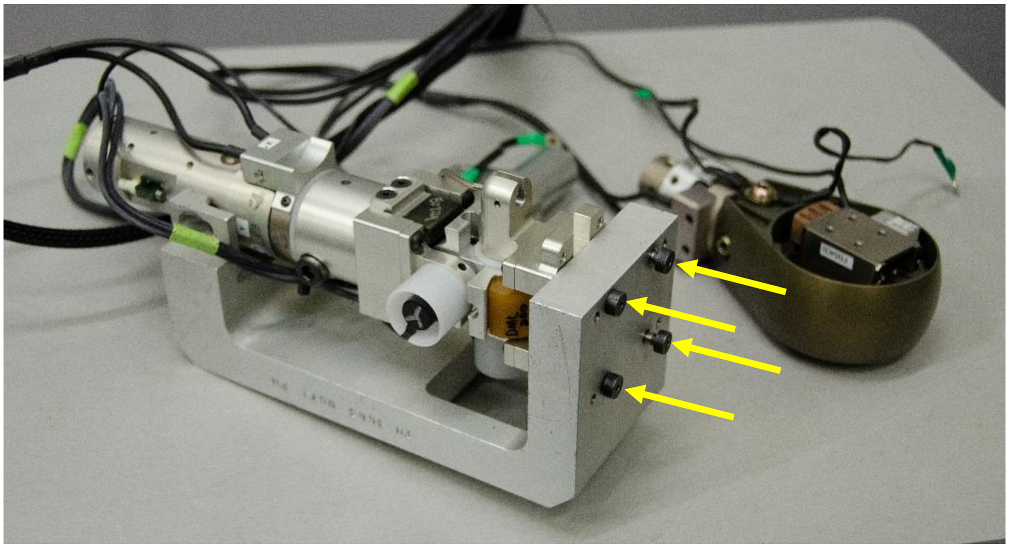


Figure 3-25. Attach lower leg zero bracket to lower ankle plate

3.6.9 Secure the lower leg zero bracket (TH-1603-0671-PR) to the lower tibia shaft (474-5540) using two M6 SHSS (Figure 3-26).

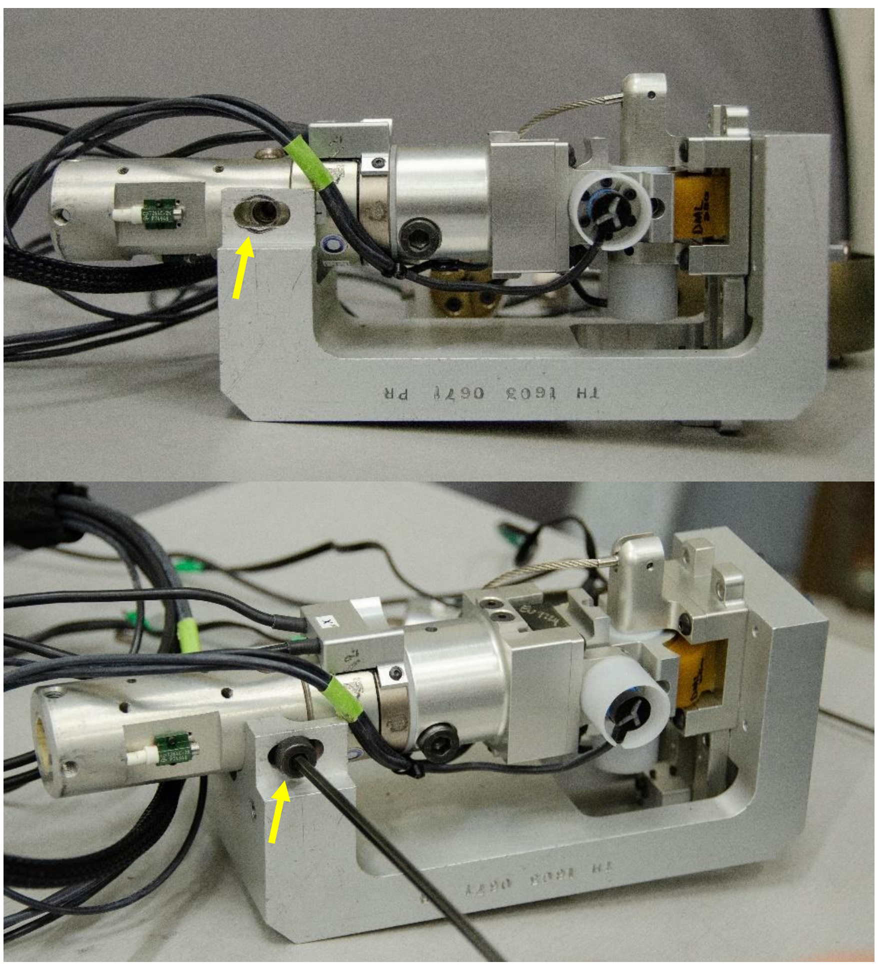


Figure 3-26. Secure lower leg zero bracket to lower tibia shaft

3.6.10 Ensure that the potentiometers are installed so that they will not pass through the electrical dead band at any point in the ankle's range of motion. Turn the potentiometer housing on the X-axis and Y-axis potentiometers until the potentiometer output is approximately 0 ± 10 deg so that the potentiometer is near mid-range (Figure 3-27). Note that the Z-axis potentiometer cannot be adjusted while in the lower leg zero bracket, but instead should be set near 0 deg (0 ± 10 deg) by following the assembly procedures described in the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

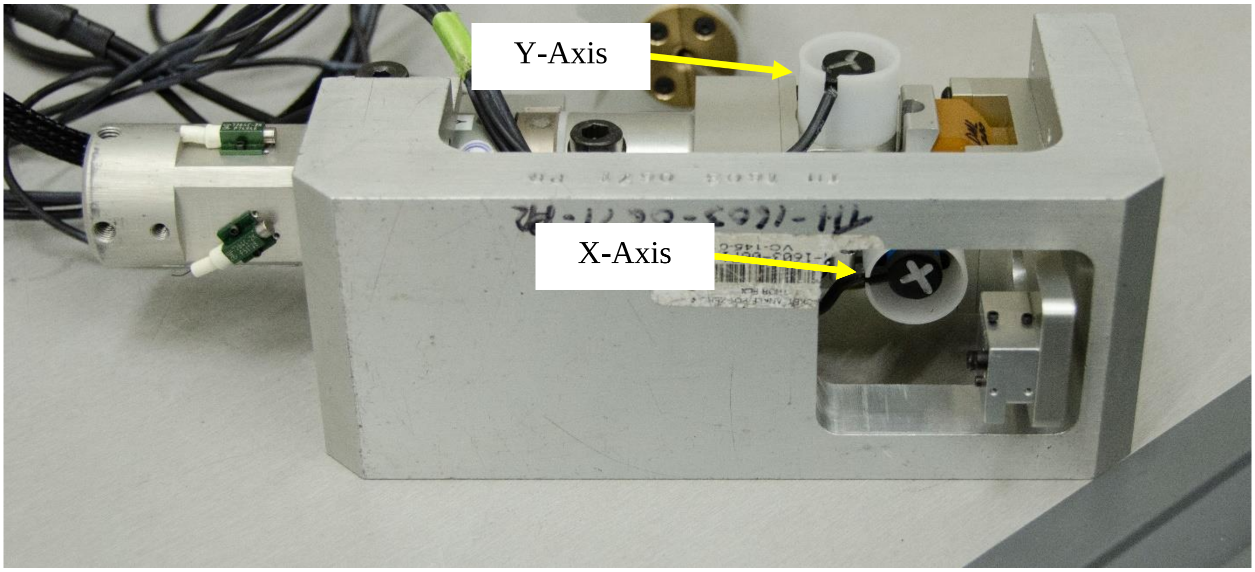


Figure 3-27. Set X-axis and Y-axis potentiometers near zero degrees

3.6.11 Record zero reference values for the X, Y, and Z potentiometers at this position:

Rotational Potentiometer	Serial Number	Zero Reference Value (degrees)
X-axis		
Y-axis		
Z-axis		

3.6.12 Remove the ankle zero bracket by removing four M4 x 25mm SHSS and two M6 SHSS (Figure 3-25 and Figure 3-26).

3.6.13 If the Achilles Cable Adjustment Procedure will be conducted immediately following this procedure, follow the steps below. Otherwise, this procedure is now complete and the lower leg can be reassembled by following the assembly procedures described in the THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

3.7 Achilles Cable Adjustment Procedure

The THOR-05F lower leg assembly (474-5500) was designed with an adjustable Achilles cable (474-5530) which can change the engagement point of the Achilles relative to the ankle rotation angle. The following procedure describes the verification and adjustment of the Achilles cable (474-5530) tension using a fixture that is used in other lower leg qualification tests.

Materials: THOR-05F lower leg assembly (474-5500), inversion/eversion test bracket (TH-1603-0675) mounted to the rigid fixture for ball of foot testing, load cell guide bar (TH-1603-0686-PR), pull wire.

Instrumentation: Tension load cell (5001500V), Y-axis ankle rotational potentiometer (SA572-S114), X-axis ankle potentiometer (for orientation), Z-axis ankle potentiometer (for orientation)

3.7.1 Ensure that the ankle rotary potentiometer zeroing procedure has been completed prior to beginning this procedure (Section 3.6).

3.7.2 Follow the leg disassembly instructions in Sections 3.6.2 through 3.6.7.

3.7.3 Remove the X-axis and Y-axis tibia accelerometers (Figure 3-28).

Figure 3-28. Remove X-axis and Y-axis tibia accelerometers

3.7.4 Check that the mounting surface for the inversion/eversion test bracket is level (Figure 3-29). Mount the inversion/eversion test bracket to the level rigid surface using four 1/2”-13 x 1.25” SHCS (Figure 3-30 and Figure 3-31).

Figure 3-29. Assure mounting surface for inversion/eversion bracket is level

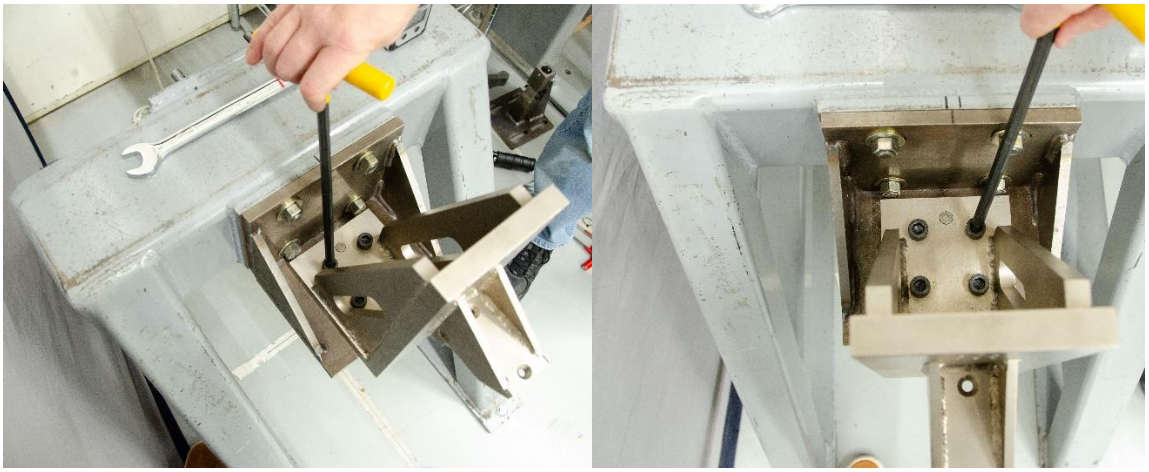


Figure 3-30. Install inversion/eversion bracket to level rigid surface

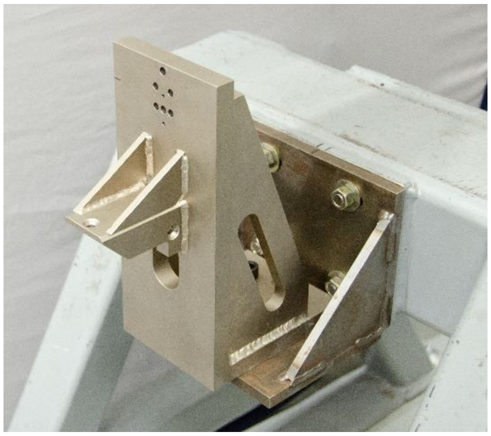


Figure 3-31. Side view of lower leg into inversion/eversion test bracket

3.7.5 Insert the lower tibia shaft into the inversion/eversion bracket with the toe pointed up. Remove the front W50-61042 BHCS that attaches the lower tibia shaft (474-5540) to the lower tibia load cell (Figure 3-32).

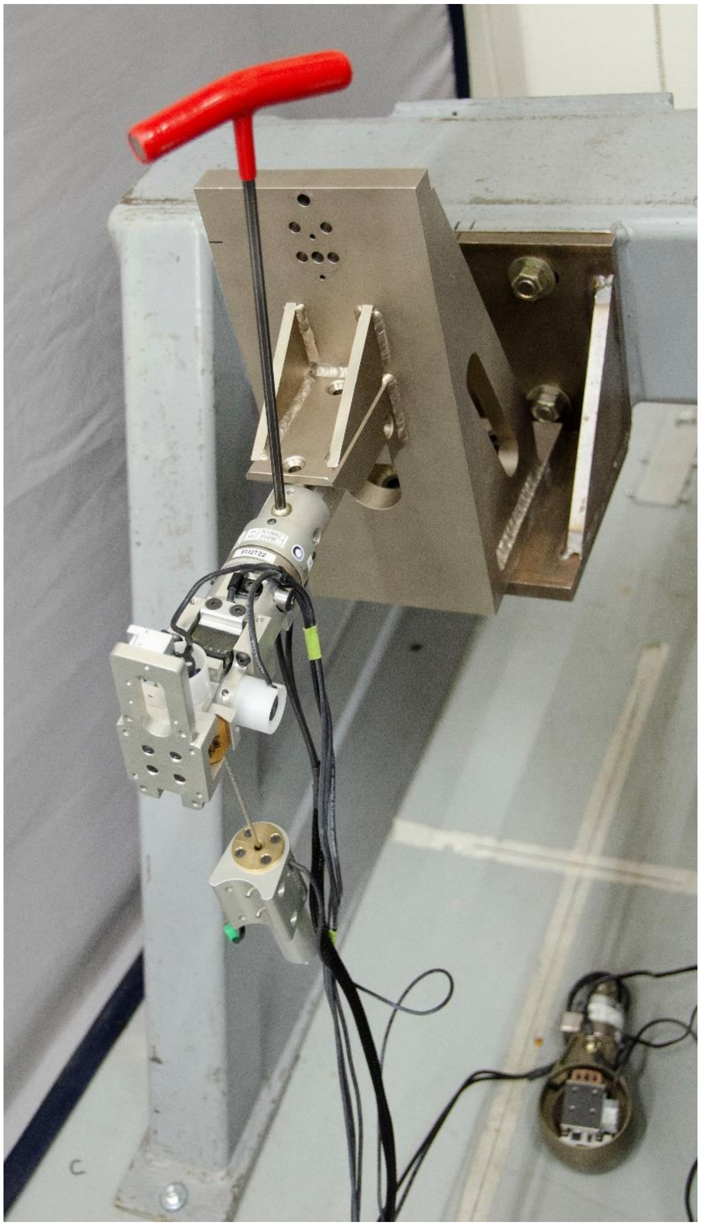


Figure 3-32. Remove front screw on lower tibia shaft

3.7.6 Attach the leg to the test bracket using four M6-1.0 X 18 FHSS, two on top and one on either side (Figure 3-33).

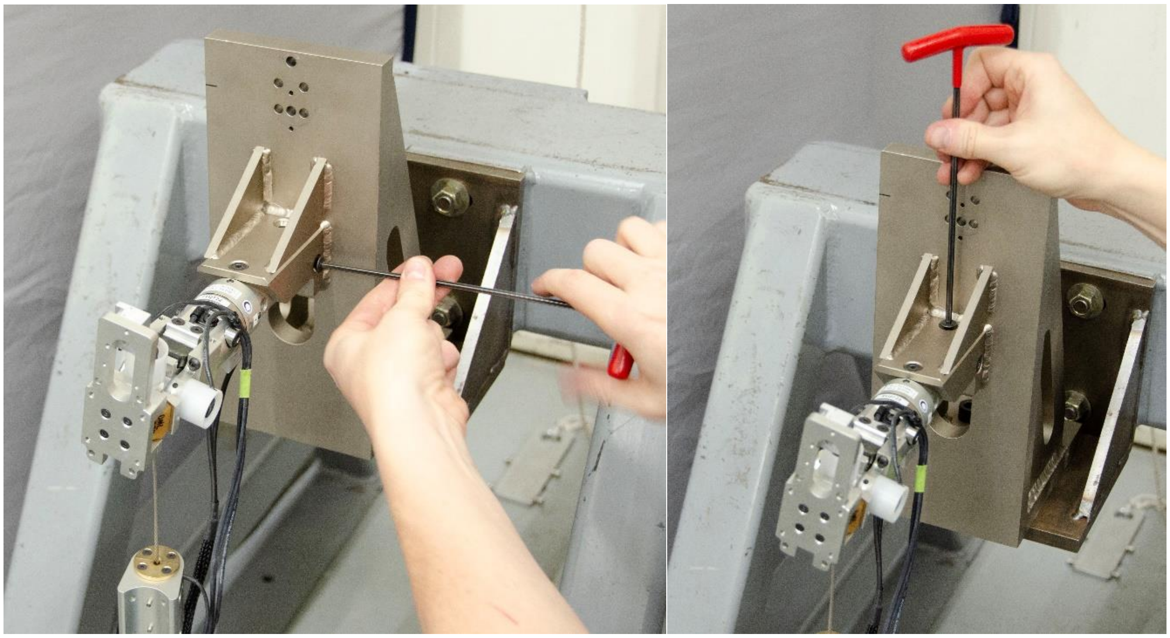


Figure 3-33. Install screws through test bracket into lower tibia

3.7.7 Reinstall the two Modified BHSS M6 Thread bolts (W50-61042) on the left and right sides of the Lower Tibia Shaft (Left) (474-5540) (Figure 3-34).

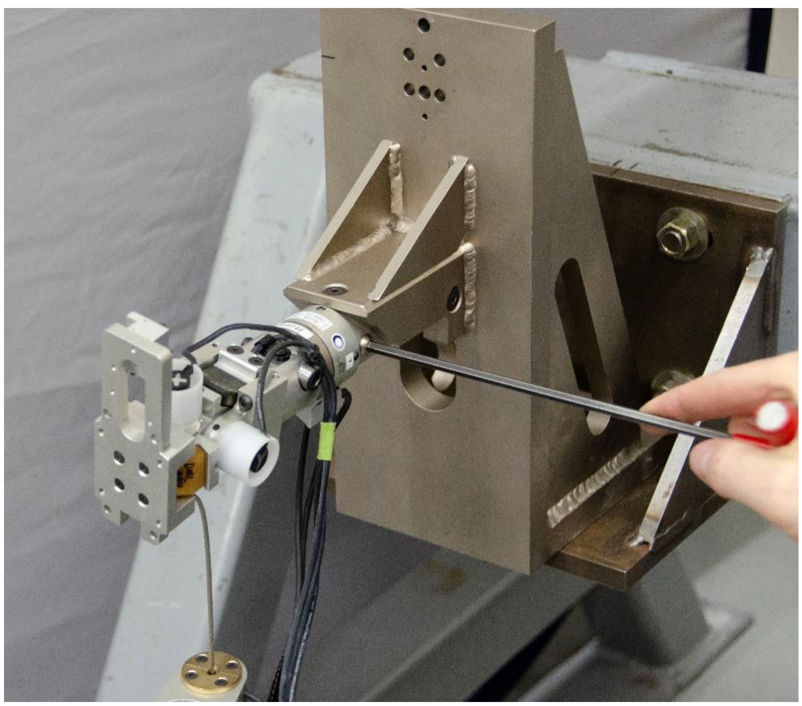


Figure 3-34. Reinstall screws into side of lower tibia shaft

3.7.8 Reattach the Achilles assembly by installing the four M4 X 0.7 X 12 LHCS (two per side) which attach the Lower Achilles spring housing (474-5504) to the rear of the lower tibia shaft (474-5540) (Figure 3-35).

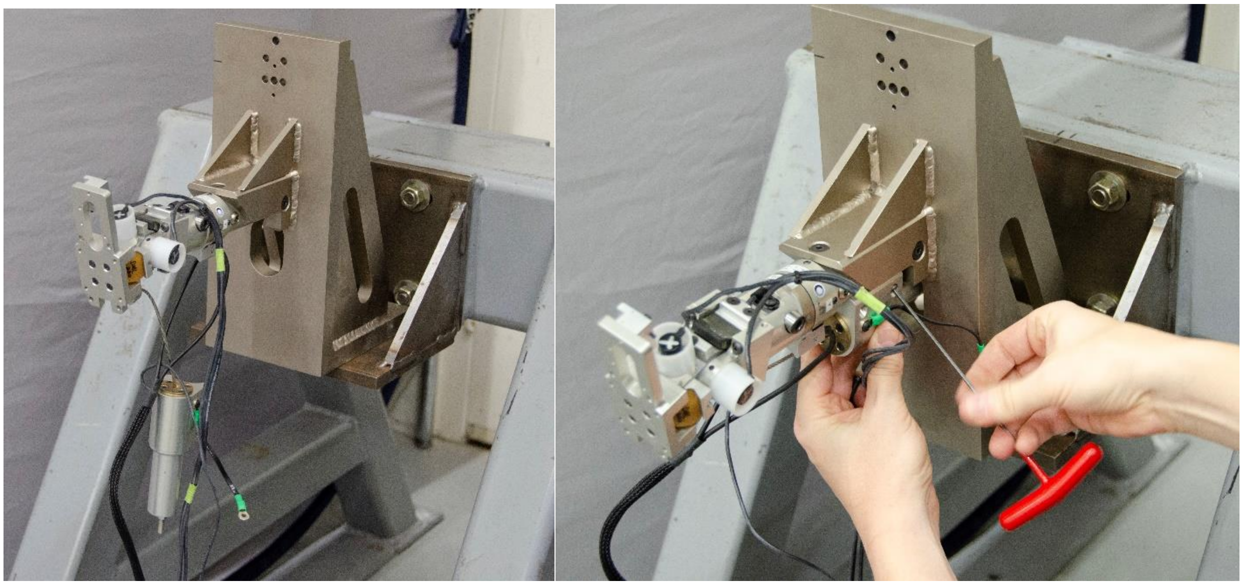


Figure 3-35. Install Achilles assembly

3.7.9 Tighten the adjustment nut on the Achilles assembly until there is no slack in the cable when the leg is resting in the neutral position against the plantar flexion bumper. NOTE: No slack should be achieved when the plastic primary load washer (474-5529) is flush with the top of the Achilles spring housing (474-5525) (Figure 3-36). Using two 8 mm thin-profile wrenches, lock the adjustment nut in this position using the jam nut.

Figure 3-36. Plastic washer flush with the top of the Achilles spring housing

3.7.10 Attach the inversion/eversion test bracket (with pull hook installed) to the bottom of the Lower Ankle Plate (474-5806-1,2) using four SHCS M4x0.7x20 (Figure 3-37).

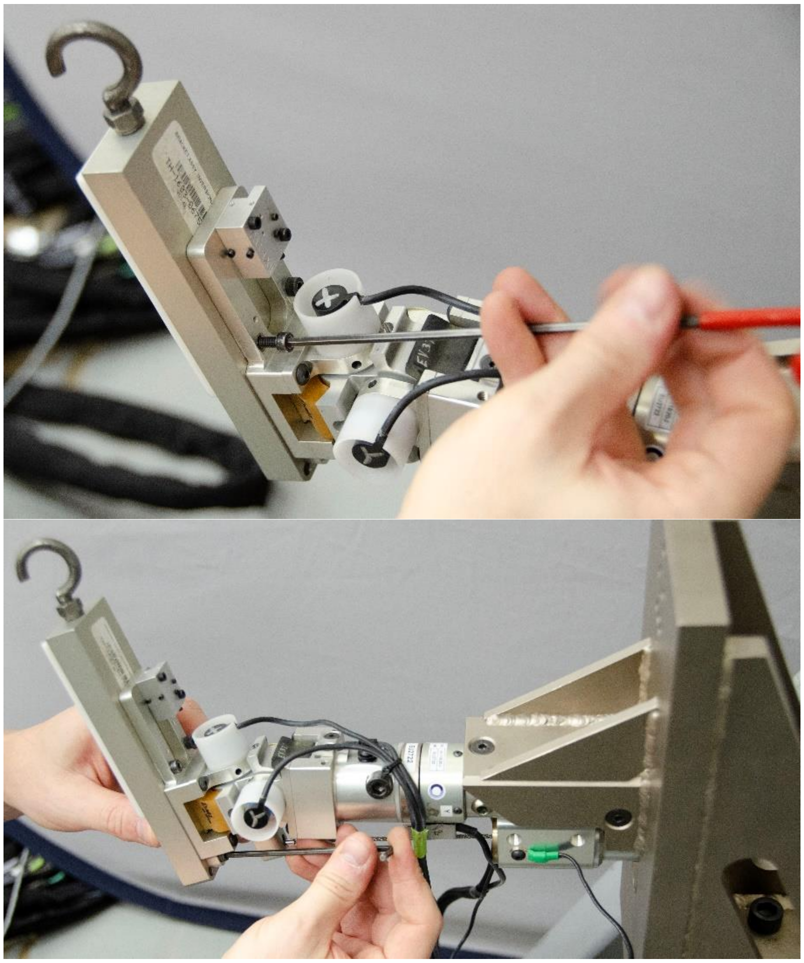


Figure 3-37. Attach inversion/eversion test bracket with hook to bottom of lower ankle plate

3.7.11 Mount the load cell guide bar (TH-1603-0686-PR) into the inversion/eversion bracket with the PTFE pad facing up (Figure 3-38); install a SHCS from the back of the fixture to secure the guide bar (Figure 3-39).

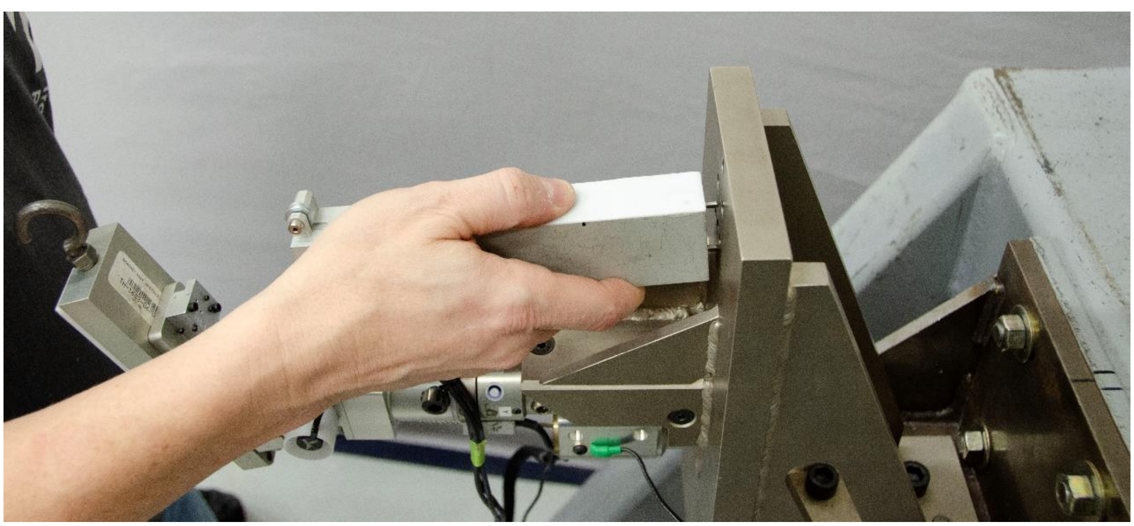


Figure 3-38. Mount load cell guide bar into inversion/eversion bracket

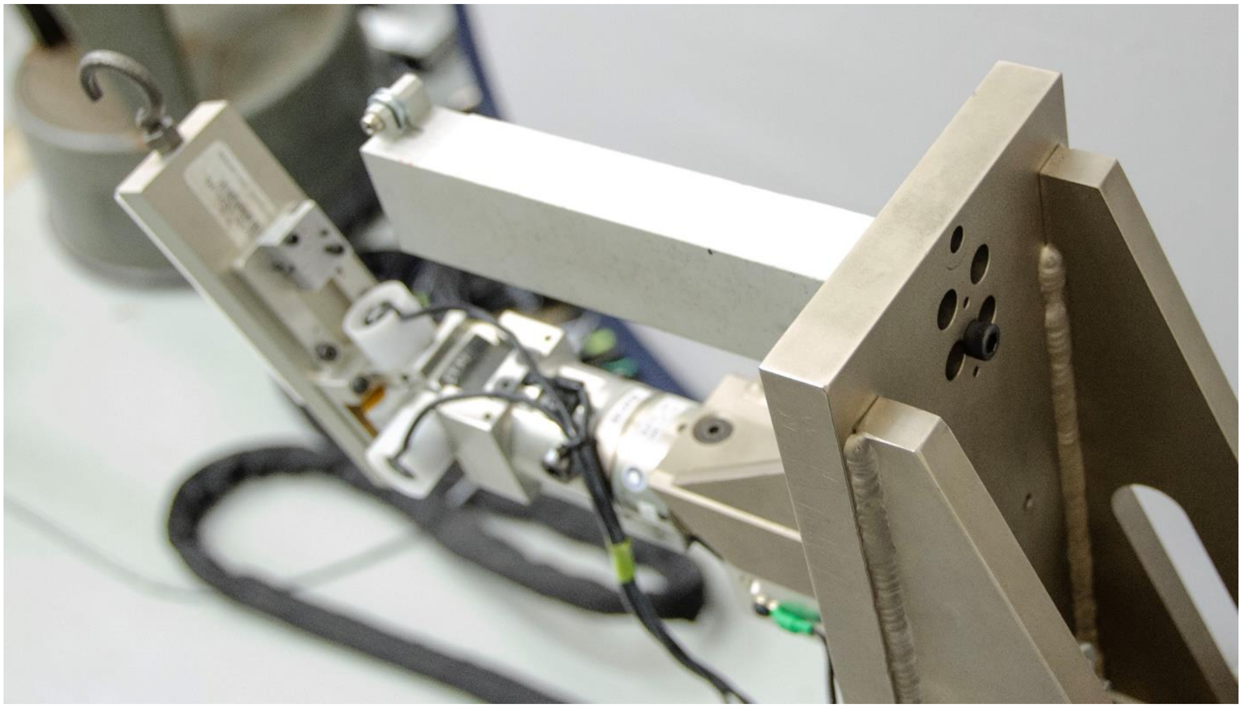


Figure 3-39. Secure the load cell guide bar with screw

3.7.12 The assembly for measuring Achilles tension is shown in Figure 3-40. Insert the threaded rod attached to the tension load cell through the hole in the inversion/eversion fixture using two flat M6 washers with a thrust bearing between them and the hex nut (Figure 3-41). Attach one loop end of the pull wire to the wire hook connected to the tension load cell (DL472-4204) and the other to the hook on the inversion/eversion test bracket. Ensure that the pull wire is centered in the groove of the pulley.

Figure 3-40. Tension load cell for measuring Achilles load during adjustment procedure

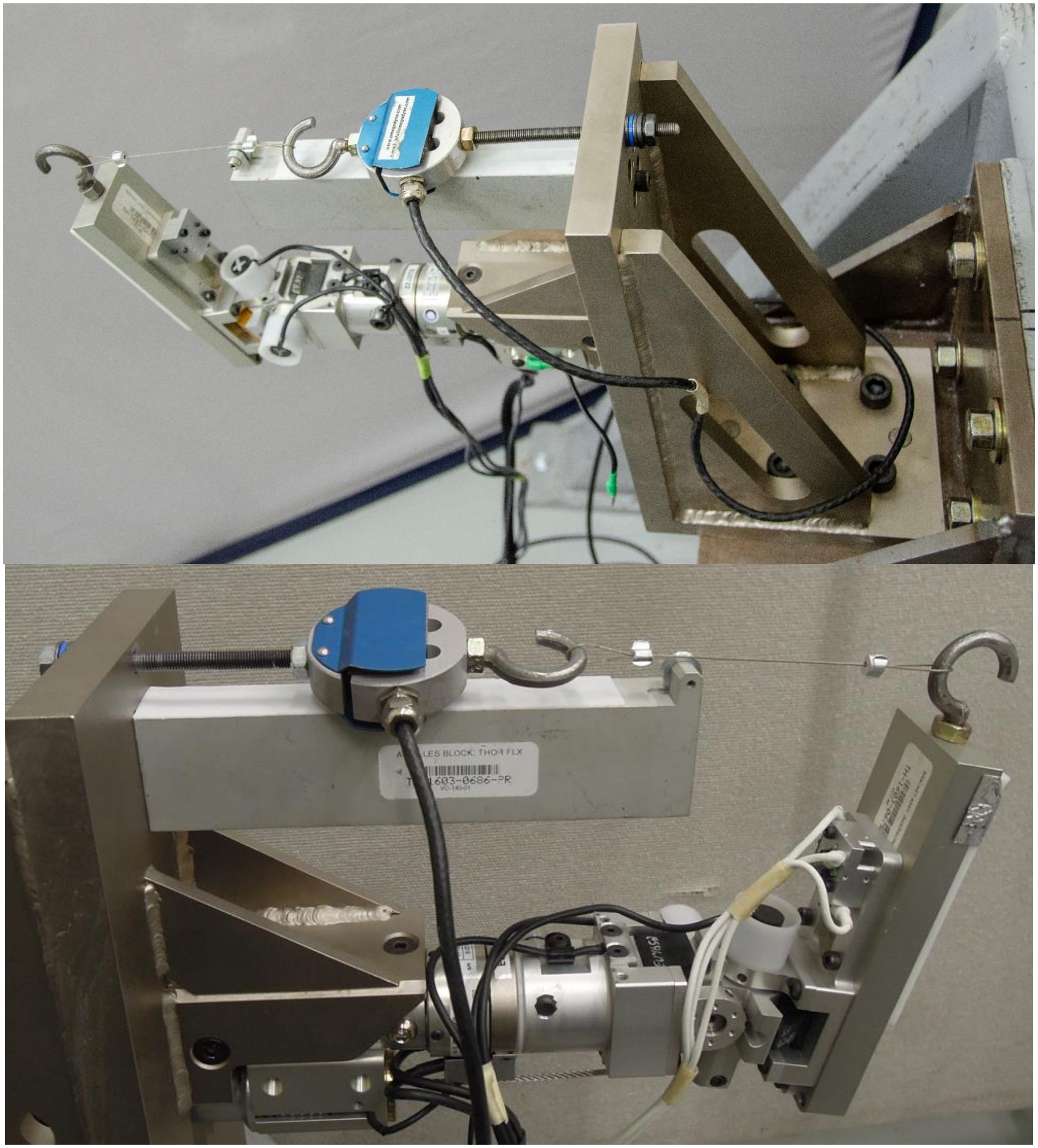


Figure 3-41. Achilles tension setup

3.7.13 Apply any necessary corrections developed in Section 3.6 to the ankle potentiometer time-history data to ensure that any positioning of the ankle rotations are relative to the position of the ankle when it was fixed within the inversion/eversion test bracket.

3.7.14 Position the ankle X-axis and Z-axis positions to 0 degrees (±0.5) by adjusting the foot about each axis until 0 degrees is achieved.

3.7.15 Zero the initial value of the tension load cell. Do not zero the ankle potentiometers.

3.7.16 At this point, the toe section of the foot plate should rest in plantarflexion (e.g. the toe is further away from the pulley than it would be in the *zero position*). If it is not, loosen the ¼-28 hex flange nut on the draw screw until the toe is in plantarflexion.

3.7.17 Set the system to record approximately 35 seconds of data, collected at 500Hz. Time zero is defined as the instant when that the ankle begins rotating.

3.7.18 Using a drill with a (long) hex nut bit, tighten the ¼-28 hex flange nut on the draw screw so that the foot moves in dorsiflexion and the ankle Y-axis potentiometer passes through the zero ankle position. The foot should be in dorsiflexion beyond the zero position at the completion of this task (Figure 3-42). Reverse the direction of the drill to unload the tension on the pull wire completely.

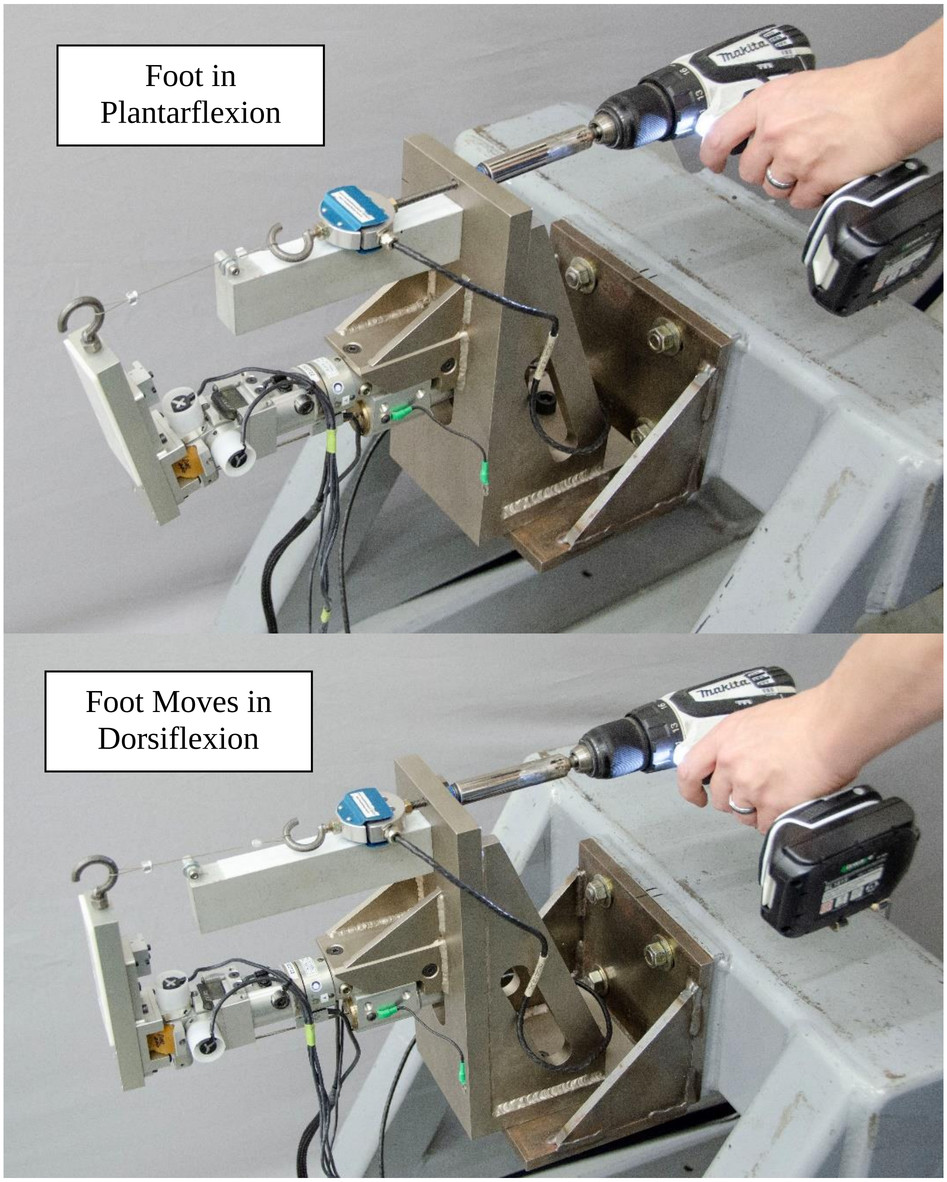


Figure 3-42. Performing the Achilles tension adjustment

3.7.19 Filter the Y axis rotation and force measured by the tension load cell using a 1 Hz (fourth order) Butterworth filter. Review the *loading* data and find the tension when the angle is closest to the zero position. If the measured force is between 3-6 N at 0° of ankle flexion, this procedure is complete. Otherwise, proceed to the next step.

3.7.20 The Achilles spring tension must be adjusted if it does not meet the tension criteria. Locate the jam nuts at the top of the spring tube (Figure 3-43). If the tension is higher than the prescribed target tension, loosen both M5 hex jam nuts and move them slightly up the Achilles cable (474-5530), releasing some tension on the compression spring assembly. If the tension is lower than the prescribed target tension, loosen the outer M5 hex jam nut and screw the inner nut slightly down the Achilles cable (474-5530), increasing tension on the compression spring assembly. Once adjustments are made, with one wrench maintaining the position of the inner adjustment nut, tighten the outer jam to 1.5 N-m. Return to Section 3.7.17; repeat the procedure as necessary, adjusting tension until a reading between 3-6 N at 0° of ankle flexion is achieved (Section 3.7.19).

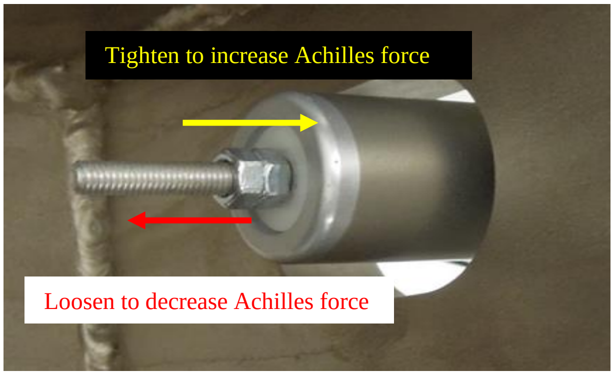
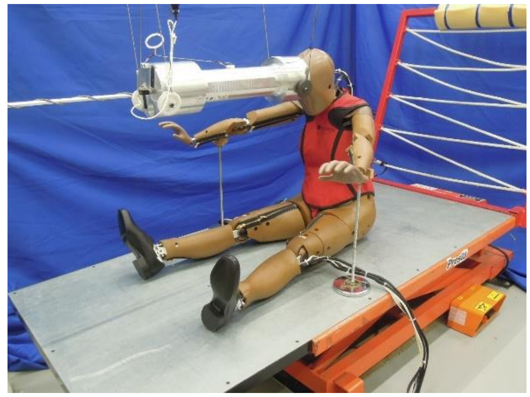


Figure 3-43. Adjusting tension on the Achilles.

3.7.21 This procedure is now complete and the lower leg can be reassembled by following the assembly procedures described in the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

4 HEAD QUALIFICATION



4.1 Description

The head qualification test is a dynamic test performed to examine the force-time and acceleration-time characteristics of the head when impacted on the forehead with a 19.2 kg rigid impactor at 2.00 m/s.

4.2 Materials

- Fully-assembled THOR-05F ATD (474-0000)
- Impactor 19.2 ± 0.02 kg in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables. The test probe is a 152.40 ± 0.3 mm diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 12.7 ± 0.3 mm.

4.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- Head center of gravity tri-axial accelerometers (SA572-S4)
- A dual-axis tilt sensor (SA572-S44) attached to head accelerometer mounting plate assembly (474-1031) to measure initial angle about “X” and “Y” axes
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about “X” and “Y” axes

4.4 Pre-Test Procedures

4.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

4.4.2 Set the LTS pitch change joint to the **slouched** position (see Section 3.1).

4.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

4.5 Test Procedure

4.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the “THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)”.

4.5.2 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward. The midsagittal plane shall be vertical within ±1 degree.

4.5.3 Support the forearms in a fully-extended orientation, palmside of the hands down, with hands angled upwards to minimize interference with the arm supports (Figure 4-1). The inability to hold this position indicates that the arm and shoulder joint torques are not set in accordance with Section 3.3.

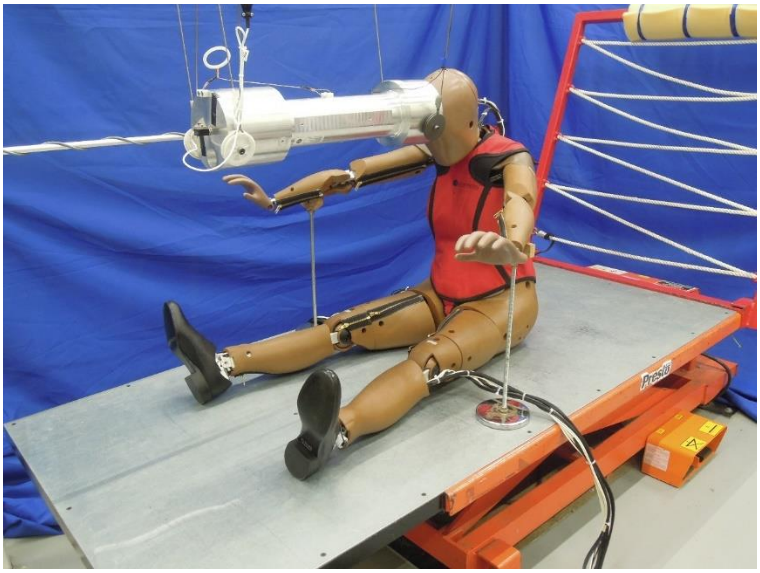


Figure 4-1. Initial setup for head qualification test.

4.5.4 Position the pelvis so that the pelvis tilt sensor reads 0 ± 0.5 deg laterally (about the X-axis) and 8 ± 1 deg (rearward tilt about the Y-axis).

4.5.5 Set the head so that the angle measured by the head CG tilt sensor is 0 ± 0.5 deg laterally (about the X-axis) and -29 ± 1 deg (forward tilt about the Y-axis) (Figure 4-2).

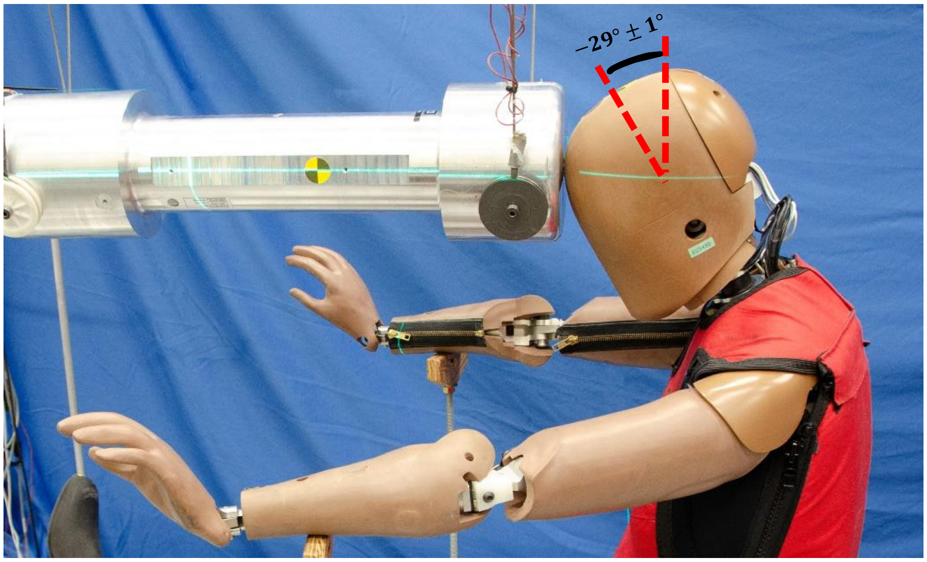


Figure 4-2. Angle of head and alignment with impactor

4.5.6 Position the dummy so that the head is just touching the impactor face when the probe is at its lowest position (at rest) (Figure 4-2). The dummy should be seated so that the centerline of the probe axis aligns with the dummy's midsagittal plane (Figure 4-3).

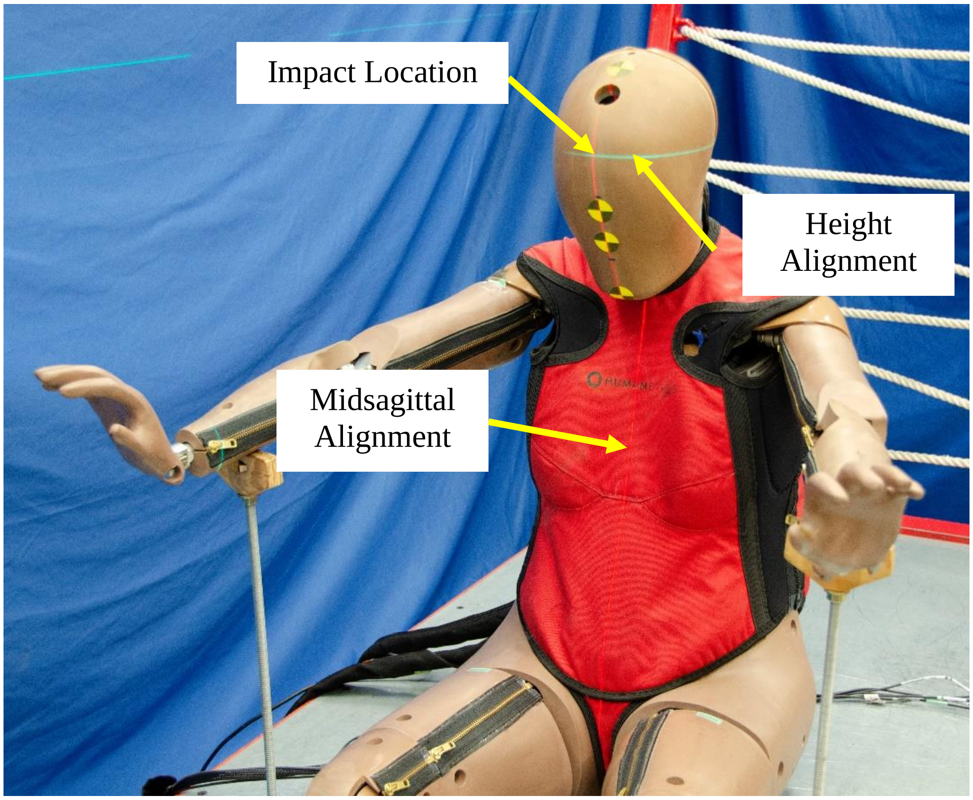


Figure 4-3. Alignment for impact location

4.5.7 Adjust the table height or impactor height so that the center of the impactor face is aligned with the head center of gravity (Figure 4-3) as indicated by a notch on the side of the head skin (Figure 4-4). A laser or a removable pointer, threaded into the centerline of the pendulum with approximately 30mm protruding, will aid this process (Figure 4-5). Remove the pointer tool when this step has been completed.

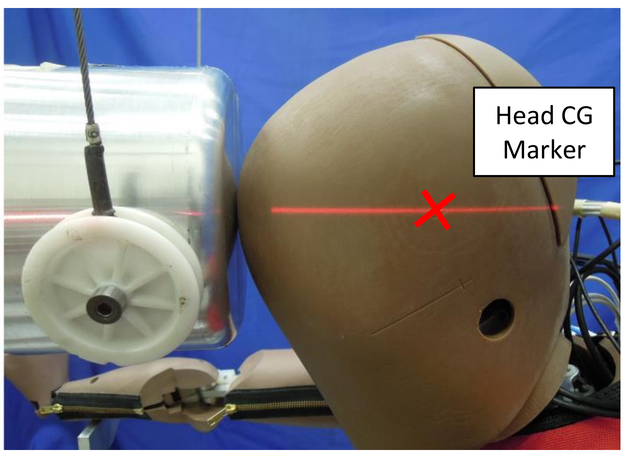


Figure 4-4. Vertical height set up during head impact test

Figure 4-5. Pointer tool for alignment (optional)

4.5.8 The probe at rest should just be contacting the head. If it is not, carefully adjust the dummy position relative to the probe while maintaining setup angles for impact position.

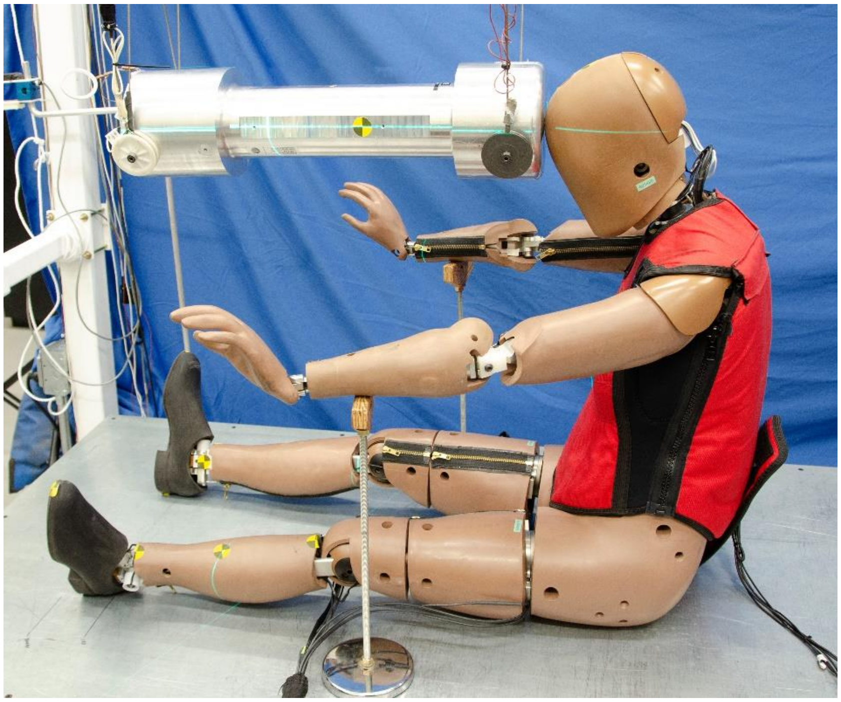


Figure 4-6. Final setup for head qualification

4.5.9 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement.

4.5.10 Record the AM channels listed in Table 4-2 in accordance with SAE J211-1.

4.5.11 Confirm the test setup parameters illustrated in Table 4-1.

Table 4-1. Head Impact Test Setup Parameters

Parameter	Setting
LTS Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: Head	X = 0 ± 0.5°; Y = -29° ± 1°
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 8 ± 1º
Wait Time Between Tests	At Least 60 Minutes

4.5.12 Ensure that at least 60 minutes have passed since the last test on the head or face.

4.5.13 Conduct the test at an impact velocity of 2.00 ± 0.05 m/s.

4.6 Data Processing

4.6.1 Perform bias removal of the AM channels listed in Table 4-2 by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

4.6.2 Filter channels basd on the CFC filter classes listed in Table 4-2.

4.6.3 Calculate time-history of impact force at the contact interface (see Section 2.7).

4.6.4 Calculate head CG resultant acceleration:

$$HDCG_R(t) = \sqrt{HDCG_X^2 + HDCG_Y^2 + HDCG_Z^2}$$

Where:

$HDCG_R(t)$ = time history of head CG resultant acceleration

$HDCG_x(t)$ = time history of head X acceleration

$HDCG_y(t)$ = time history of head Y acceleration

$HDCG_z(t)$ = time history of head Z acceleration

Table 4-2. Required Meaurement Channels for the Head Impact Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Probe Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Probe Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Head CG Accelerometer, X-axis	1000	D0HEAD0000TFACXA	XL	AM	HDCG	AC	G'S
Head CG Accelerometer, Y-axis	1000	D0HEAD0000TFACYA	YL	AM	HDCG	AC	G'S
Head CG Accelerometer, Z-axis	1000	D0HEAD0000TFACZA	ZL	AM	HDCG	AC	G'S
Head CG Resultant Accelerometer	N/A	D0HEAD0000TFACRA	RS	CM	HDCG	PP	G'S

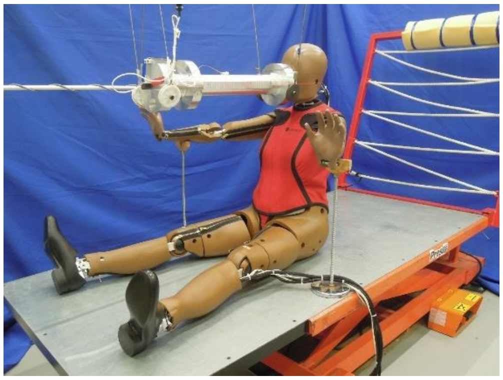
4.7 Performance Specification

Table 4-3. Head Impact Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Peak Probe Force	N	4566	5581
Peak Head CG Resultant Acceleration	G	140	171

5 FACE QUALIFICATION

5.1 Description



The face qualification test examines facial impact response to loading by a rigid 152.4 mm diameter circular disk attached to a 10.70 kg impactor at a velocity of 6.73 m/s.

5.2 Materials

- Fully-assembled THOR-05F ATD
- Impactor 10.70 ± 0.02 kg in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables. The test probe is a 152.40 ± 0.3 mm diameter rigid cylinder. The impacting surface must have a flat, right angle face with an edge radius of 12.7 ± 0.3 mm.

5.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- Head CG tri-axial accelerometers (SA572-S4)
- A dual-axis tilt sensor (SA572-S44) attached to head accelerometer mounting plate assembly (474-1031) to measure initial angle about "X" and "Y" axes
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about "X" and "Y" axes

5.4 Pre-Test Procedures

5.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

5.4.2 Set the LTS pitch change joint to the **erect** position (see Section 3.1). Note that this is the only test mode performed in the erect position.

5.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

5.5 Test Procedure

5.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

5.5.2 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward. The midsagittal plane shall be vertical within ±1 degree.

5.5.3 Support the forearms in a fully-extended orientation, palmside of the hands down, with hands angled upwards to minimize interference with the arm supports (Figure 5-1). The inability to hold this position indicates that the arm and shoulder joint torques are not set in accordance with Section 3.3.

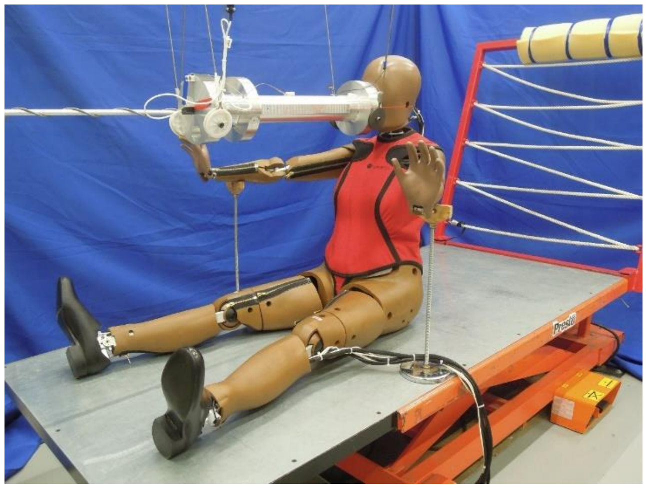


Figure 5-1. Initial setup for the face disk impact test

5.5.4 Position the pelvis so that the pelvis tilt sensor reads 0 ± 0.5 deg laterally (about the X-axis) and 7 ± 1 deg (rearward tilt about the Y-axis).

5.5.5 Set the head so that the angle measured by the head CG tilt sensor is 0 ± 0.5° laterally (about the X-axis) and 0 ± 1° about the Y-axis.

5.5.6 Position the dummy so that the face is just touching the probe when the probe is at its lowest position (at rest) (Figure 5-1). The dummy should be seated so that the centerline of the probe axis aligns with the dummy's midsagittal plane (Figure 5-2).

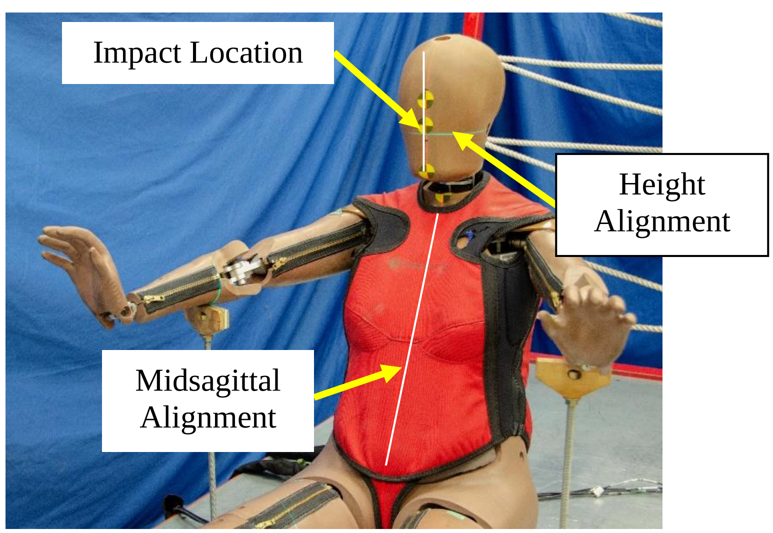


Figure 5-2. Alignment for impact location

5.5.7 Adjust the table height or impactor height so that the center of the impact face is aligned 61.8 mm below the head center of gravity (Figure 5-3) as indicated by a notch on the side of the head skin.

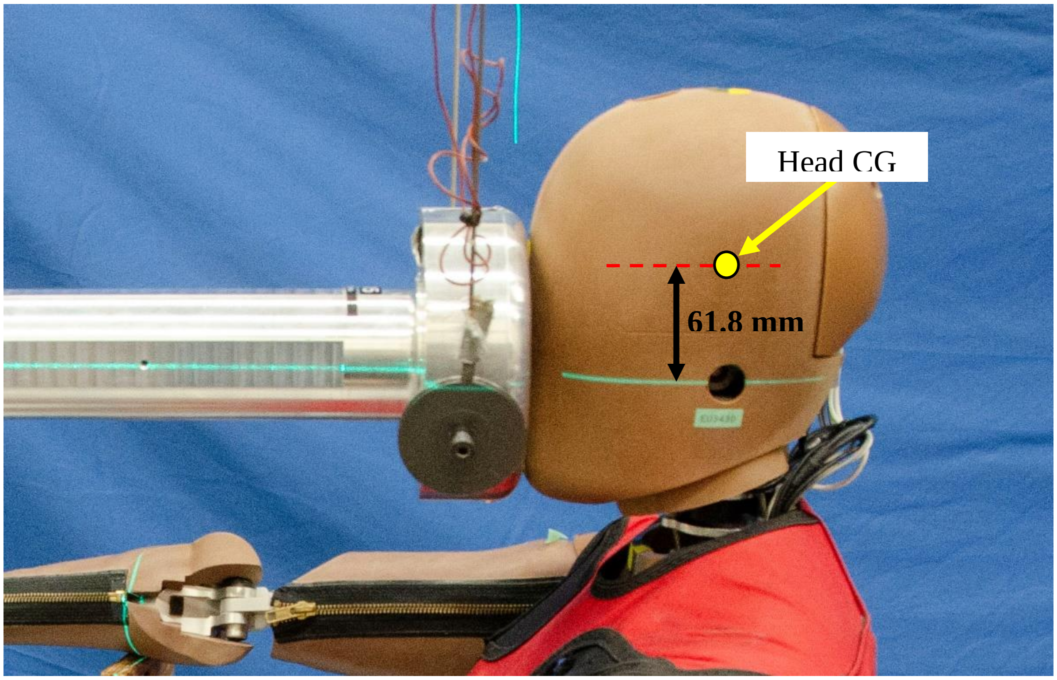


Figure 5-3. Positioning the center of the impact face to align impactor

5.5.8 The probe at rest should just be contacting the face. If it is not, adjust the dummy position relative to the probe while maintaining setup angles for impact position.

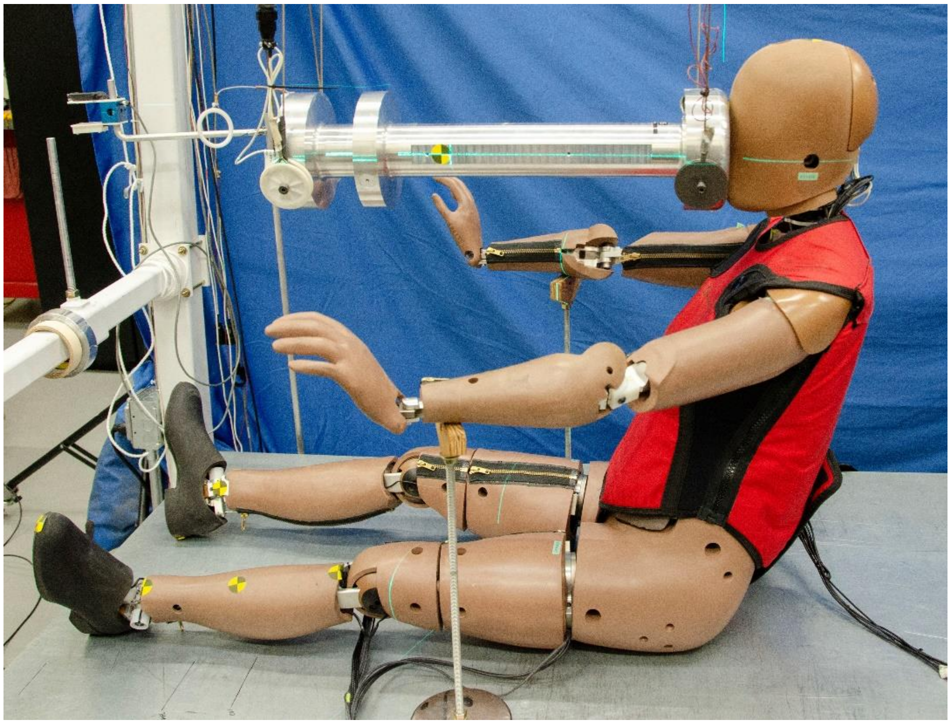


Figure 5-4. Final setup for face qualification

5.5.9 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement.

5.5.10 Record the AM channels listed in Table 5-2 accordance with SAE J211-1.

5.5.11 Confirm the test setup parameters illustrated in Table 5-1.

Table 5-1. Face Rigid Disk Impact Test Setup Parameters

Parameter	Setting
LTS Pitch Change Setting	Erect
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: Head	X = 0 ± 0.5º; Y = 0 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 7 ± 1º
Wait Time Between Tests	At Least 30 mins

5.5.12 Ensure that at least 60 minutes have passed since the last test on the head or face.

5.5.13 Conduct the test at a velocity of 6.73 ± 0.05 m/s.

5.6 Data Processing

5.6.1 Perform bias removal of the AM channels listed in Table 5-2 by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

5.6.2 Filter channels based on the CFC filter classes listed in Table 5-2.

5.6.3 Calculate time-history of impact force at the contact interface (see Section 2.7).

Table 5-2. Required Measurement Channels for Face Qualification

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Probe Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Probe Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT

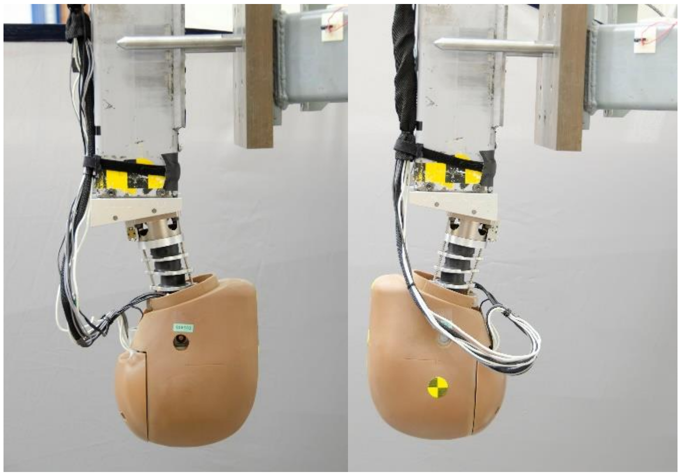
5.7 Performance Specifications

Table 5-3. Face Rigid Disk Impact Response Requirements with Honeycomb Face Insert

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	6.68	6.78
Maximum Probe Force	N	5469	6684

6 NECK QUALIFICATION

6.1 Summary



There are six procedures used to qualify the THOR-05F neck performance. Using a torsion fixture, a torsion test is conducted in the left and right directions to assess the response of the neck in rotation about its Z-axis. Flexion and extension tests resemble the Hybrid III 5th Percentile Female head-neck pendulum test defined in CFR Title 49, Part 572, Subpart O with 152.4 mm aluminum honeycomb used to decelerate the pendulum. The flexion and extension tests assess the neck performance in forward and rearward bending about the local Y-axis. The neck is also tested in a lateral mode resembling the SID-IIsD head-neck lateral pendulum test defined in CFR Title 49, Part 572, Subpart V using 76.2 mm aluminum honeycomb for pendulum deceleration. The lateral tests assess the neck performance in the left and right directions about the local X-axis. Logistically, the neck should be qualified in the torsion tests first, followed by the flexion, extension, and lateral tests.

6.2 Description

The neck qualification tests are dynamic tests performed to examine the moment, force, rotation, and angular velocity characteristics of the neck in torsion, frontal flexion, extension, and lateral flexion. The pendulum is decelerated from 5.00 m/s (frontal flexion, extension) or 3.40 m/s (torsion, lateral flexion) during contact with aluminum honeycomb.

6.3 Materials

- THOR-05F ATD head and neck assembly (474-1000 and 474-2000), including all neck spring hardware
- Head-neck pendulum (as defined in CFR Title 49, §572.33(c)3 and Figure 22).
- Neck mounting plate with 10° offset (TF-200-2357) to attach the lower neck load cell to the pendulum (Figure 6-1).

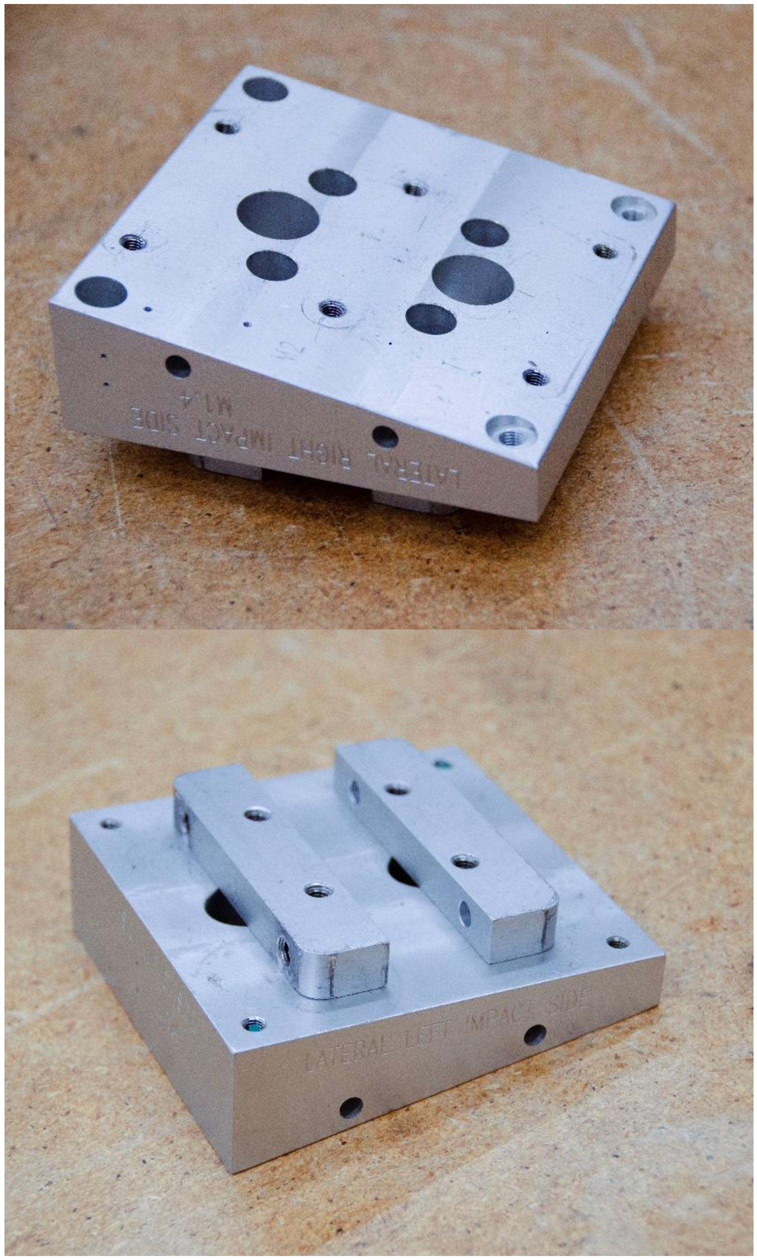


Figure 6-1. Neck mounting plate with 10° offset

- 152.4 mm deep aluminum honeycomb[2] used for decelerating the pendulum in flexion and extension modes.
- 76.2 mm deep aluminum honeycomb used for decelerating the pendulum in lateral and torsion modes.
- Neck torsion fixture (DL472-1000) with upper and lower neck THOR-05F adaptors.

[2] In all tests, length and width of the honeycomb may be varied to achieve the required deceleration pulse.

6.4 Instrumentation

- Pendulum accelerometer
- Instrumentation to measure impact velocity
- Instrumentation to determine Time Zero (T_0)
- Upper neck 6-axis load cell (SA572-S105)
- 3 ARS in the head (X, Y, Z) (SA572-S58)
- Rotational potentiometer on neck torsion fixture (SA572-S51)
- Pendulum ARS
    - Mount the ARS to a surface on the pendulum arm that is perpendicular to the plane of motion of the pendulum's longitudinal axis, such that the rotational velocity about the global Y-axis is recorded (Figure 6-2). Set the polarity of the pendulum ARS such that the rotation of the pendulum towards the honeycomb decelerator results in a positive angular velocity before impact.

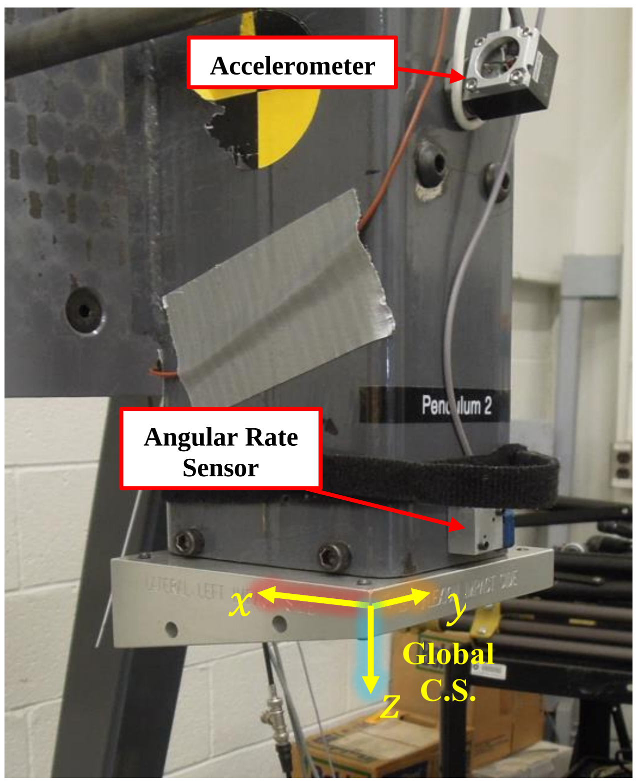


Figure 6-2. Installation of ARS on pendulum

- Front and rear neck spring load cells (SA572-S112)

6.5 Pre-Test Neck Setup Procedure

Before the neck qualification procedures are performed, the neck spring towers must be properly installed, adjusted, and locked in place using jam nuts at the top of the front and rear towers (Figure 6-3). *Once the spring tower adjustment has been made and neck qualification tests have* *been performed, **<u>do not</u>** adjust the spring towers again or new neck qualification tests must be performed.*

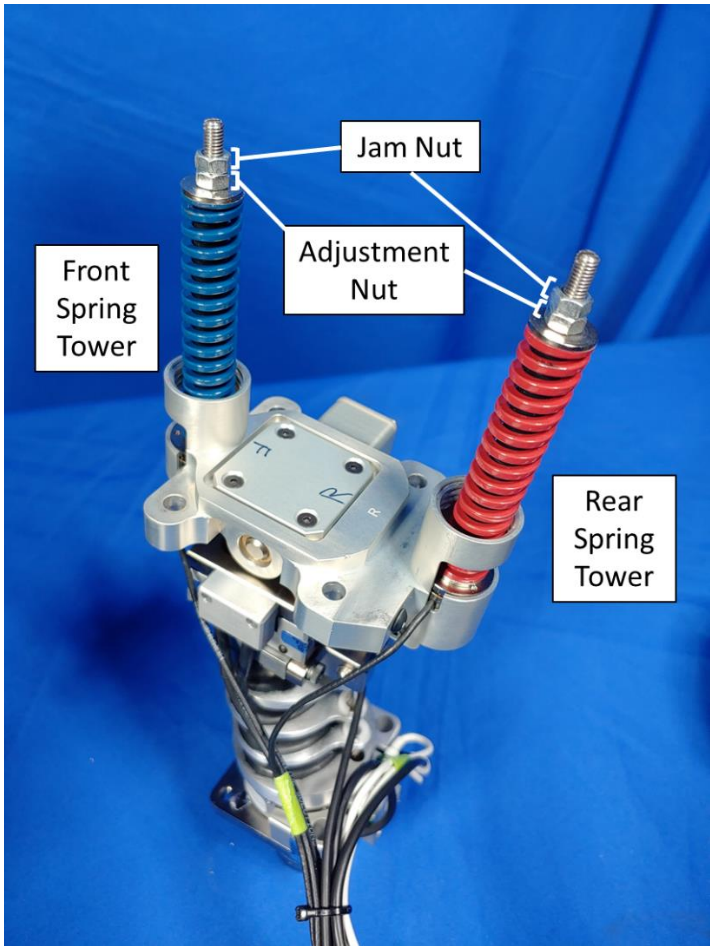


Figure 6-3. Neck spring tower jam nut configuration

6.5.1 <u>Head and Neck Removal</u>

6.5.1.1 Uninstall the neck/head assembly (including the lower neck load cell) from the torso by removing the four M5 X 0.8 X 16 mm SHCS (two anterior and two posterior) that hold the base of the lower neck load cell to the torso (Figure 6-4).

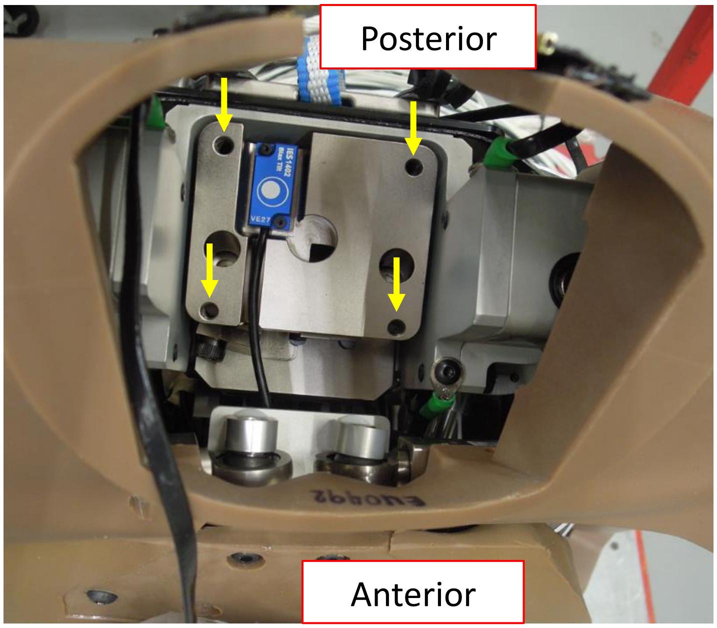


Figure 6-4. Removal of bolts that attach neck to torso

6.5.2 Spring Adjustment

6.5.2.1 Uninstall the Skull Cap (474-1020) and Cap Skin (474-1025) by removing the four M6 X 1 X 20 mm LHCS attaching it to the skull assembly (Figure 6-5).

Figure 6-5. Uninstall the Skull Cap and Cap Skin

6.5.2.2 Remove the Head Skin (474-1008) from the skull by first spreading the posterior portion away from the groove at the rear of the skull assembly, then pulling the top of the head skin forward and down (Figure 6-6).

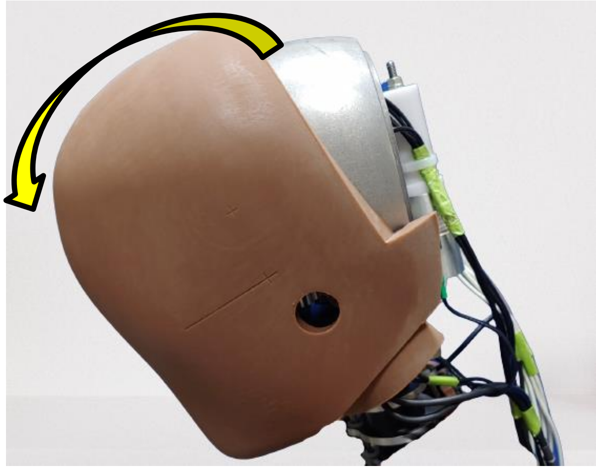


Figure 6-6. Remove the Head Skin

6.5.2.3 Remove the four M6 X 1 X 25 LG. SHCS at the bottom of the head/neck platform assembly (474-2300) to disconnect the head from the neck (Figure 6-7). Separate the head and neck by pulling the neck away from the head in a direction parallel to the neck column until the front spring tower is completely outside of the skull. If installed, remove the head instrumentation. The isolated neck assembly (474-2000-A) is shown in Figure 6-8.

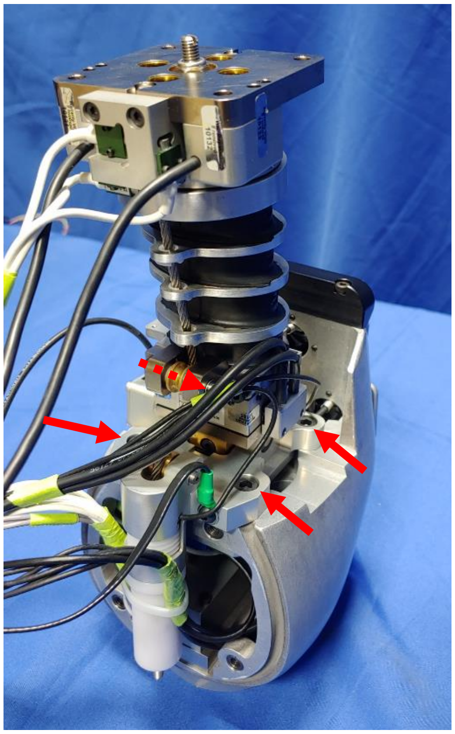


Figure 6-7. Remove the head from the neck by removing four M6 x 25 LG. SHCS from the bottom of the head/neck platform assembly

Figure 6-8. THOR-05F Neck Assembly

6.5.2.4 Remove the front and rear spring tubes (474-2303) by unscrewing by hand from the head/neck mounting platform (Figure 6-9).

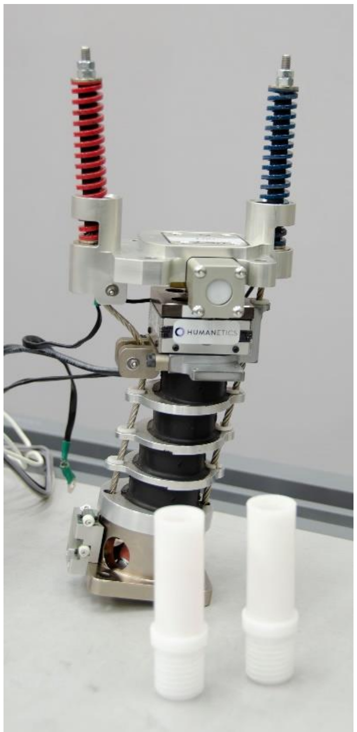


Figure 6-9. Remove front and rear spring tubes

6.5.2.5 Remove the stop assembly (474-2115) by removing four M3 x 0.5 x 8 LG FHCS from the head/neck mounting platform (474-2302) (Figure 6-10).

Figure 6-10. Remove stop assembly

6.5.2.6 Attach the lower neck load cell (474-2325) to the 10° neck mounting plate (TF-200-2357) with four M5 X 0.8 X 16mm SHCS (Figure 6-11)**.**

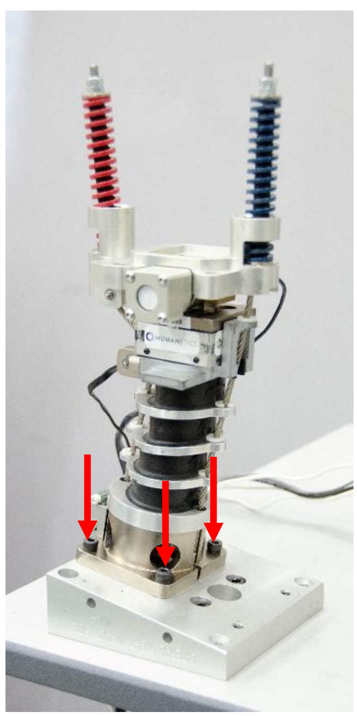


Figure 6-11. Attach lower neck load cell to 10° neck mounting plate

6.5.2.7 Zero an inclometer on a rigid, flat horizontal surface (Figure 6-12). Adjust and stabilize the neck mounting plate so an inclinometer reads 10.0 ± 0.2° about the Y-axis and 0 ± 0.5° about the X-axis.

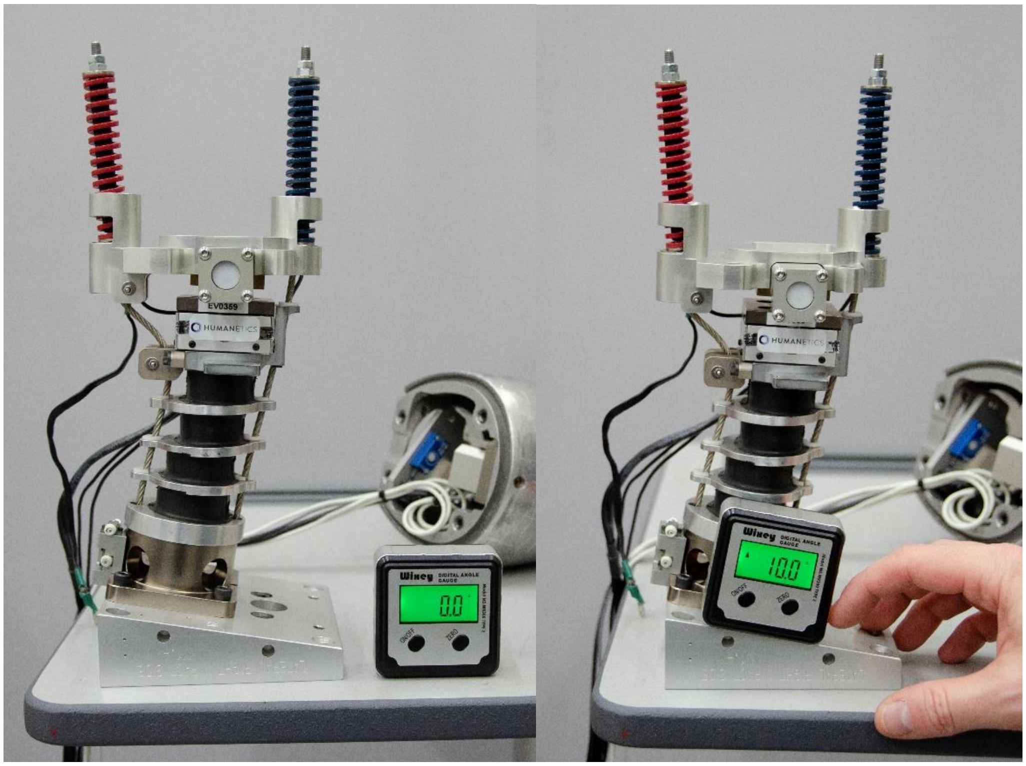


Figure 6-12. Check the surface and neck base angles

6.5.2.8 Clamp the neck mounting plate in place (Figure 6-13).

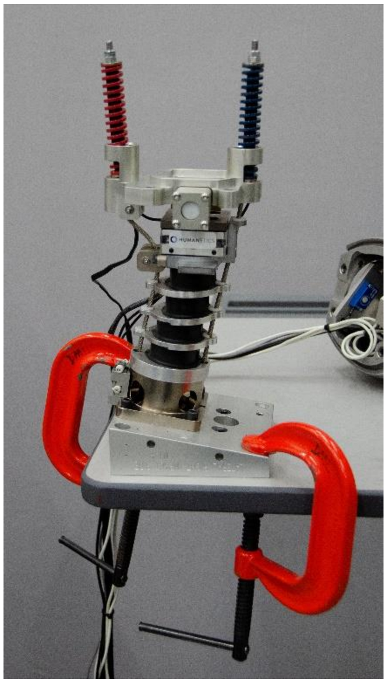


Figure 6-13. Clamp neck mounting plate

6.5.2.9 To remove the Occipital Condyle Potentiometer (SA572-S114) and Rotary Potentiometer Housing (474-2013), loosen the set screw (M3 X 0.5 X 3 SSS) from the OC pin and remove the top two M3 X 0.5 X 35 LG. BHCS SS from the OC potentiometer housing (Figure 6-14); uninstall the OC pot with housing from the neck (Figure 6-15).

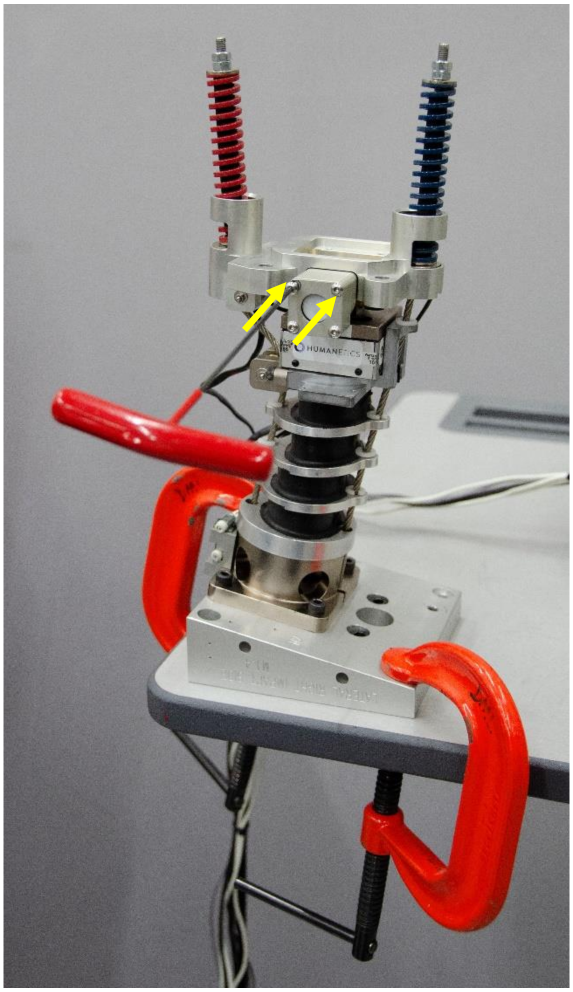


Figure 6-14. Remove occipital condyle potentiometer and housing

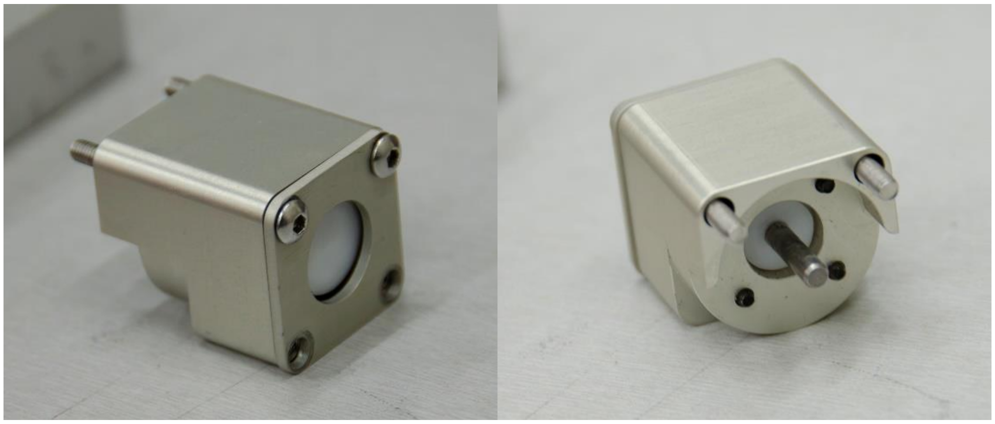


Figure 6-15. Potentiometer condyle potentiometer and housing

6.5.2.10 Loosen the M5 x 0.8 thin profile jam and adjustment nuts from the top of the front and rear spring cables. Adjust the head/neck mounting platform (474-2302-A) by bending the neck until an inclinometer at the neck top plate (474-2335) *and* on the top surface of the head/neck mounting platform are reading 0 ± 0.2° about the Y-axis and 0 ± 0.5° about the X-axis (Figure 6-16 (left)); the Upper Neck Tilt Sensor (SA572-S44) can be used to measure the angle instead of an inclinometer (Figure 6-17).

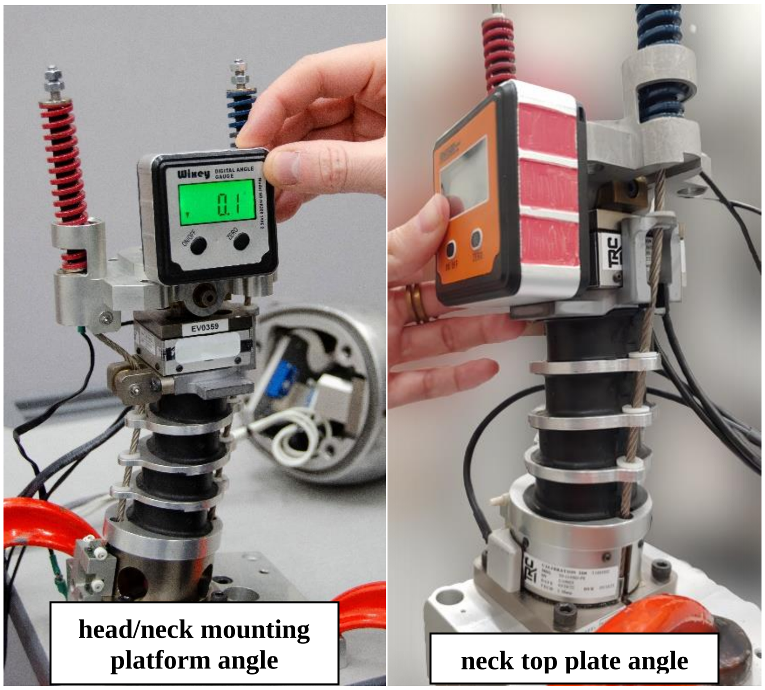


Figure 6-16. Set angles on head/neck mounting platform and neck top plate

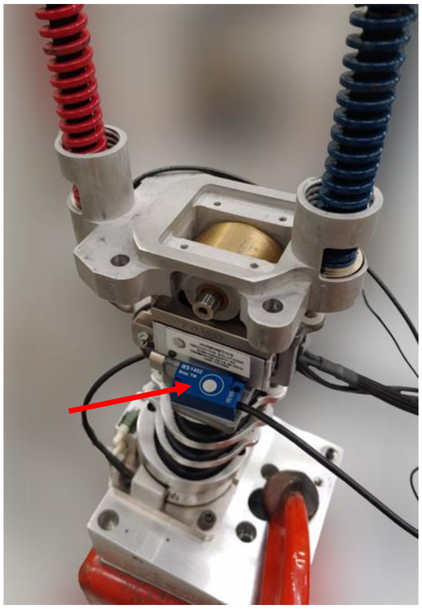


Figure 6-17. Measuring angle using upper neck tilt sensor

6.5.2.11 Tighten the front and rear M5 x 0.8 adjustment nuts so that they just contact the springs to temporarily hold mounting platform orientation (Figure 6-18). Do not yet tighten the jam nuts. NOTE: Make sure neck bend is stable before continuing.

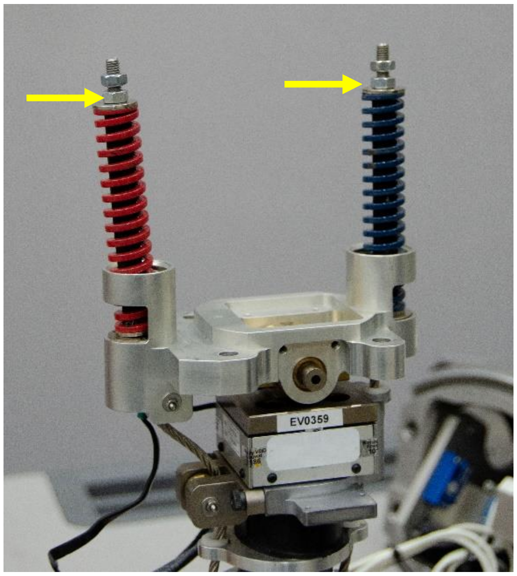


Figure 6-18. Tighten front and rear adjustment nuts until contact

6.5.2.12 Install the Flexion/Extension Stop Assembly (474-2115-A) into the head/neck mounting platform and secure with four M3 X 0.5 X 8 FHCS (Figure 6-19). The front and rear nodding blocks are the same shape, so the orientation is not critical.

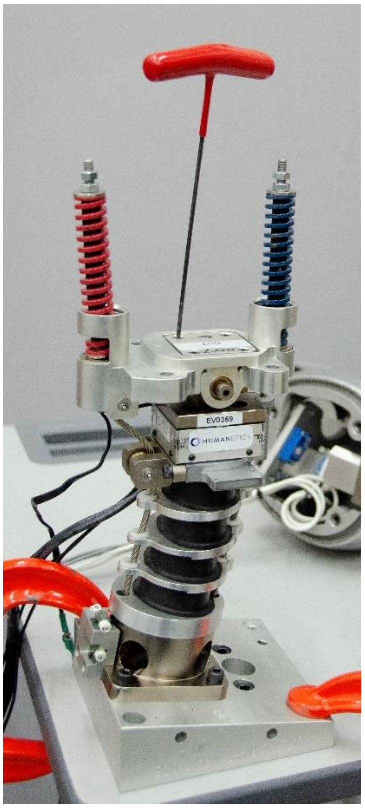


Figure 6-19. Install the flexion/extension stop assembly into the head/neck mounting platform

6.5.2.13 Ensure that the springs are properly seated on the front and rear neck cables (Figure 6-20).

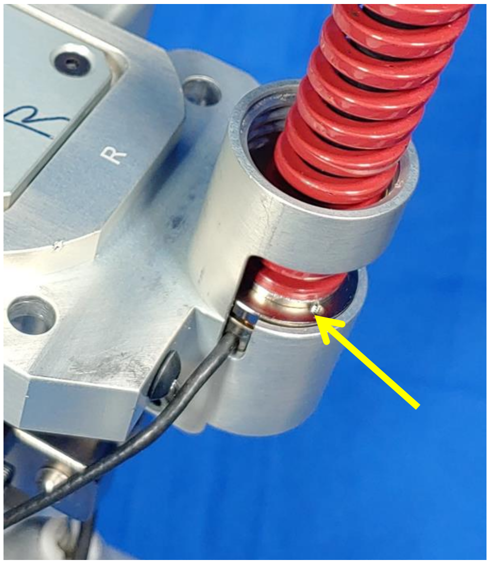


Figure 6-20. Rear spring properly seated against spring load cell

6.5.2.14 With zero compression on the front and rear neck cable load cells, acquire voltages for the front and rear skull spring load cells. ***NOTE*****:** *Load cells must have no applied pressure before balancing or the output will be unintentionally offset.*

6.5.2.15 Gently tighten the front and rear M5 X 0.8 adjustment nuts evenly until they both have 2.2-6.7 N of applied force.

6.5.2.16 Reinstall front and rear M5 x 0.8 jam nuts to lock adjustment nut position. **NOTE:** Adjustment nut may move while jamming. Confirm that applied compression on both spring load cells is 2.2-6.7 N with the head and neck Y-axis tilt sensors still at 0 ± 0.2°.

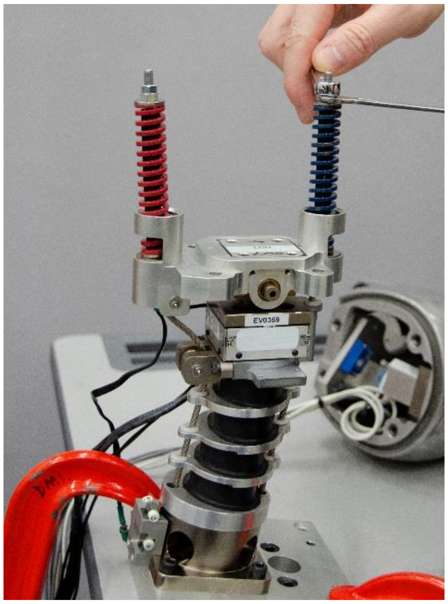


Figure 6-21. Tighten jam nuts

6.5.2.17 Reinstall the spring tubes (474-2303) (Figure 6-22).

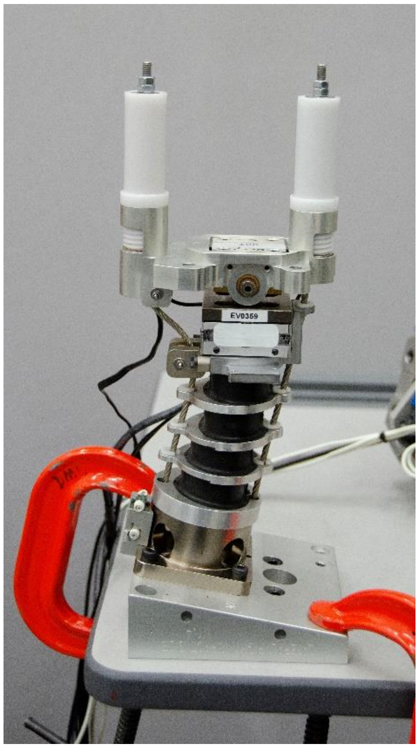


Figure 6-22. Reinstall spring tubes

6.5.2.18 Reinstall Occiptial Condyle Rotary Potentiometer (SA572-S114) (Figure 6-23) (see Section 4.3 of the THOR-05F PADI for directions).

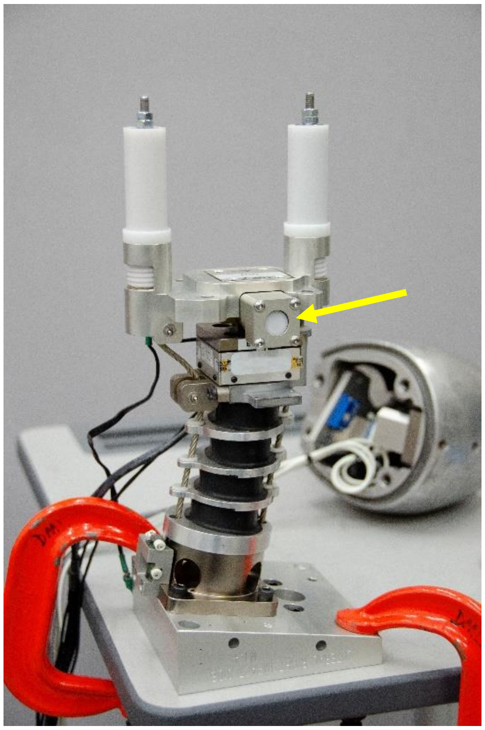


Figure 6-23. Reinstall OC potentiometer and housing

6.5.2.19 Remove the neck assembly from the 10° Neck Mounting Platform (TF-200-2357).

6.5.2.20 Once the neck cables are adjusted as above, the neck is ready for qualification testing. The cables **must not** be adjusted after qualification testing as this may invalidate the qualification results.

6.6 Neck Test Data Zero Setting, Offset Calculation, Velocity Calculation

Follow these procedures to set time zero, remove offset, and calculate velocity from the neck test data.

6.6.1 Ensure that time zero is correctly set, either by first contact, or an initial rise in the pendulum acceleration.

6.6.2 Perform bias removal of the pendulum acceleration by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contacting the honeycomb.

6.6.3 Filter the pendulum acceleration to CFC1000.

6.6.4 Time zero (t_0) for all channels is the data sample where the filtered pendulum acceleration from Step 6.6.3 exceeds 5 G.

6.6.5 Perform bias removal of the remaining measured channels listed in the “Required Measurement Channels” for the respective neck test mode by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to time zero (t_0).

6.6.6 Filter the data for all measured channels listed in the “Required Measurement Channels” table for the respective neck test mode.

6.6.7 Using the trapezoidal rule, integrate the pendulum acceleration (CFC1000) from t_0 to the end of the sample period to obtain pendulum velocity.

$$Pendulum\ Velocity(t) = \int_{t_0}^{t_f} Pend\ Accel\ (t)dt$$

Where:

$Pendulum\ Velocity(t) =$ time history of pendulum impact velocity

$Pend\ Accel(t) =$ time history of pendulum acceleration

$t_0 =$ first time point for calculation (see 6.6.4 above)

$t_f =$ final time point for collected data

6.7 Neck Torsion Test

6.7.1 Neck Torsion Test Procedure

6.7.1.1 Soak the head and neck assembly in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

6.7.1.2 Install the 76.2 mm aluminum honeycomb to meet the pendulum pulse specified in Table 6-2 for an impact velocity of 3.40 ± 0.05 m/s. Ensure that the contact area of the aluminum honeycomb engages the impactor plate on the pendulum upon impact.

6.7.1.3 Ensure that the Pre-Test Neck Setup Procedure (See Section 6.5) has been carried out.

6.7.1.4 Mount the ARS on top of the neck mounting adapter (DL474-1270) at the edge opposite the front spring tower recess, as shown in Figure 6-24.

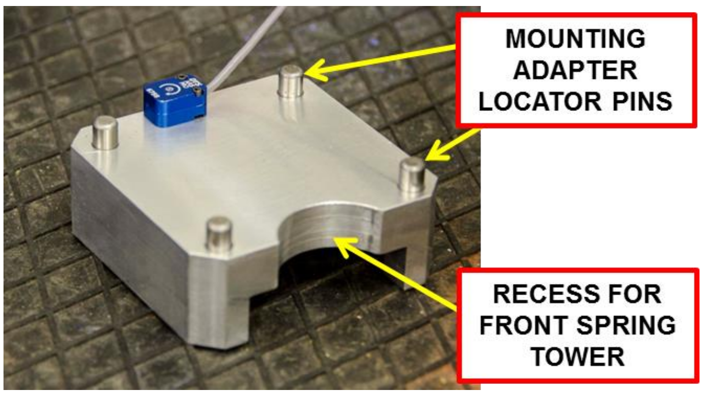


Figure 6-24. Angular rate sensor installation on upper neck mounting adaptor

6.7.1.5 Install the neck mounting adapter to the neck using four M6 X 1 X 14 mm SHCS. The semi-circular recess is oriented towards the front of the neck next to the front spring tower. This will locate the ARS closest to the rear spring tower (Figure 6-25).

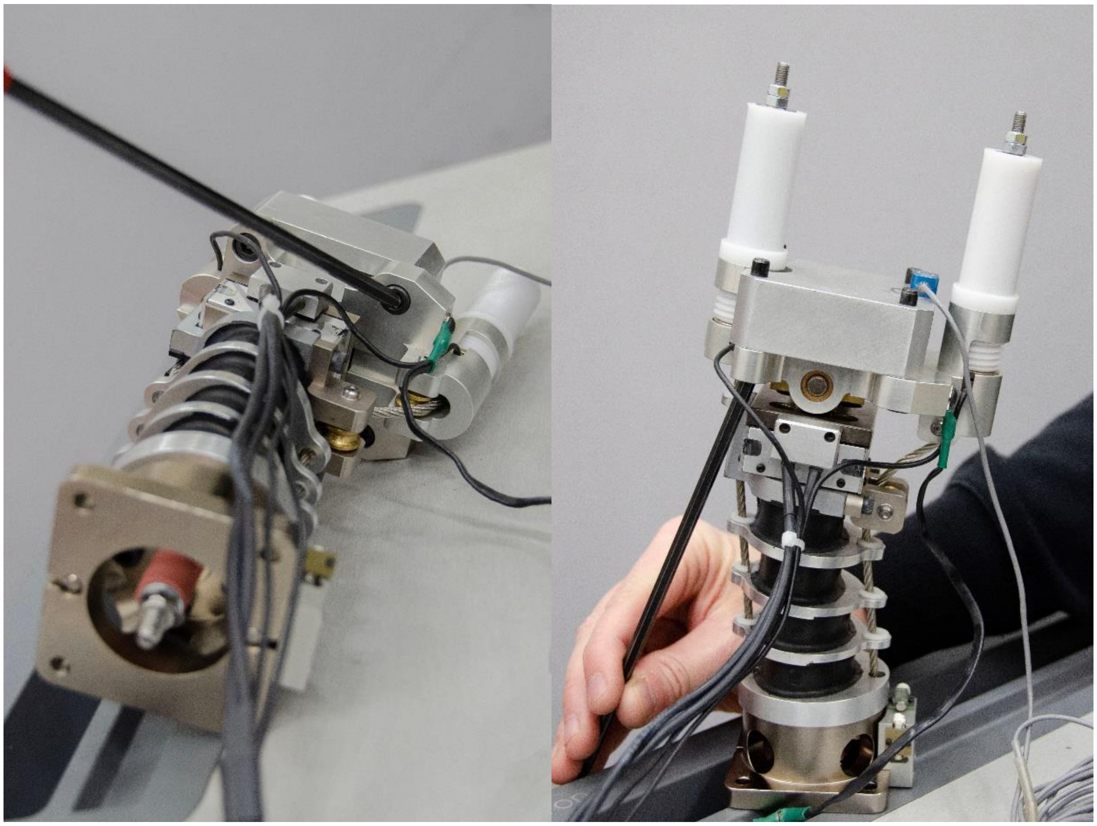


Figure 6-25. Install neck mounting adaptor to neck

6.7.1.6 Assemble the end plate of the neck torsion fixture (DL472-1130) to the THOR-05F Neck Lower adapter (DL474-1350) using four M5 X 0.8 X 16 mm SHCS (Figure 6-26 and Figure 6-27).

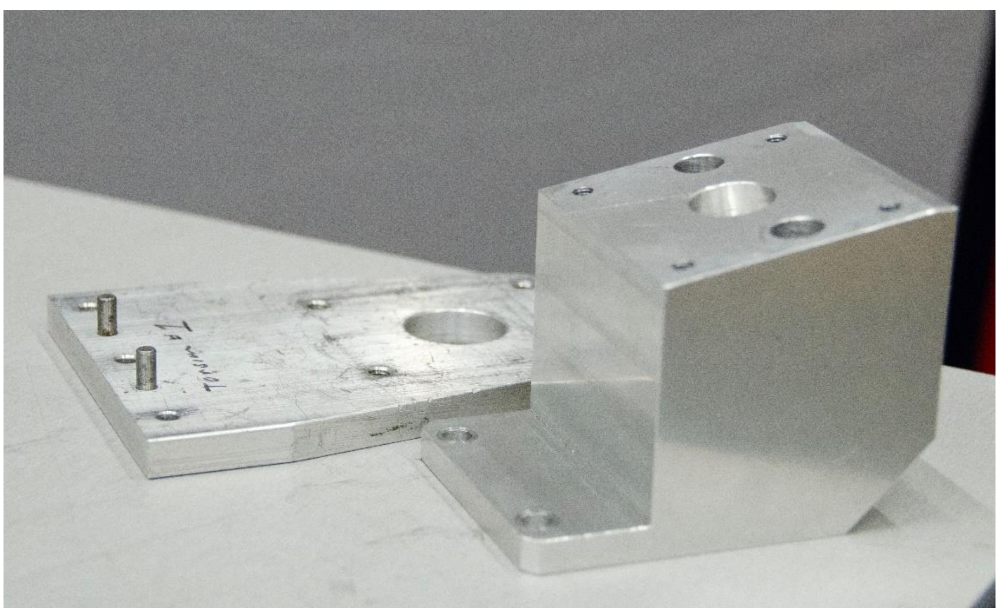


Figure 6-26. End plate assembly

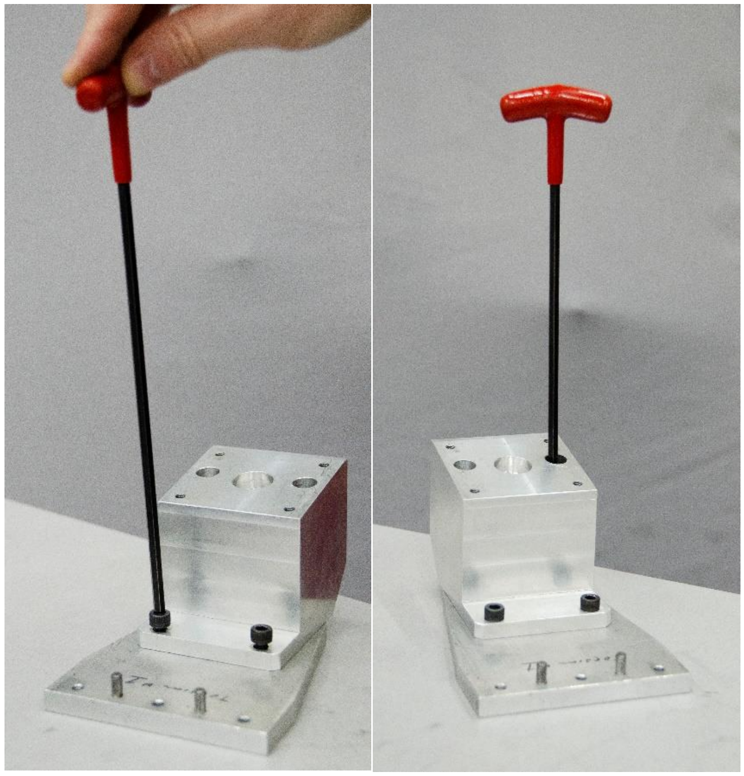


Figure 6-27. Install screws for end plate assembly

6.7.1.7 Attach the lower neck load cell to the lower neck mounting adaptor (DL474-1350) using four M5 X 0.8 X 16 mm SHCS (Figure 6-28). Orient the neck so that the bottom surface is parallel to the top surface of the upper neck mounting adaptor and the front spring tower is facing the locator pins.

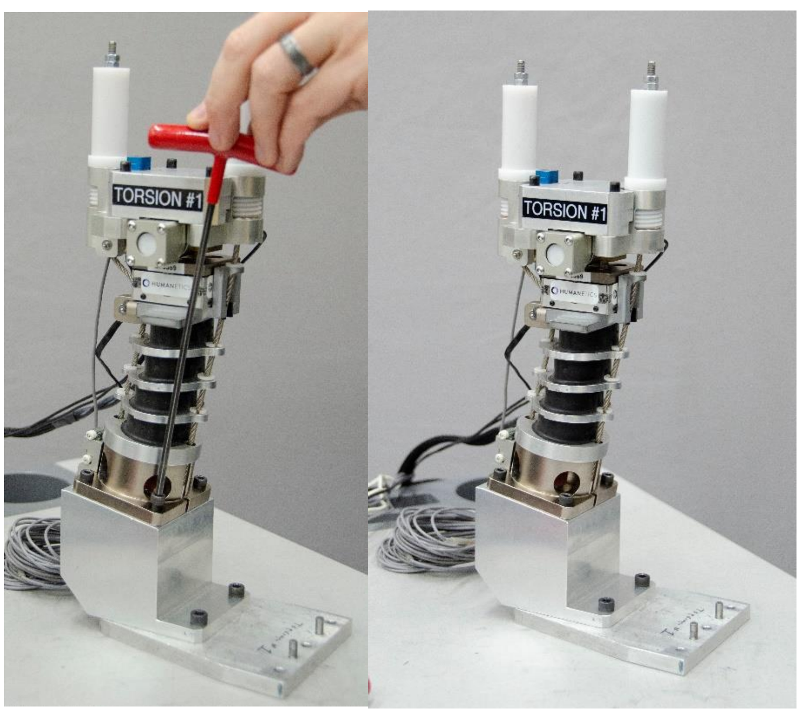


Figure 6-28. Neck with lower neck mounting adaptor (DL474-1350) and end plate assembly installed

6.7.1.8 Mount the neck torsion fixture (DL472-1000) to the bottom of the neck pendulum using four ¼-20 x 5/8 in. SHCS (Figure 6-29). Orient the long axis of the torsion fixture top plate (DL472-1110) perpendicular to the direction of motion of the pendulum (Figure 6-30).

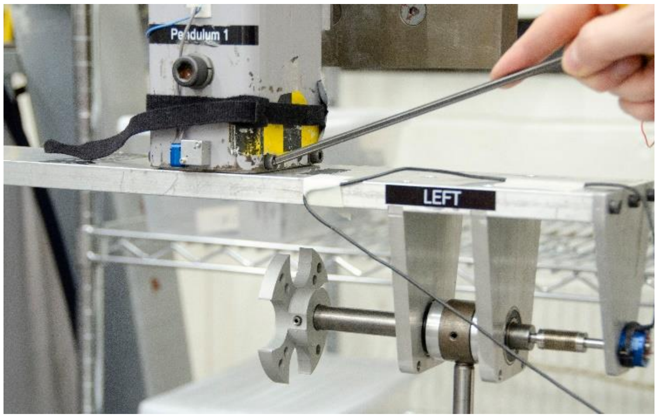


Figure 6-29. Attachment of torsion fixture to neck pendulum

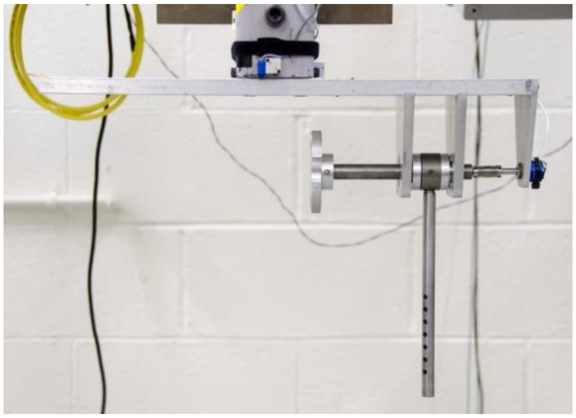


Figure 6-30. Long axis of torsion fixture top plate perpendicular to motion of neck pendulum

6.7.1.9 Orient the neck so that the rear spring tower faces the ground. Install the neck into the fixture by aligning the locator pins on the end plate assembly into the end of the torsion fixture top plate (Figure 6-32).

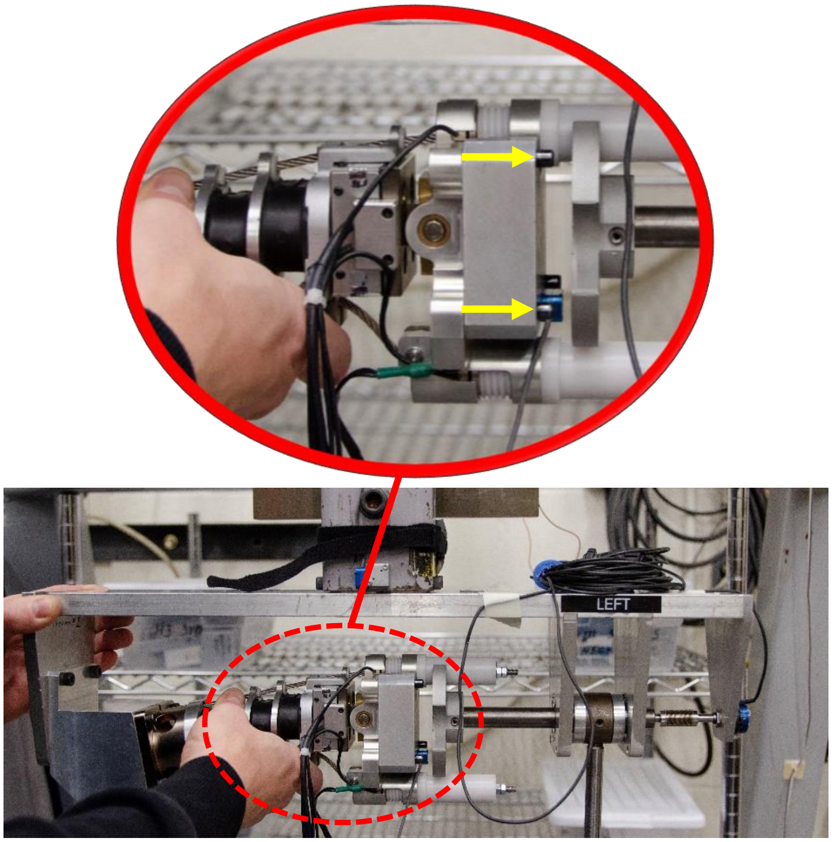


Figure 6-31

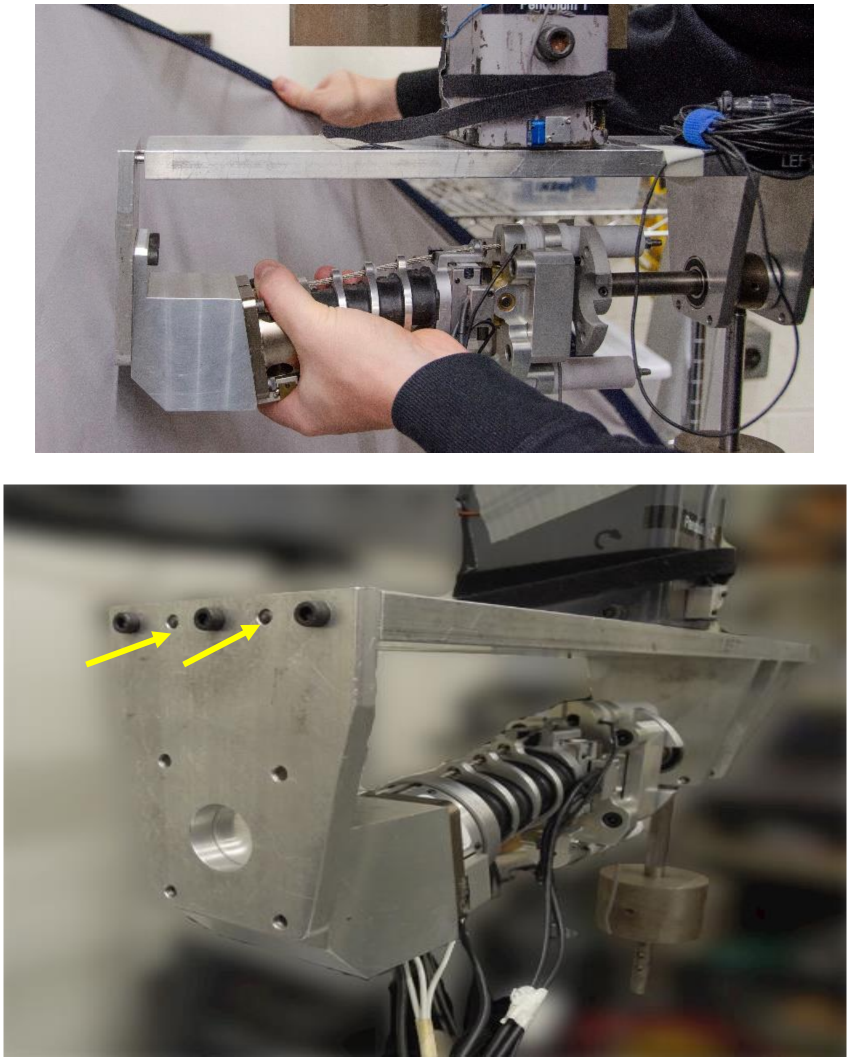


Figure 6-32. Alignment of locator pins with end plate of neck torsion fixture

6.7.1.10 While positioning the end plate assembly in Step 6.7.1.9, simultaneously align the neck mounting adapter locator pins into the neck attachment plate (DL472-1151) (Figure 6-33 and Figure 6-34).

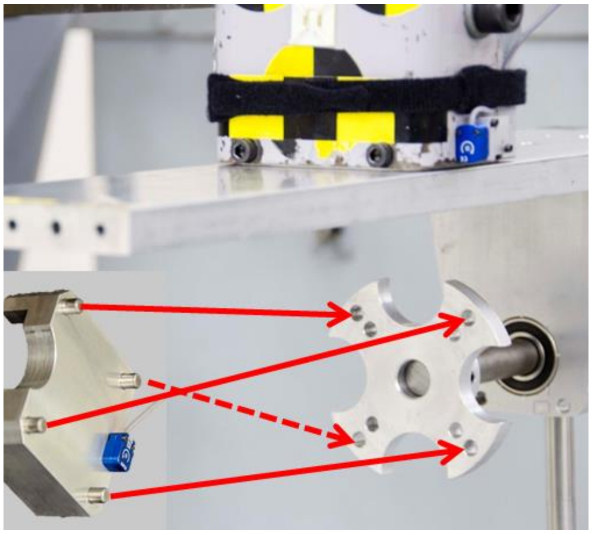


Figure 6-33. Alignment of neck mounting adapter locator pins with neck attachment plate locator holes

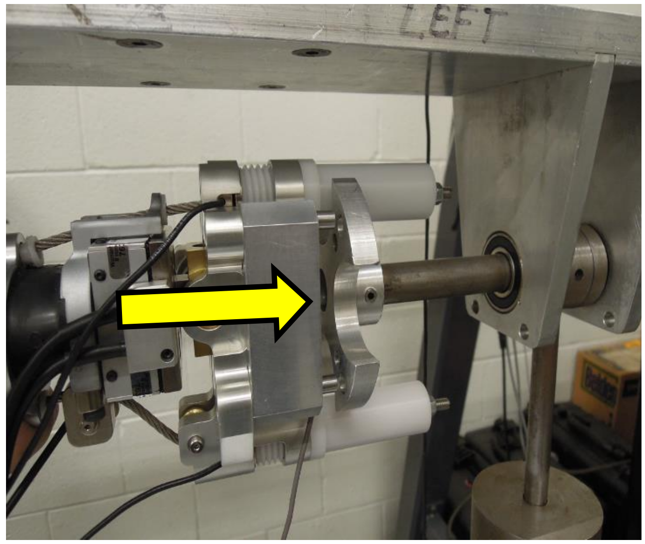


Figure 6-34. Installation of neck assembly into the torsion fixture

6.7.1.11 Once the locator pins have been placed within the locator holes, install the three #10-24 X 1 in. SHCS through the end plate assembly into the top plate to secure the neck into the fixture (Figure 6-35).

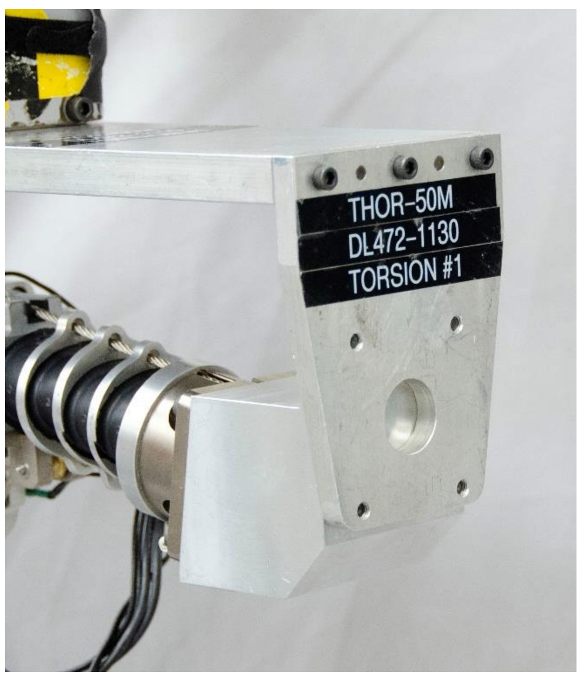


Figure 6-35. Attachment of end place to secure the neck into the torsion fixture

6.7.1.12 Tape and route the cables so they do not interfere with the neck during the test. Leave at least 30 cm of slack in the bundle of wires from the upper neck (upper neck load cell, OC potentiometer, ARS, and spring tower load cells) so that the cables do not become taut when the neck is twisted about the Z-axis (Figure 6-36). No slack is necessary in the lower neck bundle, but ensure that the wires are secured to the neck torsion fixture and do not interfere with rotation of the neck.

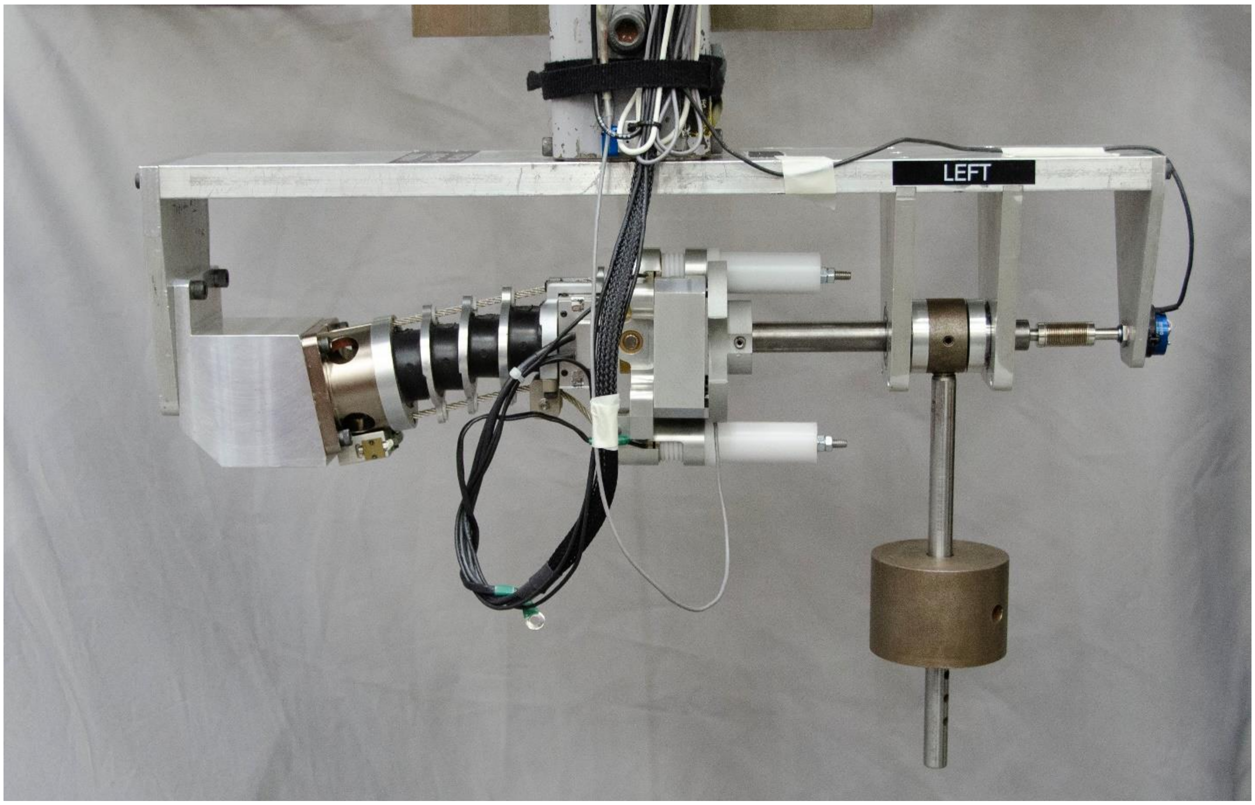


Figure 6-36. Tape wiring to minimize interference during test

6.7.1.13 Slide the 1.5 ± 0.05 kg pendulum weight onto the pendulum rod. Position the weight so that the 10-24 x 1 ½” SHCS can be installed through the weight into the second hole from the top of the rod. This corresponds to 140 mm from the centerline of the shaft assembly (Figure 6-37).

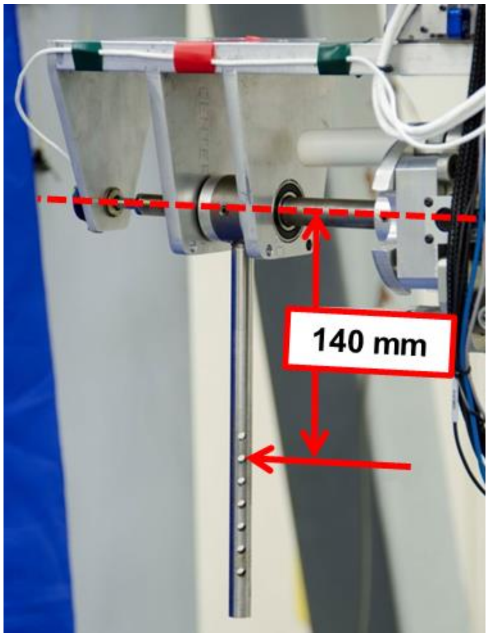


Figure 6-37. Pendulum rod hole position.

6.7.1.14 Record the AM channels listed in Table 6-1 in accordance with SAE J211-1. Determine the time of initial contact between the striker and the honeycomb. A contact switch or a change in pendulum acceleration may be used; ensure that at least 50 milliseconds of data are recorded before contact.

6.7.1.15 Ensure that at least 30 minutes have passed since the last test involving the neck.

6.7.1.16 Release the pendulum from a height to generate a 3.40 ± 0.05 m/s velocity at impact.

6.7.1.17 The procedure and pictures above describe the left neck torsion test (Figure 6-39). To conduct the right neck torsion test (Figure 6-38), remove the four ¼-20 x 5/8" SHCS attaching the neck torsion fixture to the bottom of the neck pendulum, rotate the fixture 180° about the pendulum z-axis, and reinstall the four ¼-20 x 5/8" SHCS (Figure 6-29). Repeat Steps 6.7.1.14 through 6.7.1.16.

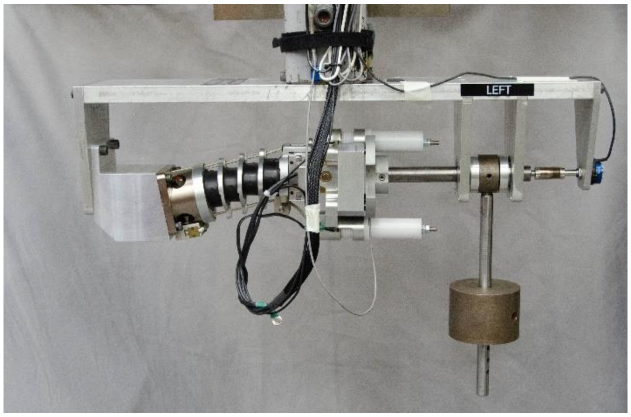


Figure 6-38. Torsion test for twist to the left

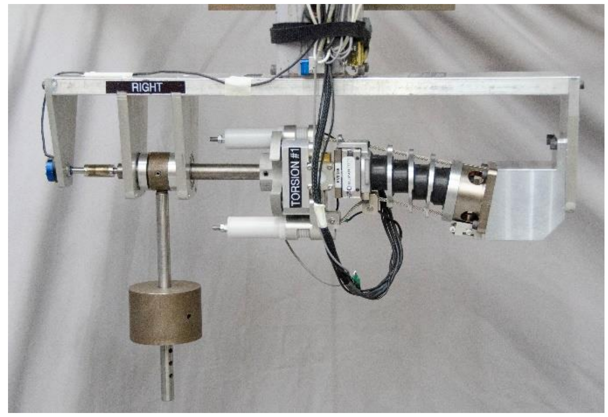


Figure 6-39. Torsion test for twist to the right

6.7.2 Torsion Data Processing

6.7.2.1 Follow the procedures in Section 6.6 Neck Test Data Zero Setting, Offset Calculation.

Table 6-1. Required Measurement Channels for the Neck Torsion Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer, X-axis	1000	T0SENSMI0000ACXA	XG	AM	PEND	AC	G'S
Pendulum Velocity, X-axis	N/A	T0SENSMI0000VAXD	XG	CM	PEND	PP	MPS
Upper Neck Moment, Z-axis	600	D0NECKUP00TFMOZB	ZL	AM	NEKU	LC	NWM
Upper Neck Angular Velocity, Z-axis (ARS)	60	D0NECKUP00TFAVZD	ZL	AM	NEKU	AV	DPS
Neck Fixture Rotation	60	T0SENSMI0000ANZD	ZL	AM	PEND	AD	DEG

6.7.3 Torsion Test Performance Specification

The pendulum pulse must be within the ranges indicated in Table 6-2. The neck torsion response must be within the ranges provided in

Table **6-3** and Table 6-4.

Table 6-2. Pendulum Pulse for Neck Torsion Qualification Test

Parameter	Units	Specification	
		Min.	**Max.**
Pendulum velocity at 7 ms after T0	m/s	0.90	1.10
Pendulum velocity at 14 ms after T0	m/s	1.87	2.27
Pendulum velocity at 21 ms after T0	m/s	2.79	3.41

Table 6-3. Neck Left Torsion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	3.35	3.45
Maximum Upper Neck M_z	N-m	18.3	22.4
Minimum Neck Fixture Rotation	deg	-56.6	-46.3
Minimum Upper Neck Angular Velocity ω_z (relative to earth)	deg/s	-1413	-1156

Table 6-4. Neck Right Torsion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	3.35	3.45
Minimum Upper Neck M_z	N-m	-22.4	-18.3
Maximum Neck Fixture Rotation	deg	46.3	56.6
Maximum Upper Neck Angular Velocity ω_z (relative to earth)	deg/s	1156	1413

6.8 Neck Frontal Flexion Test

6.8.1 <u>Neck Frontal Test Procedure</u>

6.8.1.1 Soak the head and neck assembly in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

6.8.1.2 Attach the head assembly (474-1000) to the neck assembly. The front neck spring tower should slide into the skull. Install four M6 X 1 X 25 mm SHCS at the bottom of the head/neck mounting platform to secure the head to the neck (Figure 6-40) and torque to 12.0 N-m.

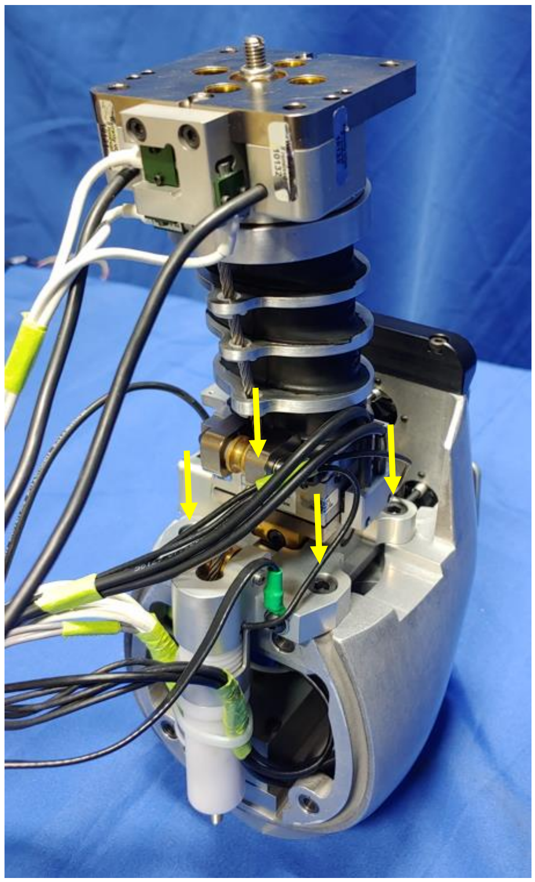


Figure 6-40. Install 4 M6 SHCS to connect the head to the neck

6.8.1.3 Ensure that the face insert (474-1401) is positioned in the head skin assembly (474-1008). Install the head skin assembly by positioning it in front of and below the skull and moving it over the skull in an up-and-back motion until the head skin posterior flaps are positioned along the posterior groove of the skull. Install the skull cap and cap skin (474-1020 and 474-1025) using four M6 X 1 X 20 mm LHCS torqued to 20.3 N-m, ensuring the wire bundles are positioned in both recesses of the skull cap.

6.8.1.4 Install the 152.4 mm aluminum honeycomb[3] to meet the pendulum pulse specified in Table 6-6 for an impact velocity of 5.00 ± 0.05 m/s. Ensure that the contact area of the aluminum honeycomb covers the impactor plate on the pendulum upon impact.

6.8.1.5 Mount the bottom of the neck assembly rigidly to the neck mounting plate using four M6 X 1 X 25 mm SHCS torqued to 20.3 N-m.

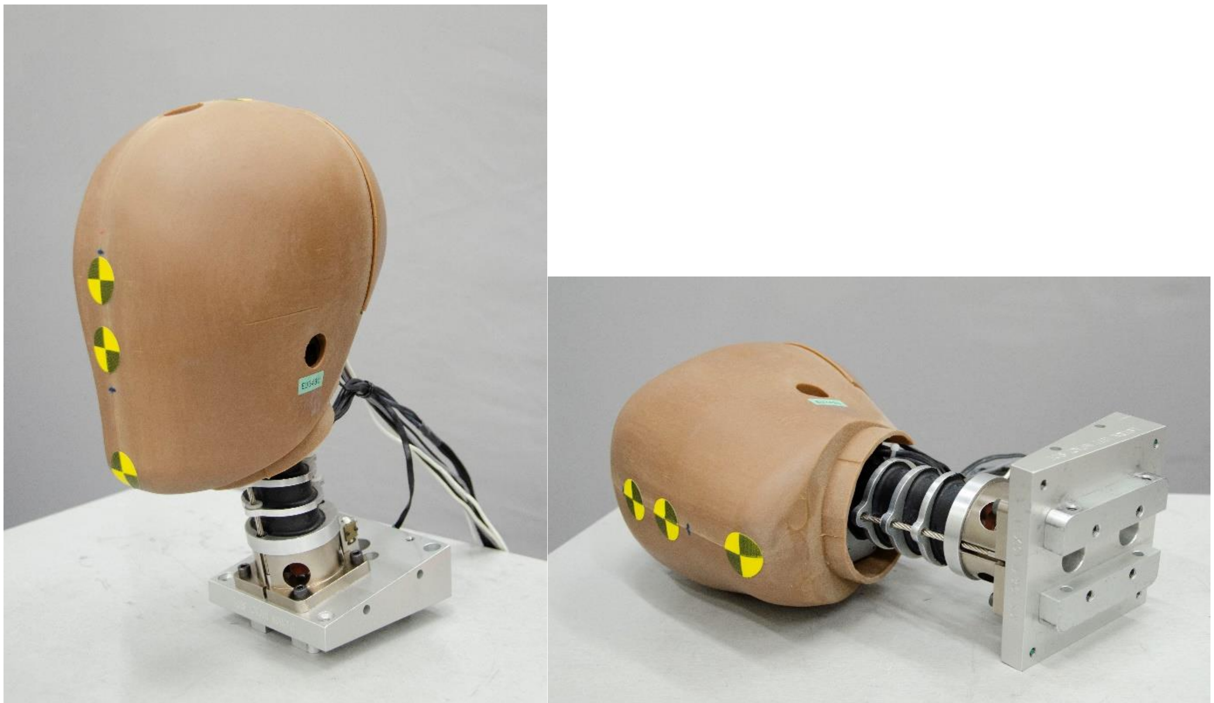


Figure 6-41. Head and neck mounted to neck mounting plate for frontal flexion

6.8.1.6 Attach the neck mounting plate (TF-200-2357) to the bottom of the pendulum arm such that the thickest side of the wedge is facing away from the direction of impact with the front edge of the lower neck aligned with the leading edge of the pendulum arm (forehead facing the direction of impact). For the frontal flexion test, the neck is placed such that the midsagittal plane of the head is vertical (±0.5°) and coincides with the plane of motion of the pendulum's longitudinal axis, with the positive X-axis of the head coordinate system pointing in the direction of travel of the pendulum (Figure 6-42).

---

[3] As a starting point, use the same aluminum honeycomb configuration used in the Hybrid III 5th neck flexion test. Length and width of the honeycomb may be varied to achieve the required deceleration pulse.

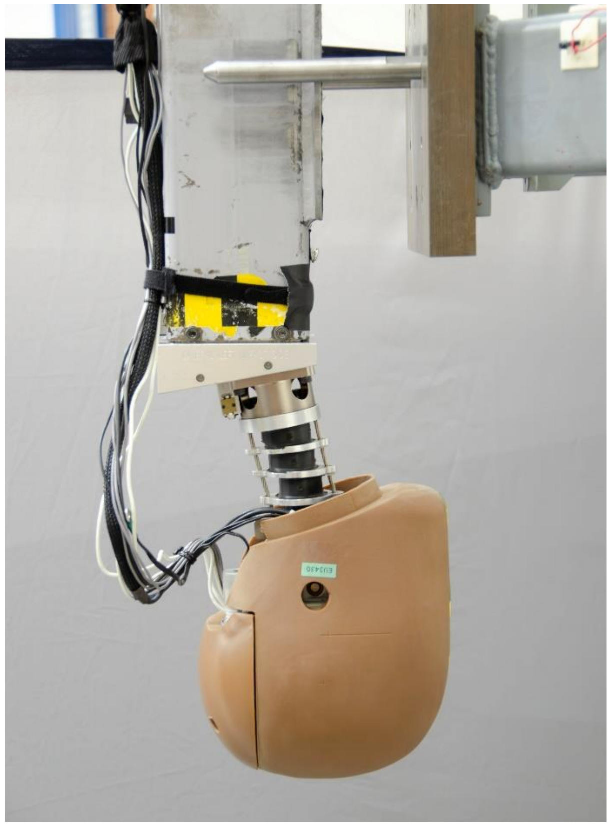


Figure 6-42. Head-neck assembly orientation for neck flexion tests

6.8.1.7 Record the AM channels listed in Table 6-5 in accordance with SAE J211-1. Determine the time of first contact between the striker and the honeycomb. A contact switch or a change in pendulum acceleration may be used; ensure that at least 50 milliseconds of data are recorded before contact.

6.8.1.8 Ensure that at least 30 minutes have passed since the last neck qualification test.

6.8.1.9 Release the pendulum from a height to generate a 5.00 ± 0.05 m/s velocity at impact.

6.8.2 <u>Neck Frontal Flexion Data Processing</u>

6.8.2.1 Follow the procedures in Section 6.6 Neck Test Data Zero Setting, Offset Calculation.

6.8.2.2 Confirm that the polarity of the pendulum ARS is set such that the angular velocity of the pendulum as it falls towards the decelerator is positive.

6.8.2.3 Calculate the head rotation angle relative to the pendulum. Begin integration at time zero:

$$Head\ Rotation(t) = \int_{t_0}^{t_f} -\omega_{y,head}(t) - \omega_{y,pendulum}(t)dt$$

Where:

$Head\ Rotation(t)$ = time history of head Y rotation

$\omega_{y,head}(t)$ = time history of head Y angular velocity

$\omega_{y,pendulum}(t)$ = time history of pendulum Yangular velocity

t_0 = first time point for calculation (see 6.6.4)

t_f = final time point for collected data

Table 6-5. Required Measurement Channels for the Neck Flexion Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer, X-axis	1000	T0SENSMI0000ACXA	XG	AM	PEND	AC	G'S
Pendulum Velocity, X-axis	N/A	T0SENSMI0000VAXD	XG	CM	PEND	PP	MPS
Upper Neck Force, Z-axis	1000	D0NECKUP00TFFOZA	ZL	AM	NEKU	LC	NWT
Upper Neck Moment, Y-axis	600	D0NECKUP00TFMOYB	YL	AM	NEKU	LC	NWM
Head Angular Velocity, Y-axis (ARS)	60	D0HEAD0000TFAVYD	YL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00TFAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000TFANYD	YL	CM	HDCG	PP	DEG

6.8.3 Neck Frontal Flexion Test Performance Specification

The pendulum pulse must achieve a velocity time-history that meets all three of the requirements in Table 6-6. The neck flexion response must be within the ranges provided in Table 6-7.

Table 6-6. Neck Flexion Input Requirements

Parameter	Units	Specification	
		Min.	Max.
Pendulum velocity at 8 ms after T0	m/s	1.55	1.89
Pendulum velocity at 16 ms after T0	m/s	3.13	3.82
Pendulum velocity at 24 ms after T0	m/s	4.44	5.43

Table 6-7. Neck Flexion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	4.95	5.05
Maximum Upper Neck M_y	N-m	16.0	19.5
Maximum Upper Neck F_z prior to 40 ms	N	693	847
Minimum Head Angular Velocity ω_y (relative to earth)	deg/s	-2350	-1923
Minimum Head Rotation (relative to pendulum)	deg	-86.1	-70.4

6.9 Neck Extension Test

6.9.1 Neck Extension Test Procedure

6.9.1.1 Soak the head and neck assembly in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

6.9.1.2 If the head and neck assembly is already installed from a previous neck extension, flexion, or lateral flexion test, proceed to the next step. Otherwise, follow the instructions provided in Steps 6.8.1.2 and 6.8.1.3 to assemble the head and neck.

6.9.1.3 Install the 152.4 mm size aluminum honeycomb[4] to meet the pendulum pulse specified in Table 6-9 for an impact velocity of 5.00 ± 0.05 m/s. Ensure that the contact area of the aluminum honeycomb covers the impactor plate on the pendulum upon impact.

6.9.1.4 Attach the neck mounting plate to the bottom of the pendulum arm such that the thickest side of the wedge is facing towards the direction of impact. Mount the bottom of the neck assembly rigidly to the neck mounting plate using four M6 X 1 X 25 mm SHCS torqued to 20.3 N-m such that the rear edge of the lower neck is aligned with the leading edge of the pendulum arm. For the extension test, the neck is placed such that the midsagittal plane of the head is vertical (±0.5°) and coincides with the plane of motion of the pendulum's longitudinal axis, with the with the negative X-axis of the head coordinate system pointing in the direction of travel of the pendulum (Figure 6-43).

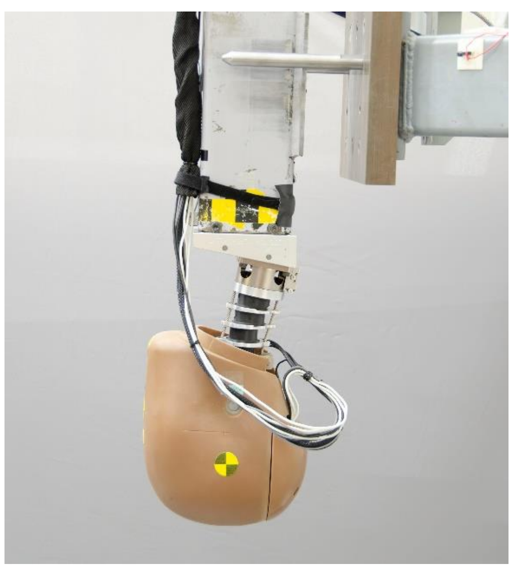


Figure 6-43. Mounting the head-neck assembly for neck extension tests.

[4] Length and width may vary to meet the pulse requirements.

6.9.1.5 Record the AM channels listed in Table 6-8 in accordance with SAE J211. Determine the time of first contact between the striker and the honeycomb. A contact switch or a change in pendulum acceleration may be used; ensure that at least 20 milliseconds of data are recorded before contact.

6.9.1.6 Ensure that at least 30 minutes have passed since the last neck qualification test.

6.9.1.7 Release the pendulum from a height to generate a 5.00 ± 0.05 m/s velocity at impact.

6.9.2 **Neck Extension Data Processing**

6.9.2.1 Follow the procedures in Section 6.6 Neck Test Data Zero Setting, Offset Calculation.

6.9.2.2 Confirm that the polarity of the pendulum ARS is set such that the angular velocity of the pendulum as it falls towards the decelerator is positive.

6.9.2.3 Calculate the head rotation angle relative to the pendulum:

$$Head\ Rotation(t) = \int_{t_0}^{t_f} \omega_{y,head}(t) - \omega_{y,pendulum}(t)dt$$

Where:

$Head\ Rotation(t) =$ time history of head Y rotation

$\omega_{y,head}(t) =$ time history of head Y angular velocity

$\omega_{y,pendulum}(t) =$ time history of pendulum Y angular velocity

$t_0 =$ first time point for calculation (see 6.6.4)

$t_f =$ final time point for collected data

Table 6-8. Required Measurement Channels for the Neck Extension Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer, X-axis	1000	T0SENSMI0000ACXA	XG	AM	PEND	AC	G'S
Pendulum Velocity, X-axis	N/A	T0SENSMI0000VAXD	XG	CM	PEND	PP	MPS
Upper Neck Force, Z-axis	1000	D0NECKUP00TFFOZA	ZL	AM	NEKU	LC	NWT
Upper Neck Moment, Y-axis	600	D0NECKUP00TFMOYB	YL	AM	NEKU	LC	NWM
Head Angular Velocity, Y-axis (ARS)	60	D0HEAD0000TFAVYD	YL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00TFAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000TFANYD	YL	CM	HDCG	PP	DEG

6.9.3 Neck Extension Test Performance Specification

The pendulum pulse must be within the ranges indicated in Table 6-9. The neck extension response must be within the ranges provided in Table 6-10.

Table 6-9. Pendulum Pulse for Neck Extension Qualification Test

Parameter	Units	Specification	
		Min.	Max.
Pendulum velocity at 8 ms after T0	m/s	1.54	1.88
Pendulum velocity at 16 ms after T0	m/s	3.12	3.81
Pendulum velocity at 24 ms after T0	m/s	4.44	5.43

Table 6-10. Neck Extension Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.95	5.05
Minimum Upper Neck M_y	N-m	-20.8	-17.0
Minimum Upper Neck F_z	N	-1469	-1202
Maximum Head Angular Velocity ω_y (relative to earth)	deg/s	2154	2632
Maximum Head Rotation (relative to pendulum)	deg	79.1	96.7

6.10 Neck Lateral Flexion Test

6.10.1 <u>Neck Lateral Flexion Test Procedure</u>

6.10.1.1 Soak the head and neck assembly in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

6.10.1.2 If the head and neck assembly is already installed from a previous neck extension, flexion, or lateral flexion test, proceed to the next step. Otherwise, follow the instructions provided in Steps 6.8.1.2 and 6.8.1.3 to assemble the head and neck.

6.10.1.3 Install the 76.2 mm size aluminum honeycomb[5] to meet the pendulum pulse specified in Table 6-12 for an impact velocity of 3.40 ± 0.05 m/s. Ensure that the contact area of the aluminum honeycomb covers the impactor plate on the pendulum upon impact.

6.10.1.4 Attach the neck mounting plate to the bottom of the pendulum arm such that the thickest side of the wedge is facing 90° ± 0.5° from the direction of impact. Mount the bottom of the neck assembly rigidly to the neck mounting plate using four M6 x 1 x 25 mm SHCS torqued to 20.3 N-m such that the rear edge of the lower neck is aligned with the thickest side of the wedge.

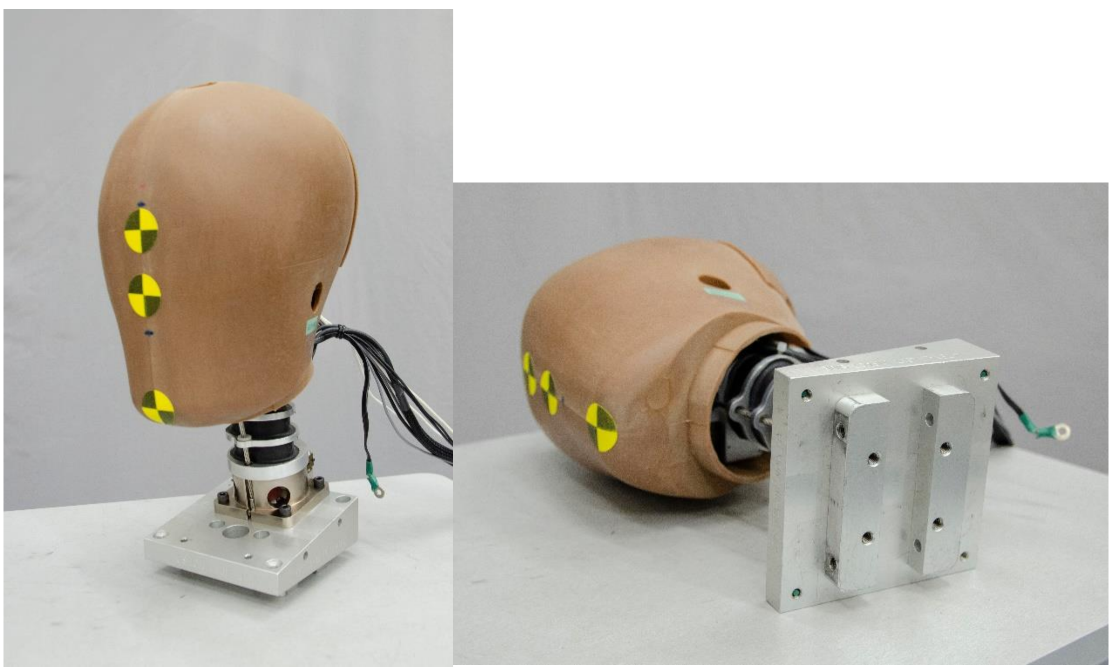


Figure 6-44: Head and neck mounted to neck mounting plate for lateral flexion

[5] Length and width may vary to meet the pulse requirements.

6.10.1.5 For the lateral flexion test, the neck is placed such that such that the positive Y-axis (right lateral) or negative Y-axis (left lateral) of the head coordinate system is pointing in the direction of travel of the pendulum. The occipital condyle should be aligned with the longitudinal centerline of the pendulum arm. The neck is tested in both left and right lateral modes (Figure 6-45 and Figure 6-46).

Neck Lateral Flexion, Left

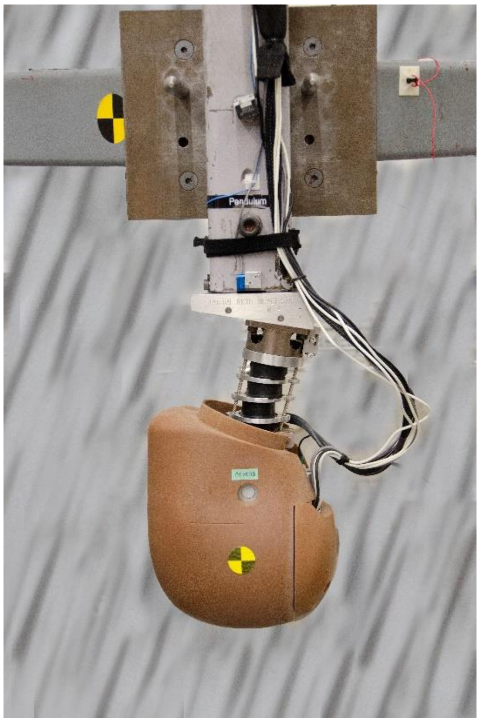


Figure 6-45. Left neck lateral flexion setup

Neck Lateral Flexion, Right

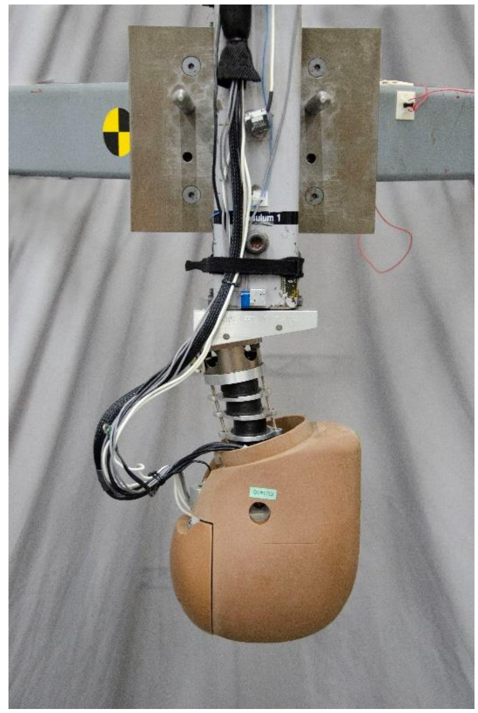


Figure 6-46. Right neck lateral flexion setup

6.10.1.6 Record the AM channels listed in Table 6-11 in accordance with SAE-J211-1. Determine the time of first contact between the striker and the honeycomb. A contact switch or a change in pendulum acceleration may be used; ensure that at least 50 milliseconds of data are recorded before contact.

6.10.1.7 Ensure that at least 30 minutes have passed since the last neck qualification test.

6.10.1.8 Release the pendulum from a height to generate a 3.40 ± 0.05 m/s velocity at impact.

6.10.1.9 Repeat Section 6.10 for the opposite direction of loading.

6.10.2 <u>Neck Lateral Flexion Data Processing</u>

6.10.2.1 Follow the procedures in Section 6.6 Neck Test Data Zero Setting, Offset Calculation.

6.10.2.2 Confirm that the polarity of the pendulum ARS is set such that the angular velocity of the pendulum as it falls towards the decelerator is positive.

6.10.2.3 Calculate the head rotation angle relative to the pendulum:

$$Left: Head\ Rotation(t) = \int_{t_0}^{t} -\omega_{x,head}(t) - \omega_{y,pendulum}(t)dt$$

$$Right: Head\ Rotation(t) = \int_{t_0}^{t} \omega_{x,head}(t) - \omega_{y,pendulum}(t)dt$$

Where:

$Head\ Rotation\ (t)$ = time history of Head X Rotation

$\omega_{x,head}(t)$ = time history of Head X Angular Velocity

$\omega_{y,pendulum}(t)$ = time history of Pendulum Y Angular Velocity

t_0 = first time point for calculation (see 6.6.4)

t_f = final time point for collected data

Table 6-11. Required Measurement Channels for the Neck Lateral Flexion Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer, X-axis	1000	T0SENSMI0000ACXA	XG	AM	PEND	AC	G'S
Pendulum Velocity, X-axis	N/A	T0SENSMI0000VAXD	XG	CM	PEND	PP	MPS
Upper Neck Moment, X-axis	600	D0NECKUP00TFMOXB	XL	AM	NEKU	LC	NWM
Head Angular Velocity, X-axis (ARS)	60	D0HEAD0000TFAVXD	XL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00TFAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000TFANXD	XL	CM	HDCG	PP	DEG

6.10.3 <u>Neck Lateral Flexion Test Performance Specification</u>

The pendulum pulse must be within the ranges indicated in Table 6-12. The neck lateral flexion response must be within the ranges provided in Table 6-13 and Table 6-14.

Table 6-12. Pendulum Pulse for Neck Lateral Flexion Qualification Test

Parameter	Units	Specification	
		Min.	Max.
Pendulum velocity at 5 ms after T0	m/s	0.90	1.10
Pendulum velocity at 10 ms after T0	m/s	1.89	2.31
Pendulum velocity at 15 ms after T0	m/s	2.75	3.36

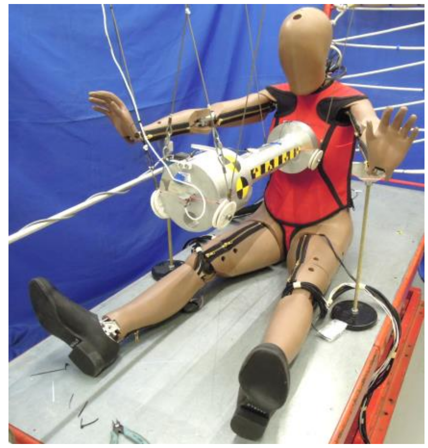
Table 6-13. Neck Left Lateral Flexion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	3.35	3.45
Upper Neck M_x most positive value after 40.0 ms	N-m	27.6	33.7
First Peak Head Angular Velocity ω_x (relative to earth)	deg/s	-1495	-1223
Peak Head Rotation (relative to pendulum)	deg	-54.2	-44.4

Table 6-14. Neck Right Lateral Flexion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Upper Neck M_x most negative after 40.0 ms	N-m	-33.7	-27.6
First Peak Head Angular Velocity ω_x (relative to earth)	deg/s	1223	1495
Peak Head Rotation (relative to pendulum)	deg	44.4	54.2

7 UPPER THORAX QUALIFICATION



7.1 Description

The upper thorax qualification test is a dynamic test performed to examine the resultant deflection and corresponding force of the upper thorax when impacted at mid-sternum with a 13.97 kg rigid impactor at 4.30 m/s.

7.2 Materials

- Fully-assembled THOR-05F ATD
- Impactor 13.97 ± 0.02 kg (30.8 ± 0.04 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables, as specified in Part 572[6]. The test probe is a 152.40 ± 0.25 mm diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 12.7 ± 0.3 mm.

7.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T8) to measure initial angles about “X” and “Y” axes
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about “X” and “Y” axes
- Sensors to measure 3D displacements in the upper left and upper right thorax

7.4 Pre-Test Procedures

7.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

7.4.2 Set the LTS pitch change joint to the **slouched** position (see Section 3.1).

7.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

7.4.4 Set the arm and shoulder joint torques as described in Section 3.3.

[6] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.137(a).

7.5 Test Procedure

7.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

7.5.2 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward. The midsagittal plane shall be vertical within ±1 degree.

7.5.1 Support the forearms in a fully-extended orientation, palmside of the hands down, with hands angled upwards to minimize interference with the arm supports (Figure 7-1). The inability to hold this position indicates that the arm and shoulder joint torques are not set in accordance with Section 3.3.

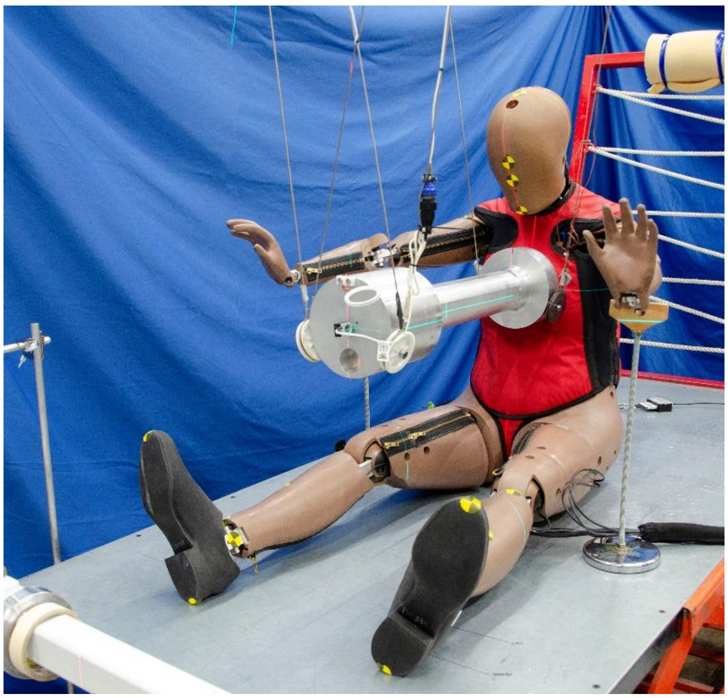


Figure 7-1. Initial setup for upper thorax qualification

7.5.2 To remove the jacket, first pull the strap (474-3810) off of the Velcro on the bottom of the Back Panel Assembly (474-3910) (Figure 7-2).

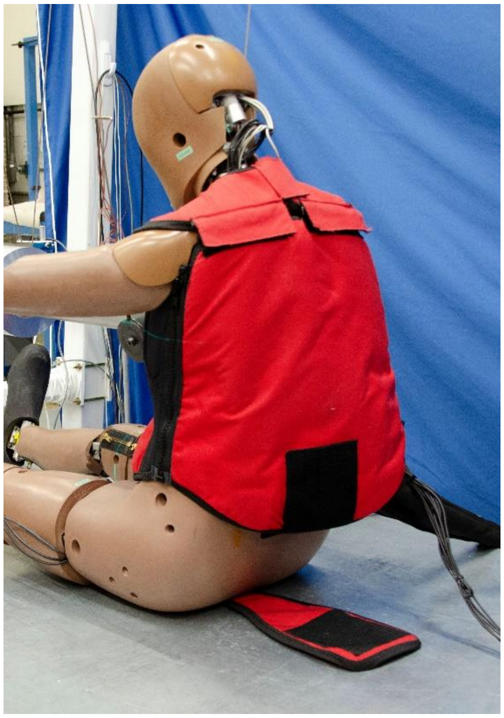


Figure 7-2. Uninstall strap from back panel assembly

7.5.3 Unzip the left and right Shoulder Zippers (474-3823) and left and right Side Zippers (474-3925). Uninstall the left and right Hook for Shoulders (474-3834) to fully remove the back panel assembly and expose the rib cage (Figure 7-3). Leave the strap in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

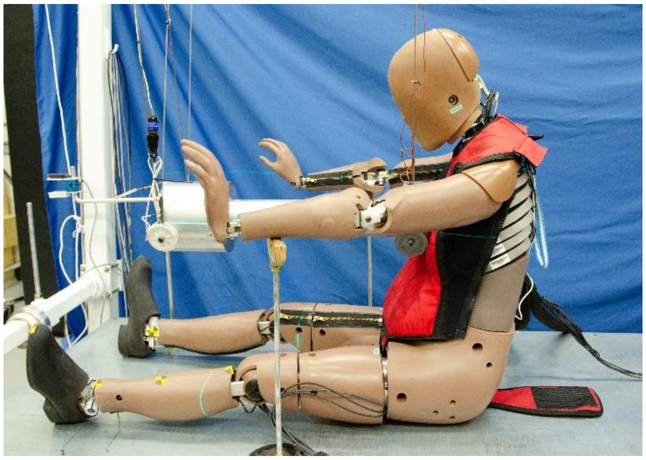


Figure 7-3. Remove back panel assembly

7.5.4 Lift the Flap for Neck (474-3833) away from the Loop Velcro for Neck Flap (474-3833B) to allow the front body assembly to be placed between the legs (Figure 7-4). Leave the front body assembly in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

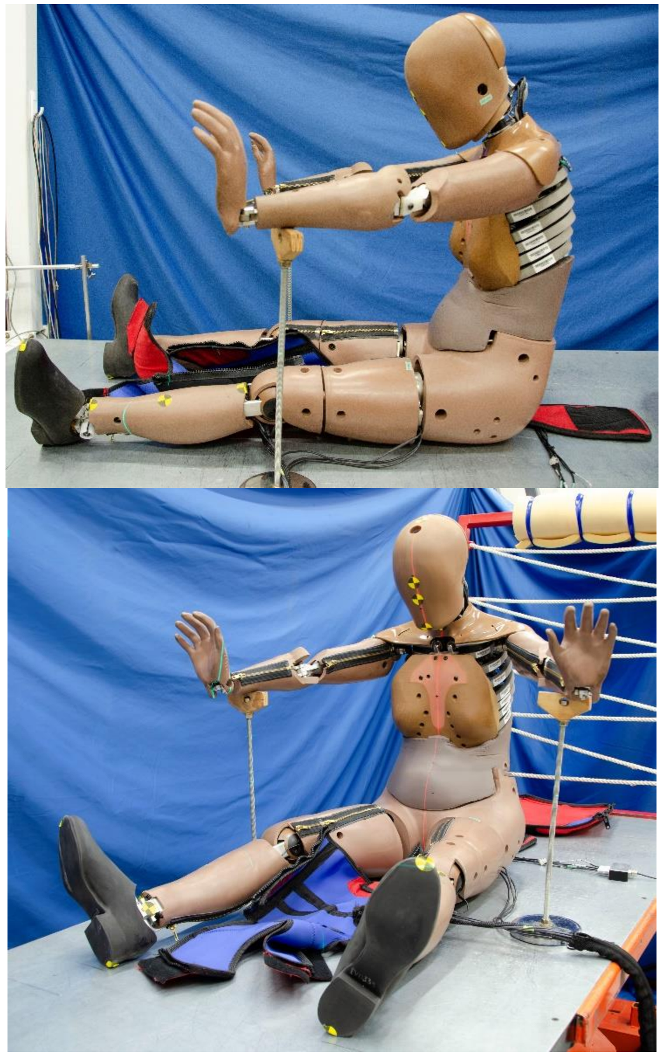


Figure 7-4. Remove front body assembly

7.5.5 Position the arms approximately equi-distant from the centerline of the probe, just far enough so that the suspension cables do not interfere with the arms when the probe contacts the target area.

7.5.6 Position the pelvis so that the pelvis tilt sensor reads and 11 ± 1 deg (rearward tilt about the Y-axis) and 0 ± 0.5 deg laterally (about the X-axis).

7.5.7 Position the thorax so that the T8 tilt sensor reads 0 ± 1 deg (about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

7.5.8 Adjust the table height or impactor height so that the center of the impact face is at the vertical level of the center of the third rib anteriorly, as indicated by the bolts that attach the 3D displacement sensors at the left and right upper thorax (Figure 7-5).

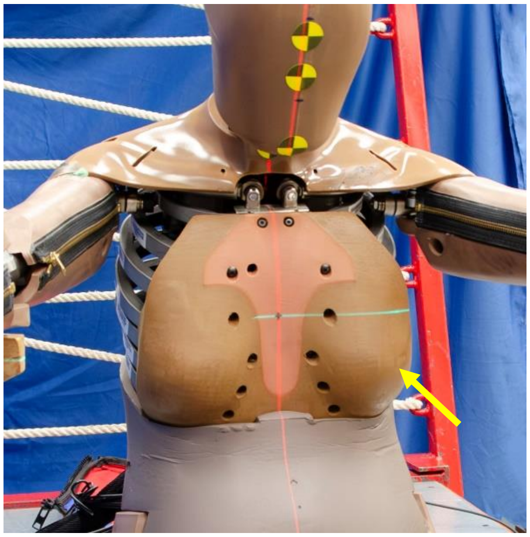


Figure 7-5. Vertical alignment of impact location

7.5.9 Align the vertical centerline of the probe with the midsagittal plane of the dummy (Figure 7-6). The midsagittal plane can be visualized using the center of the bottom face load cell detent on the head skin, the midpoint between the 3D displacement sensor attachment bolts, the umbilicus detent on the abdomen, and the pelvis flesh at the pubic symphysis.

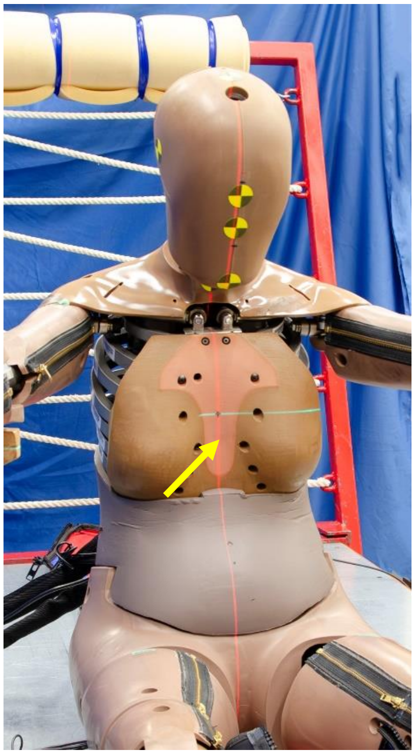


Figure 7-6. Align the midsagittal plane

7.5.10 A removable pointer will ensure proper alignment (Figure 7-7). Align the impactor face with the intersection of the midsagittal plane and vertical centerline located in Section 7.5.9 (Figure 7-6 and Figure 7-8). Remove the pointer tool when this step has been completed.

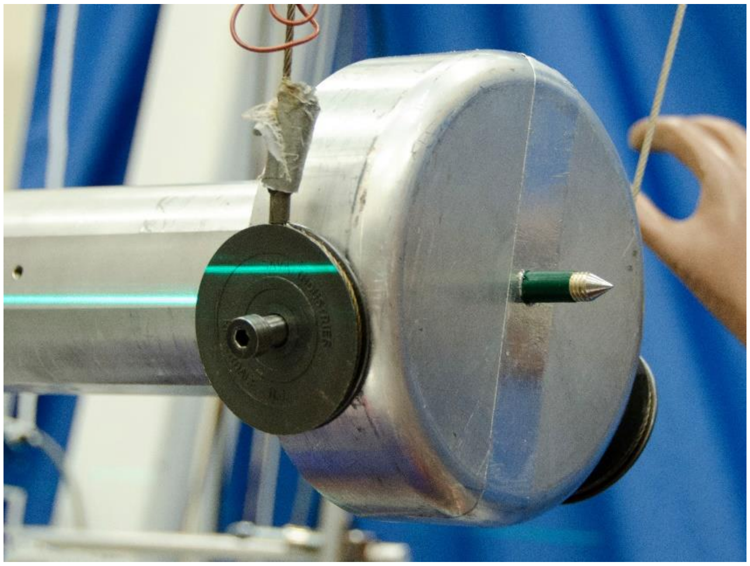


Figure 7-7. Pointer tool for impact point alignment

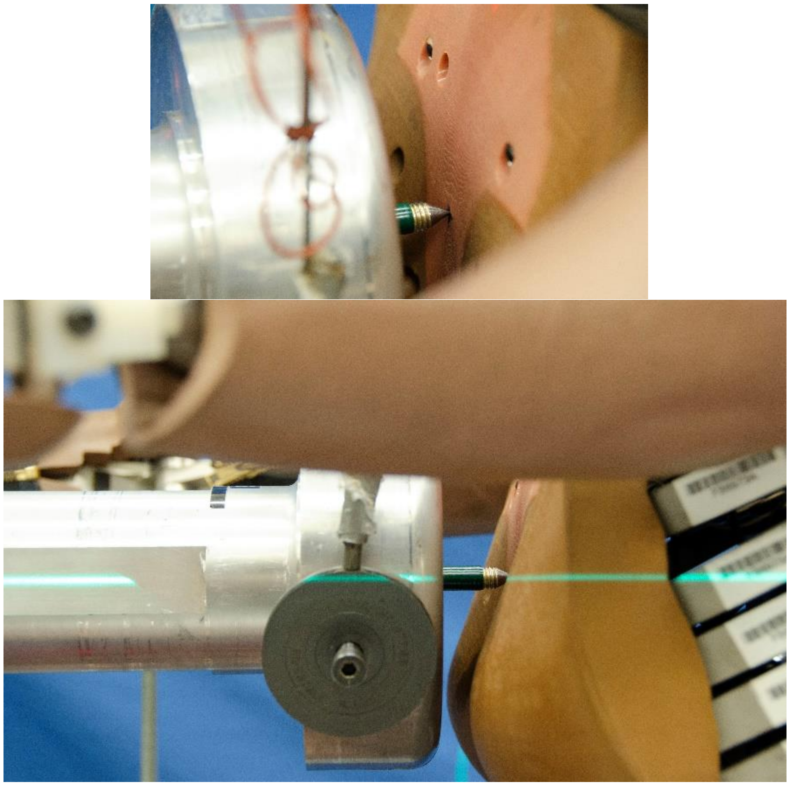


Figure 7-8. Alignment of impact location using laser and pointer tool

7.5.11 Carefully reinstall the jacket front body assembly by fastening the Velcro at the neck flap. Align the frontal (coronal) plane of the dummy perpendicular to the impact direction. Position the dummy so the chest is just touching the impact probe when the probe is at rest (Figure 7-9).

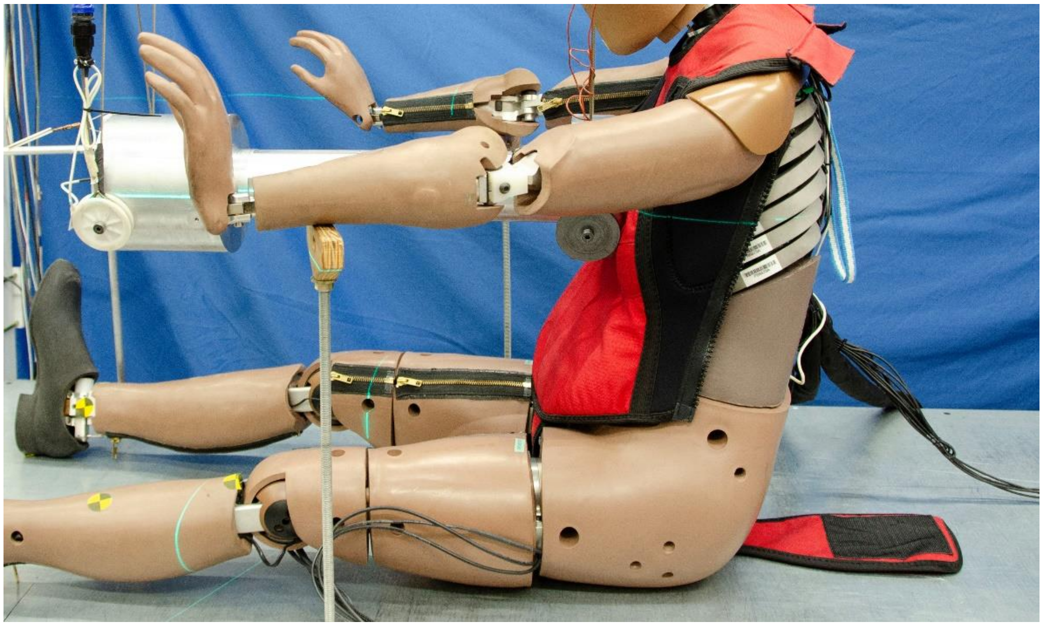


Figure 7-9. Align dummy perpendicular to impact

7.5.12 Continue to reinstall the dummy's jacket by zipping the left and right side zippers. Then zipper the left and right shoulder zippers and adhere the left and right hook for the shoulders. Attach the hook portion of the crotch strap to the loop portion of the back panel assembly (Figure 7-10).

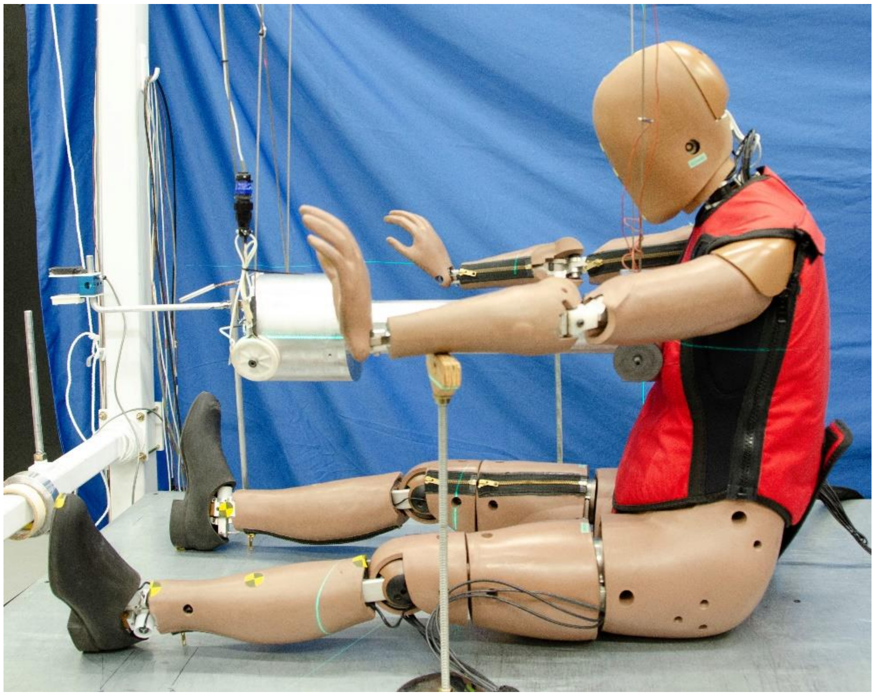


Figure 7-10. Final setup for upper thorax qualification

7.5.13 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement.

7.5.14 Record the AM channels listed in Table 7-2 in accordance with SAE J211-1. The pre-event bias of the abdomen pressure sensors must not be removed at any time during data collection.

7.5.15 Confirm the test setup parameters illustrated in Table 7-1.

Table 7-1. Upper Thorax Qualification Setup Parameters

Parameter	Setting
LTS Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T8	X = 0 ± 0.5º; Y = 0 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 11 ± 1º
Wait Time Between Tests	At Least 30 Minutes

7.5.16 Ensure that at least 30 minutes have passed since the last upper thorax or lower thorax test on this ATD.

7.5.17 Conduct the test at an impact velocity of 4.30 ± 0.05 m/s.

7.6 Data Processing

7.6.1 With the exception of the sensors used to calculate the 3D displacements, perform bias removal of the AM channels listed in Table 7-2 by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

7.6.2 Filter channels based on the CFC filter classes listed in Table 7-2. Do not filter any of the sesnors used to calculate the 3D displacements.

7.6.3 Calculate the time-history of the impact force at the contact interface (see Section 2.7).

7.6.4 Follow instruction in Section 15 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)") to calculate the upper left and upper right thorax X-axis, Y-axis, and Z-axis deflections in the UTS *local spine coordinate system*. Use CFC 180 when instructed in the calculations to filter *R* and any associated potentiometer time histories.

7.6.5 Calculate the upper left and upper right resultant thorax deflections in the UTS *local spine coordinate system*.

$$UPTH_{DR}(t) = \sqrt{D_X^2 + D_Y^2 + D_Z^2}$$

Where:

$UPTH_{DR}(t)$ = time history of upper thorax resultant deflection (L or R)

D_X = time history of upper thorax X deflection (L or R)

D_Y = time history of upper thorax Y deflection (L or R)

D_Z = time history of upper thorax Z deflection (L or R)

7.6.6 Calculate the absolute value of the difference between the maximum left and maximum right resultant deflections in the *local coordinate system* (UTS).

Table 7-2. Required Measurement Channels for the Upper Thorax Qualification Test

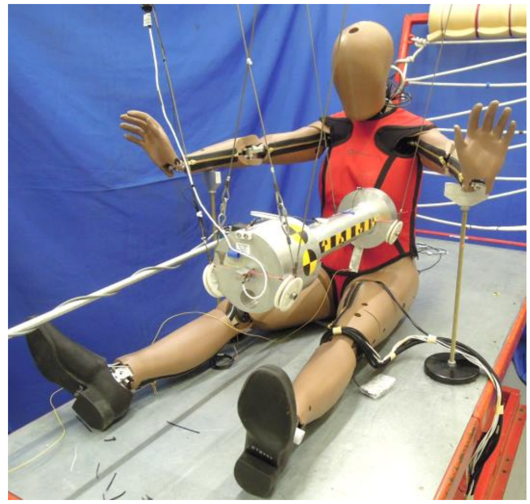
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Upper left IR-TRACC tube	N/A	D0CHSTLEUPTFVO0C	NA	AM	CHLU	DS	VOL
Upper left Y-axis rotational potentiometer	180	D0CHSTLEUPTFANYC	YL	AM	CHLU	AD	DEG
Upper left Z-axis rotational potentiometer	180	D0CHSTLEUPTFANZC	ZL	AM	CHLU	AD	DEG
Upper right IR-TRACC tube	N/A	D0CHSTRIUPTFVO0C	NA	AM	CHRU	DS	VOL
Upper right Y-axis rotational potentiometer	180	D0CHSTRIUPTFANYC	YL	AM	CHRU	AD	DEG
Upper right Z-axis rotational potentiometer	180	D0CHSTRIUPTFANZC	ZL	AM	CHRU	AD	DEG
Probe Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Probe Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Upper left X-axis deflection WRT UTS	N/A	D0CHSTLEUPTFDSXC	XL	CM	CHLU	PP	MM
Upper left Y-axis deflection WRT UTS	N/A	D0CHSTLEUPTFDSYC	XL	CM	CHLU	PP	MM
Upper left Z-axis deflection WRT UTS	N/A	D0CHSTLEUPTFDSZC	XL	CM	CHLU	PP	MM
Upper right X-axis deflection WRT UTS	N/A	D0CHSTRIUPTFDSXC	XL	CM	CHRU	PP	MM
Upper right Y-axis deflection WRT UTS	N/A	D0CHSTRIUPTFDSYC	XL	CM	CHRU	PP	MM
Upper right Z-axis deflection WRT UTS	N/A	D0CHSTRIUPTFDSZC	XL	CM	CHRU	PP	MM
Upper left resultant deflection WRT UTS	N/A	D0CHSTLEUPTFDSRC	NA	CM	CHLU	PP	MM
Upper right resultant deflection WRT UTS	N/A	D0CHSTRIUPTFDSRC	NA	CM	CHRU	PP	MM

7.7 Performance Specifications

Table 7-3. Upper Thorax Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.25	4.35
Peak Probe Force	N	1796	2195
Peak Upper Left Resultant Deflection	mm	31.7	38.8
Peak Upper Right Resultant Deflection	mm		
Difference Between Peak Left & Right Resultant Deflections	mm		< 5.0
Force at Left Peak Resultant Deflection	mm	1616	1976
Force at Right Peak Resultant Deflection			

8 LOWER THORAX QUALIFICATION



8.1 Description

The lower thorax qualification test is a dynamic test performed to examine the resultant deflection and corresponding force of the lower thorax when impacted with a 13.97 kg rigid impactor at 4.30 m/s. This test is carried out on both the left and right lower rib cage locations.

8.2 Materials

- Fully-assembled THOR-05F ATD
- Impactor 13.97 ± 0.02 kg in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables, as specified in Part 572[7]. The test probe is a 152.4 ± 0.25 mm (6.00 ± 0.01 in) diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 12.7 ± 0.3 mm.

8.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T8) to measure initial angles about "X" and "Y" axes
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about "X" and "Y" axes
- Sensors to measure 3D displacements in the lower left and lower right thorax

8.4 Pre-Test Procedures

8.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

8.4.2 Set the LTS pitch change joint to the **slouched** position (see Section 3.1).

8.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

8.4.4 Set the arm and shoulder joint torques as described in Section 3.3.

---

[7] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.137(a).

8.5 Test Procedure

8.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

8.5.2 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward. The midsagittal plane shall be vertical within ± 1 degree.

8.5.3 Support the forearms in a fully-extended orientation, palmside of the hands down, with hands angled upwards to minimize interference with the arm supports (Figure 8-1). The inability to hold this position indicates that the arm and shoulder joint torques are not set in accordance with Section 3.3.

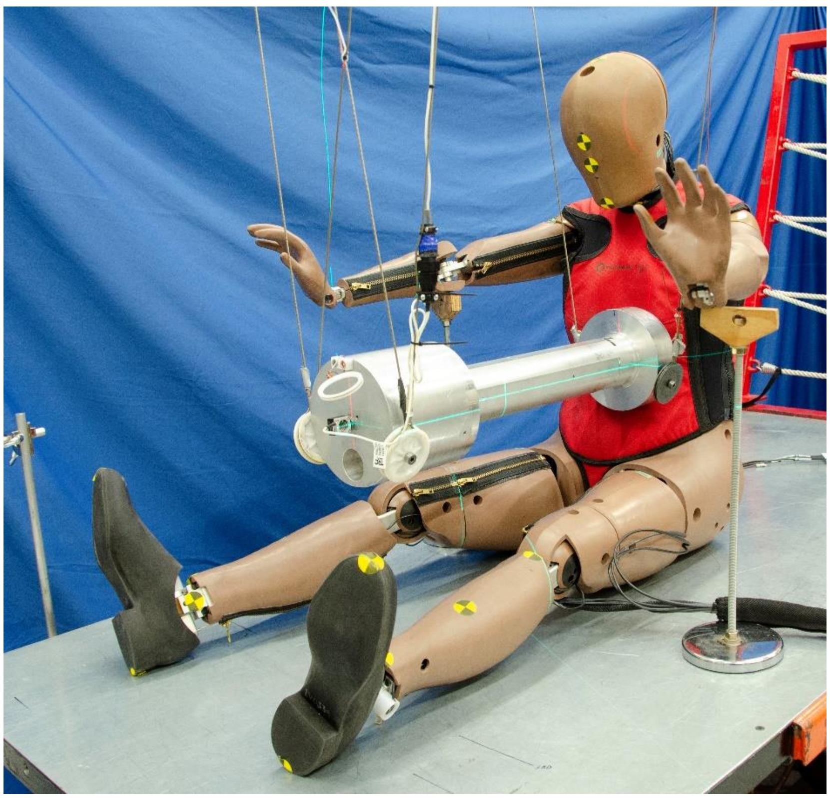


Figure 8-1. Initial setup for lower thorax qualification

8.5.4 To remove the jacket, first pull the strap (474-3810) off of the Velcro on the bottom of the Back Panel Assembly (474-3910) (Figure 7-2).

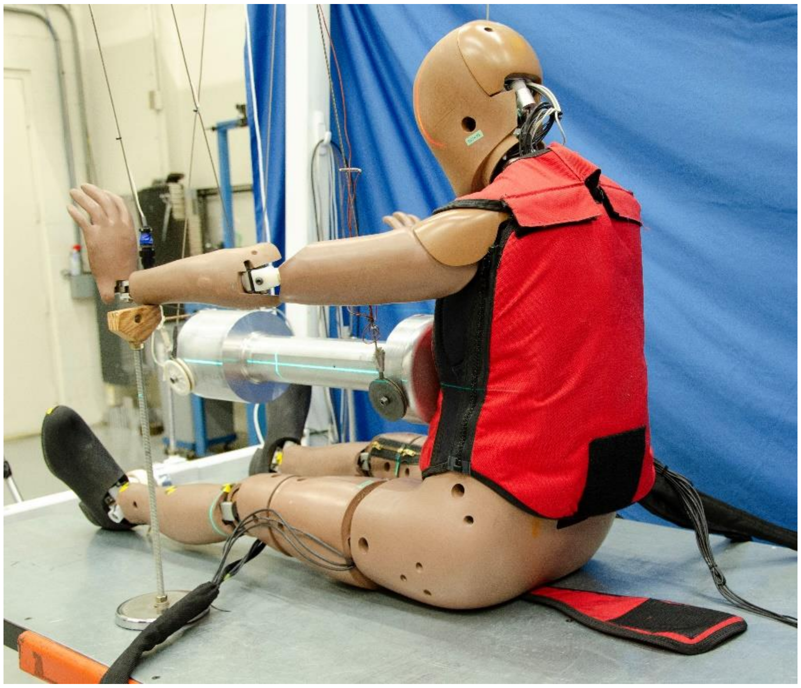


Figure 8-2. Uninstall strap from back panel assembly

8.5.5 Unzip the left and right Shoulder Zippers (474-3823) and left and right Side Zippers (474-3925). Uninstall the left and right Hook for Shoulders (474-3834) to fully remove the back panel assembly and expose the rib cage (Figure 8-3). Leave the strap in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

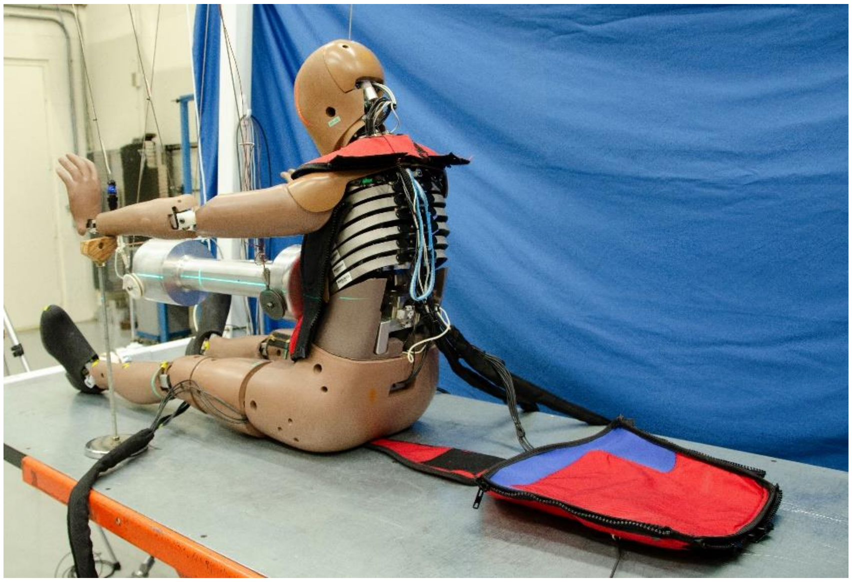


Figure 8-3. Remove back panel assembly

8.5.6 Lift the Flap for Neck (474-3833) away from the Loop Velcro for Neck Flap (474-3833B) to allow the front body assembly to be placed between the legs (Figure 8-4). Leave the front body assembly in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

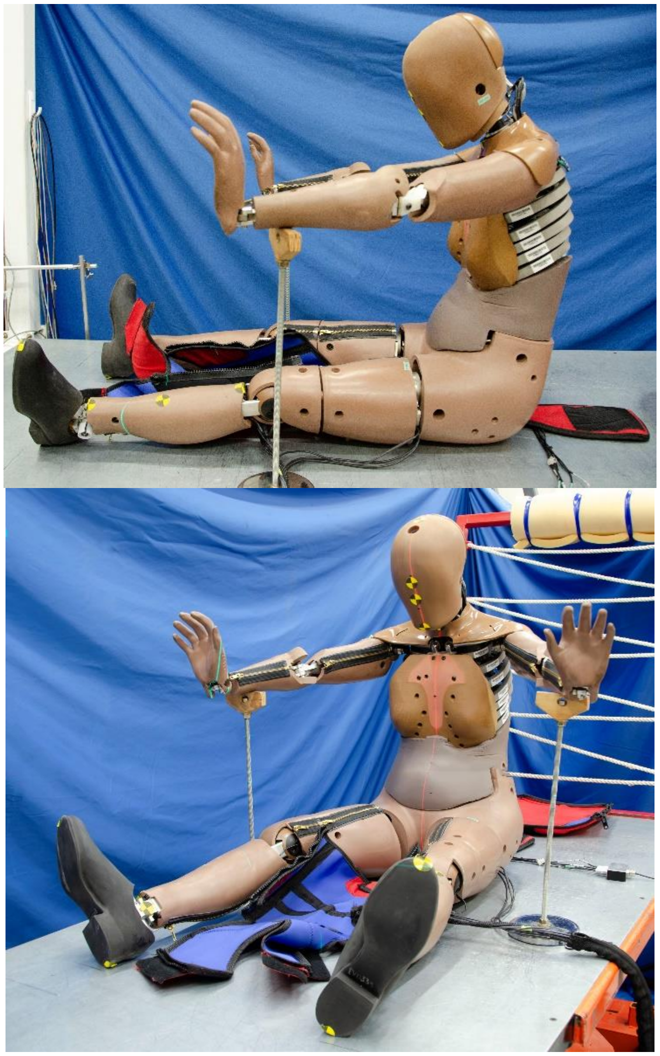


Figure 8-4. Remove front body assembly

8.5.7 Position the arms approximately equi-distant from the centerline of the probe, just far enough so that the suspension cables do not interfere with the arms when the probe contacts the target area.

8.5.8 Position the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5 deg (about the X-axis) and 11 ± 1 deg (rearward tilt about the Y-axis).

8.5.9 Position the thorax so that the T8 tilt sensor reads 0 ± 0.5 deg (about the X-axis) and 0 ± 0.5 deg (about the Y-axis).

8.5.10 Adjust the table height or impactor height so that the center of the impact face is at the vertical level of the center of the sixth rib anteriorly, as indicated by the attachment bolt of the lower left or right thorax 3D displacement sensors (Figure 8-5).

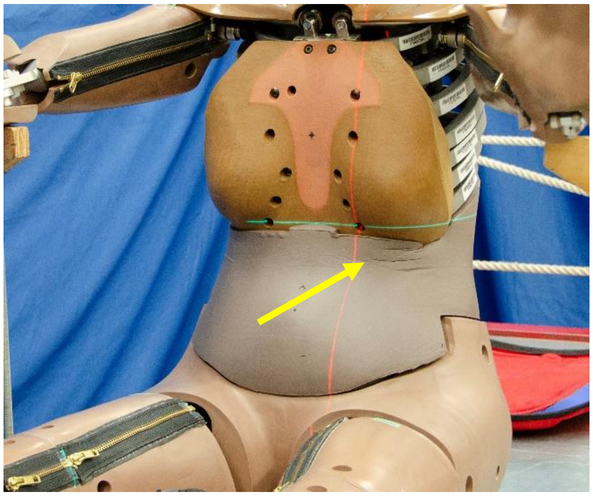


Figure 8-5. Vertical alignment of impact location

8.5.11 Align the impactor face with the center of the bolt that attaches the 3D displacement sensor at the left or right lower thorax. A removable pointer will ensure proper alignment (Figure 8-6). Remove the pointer tool when this step has been completed.

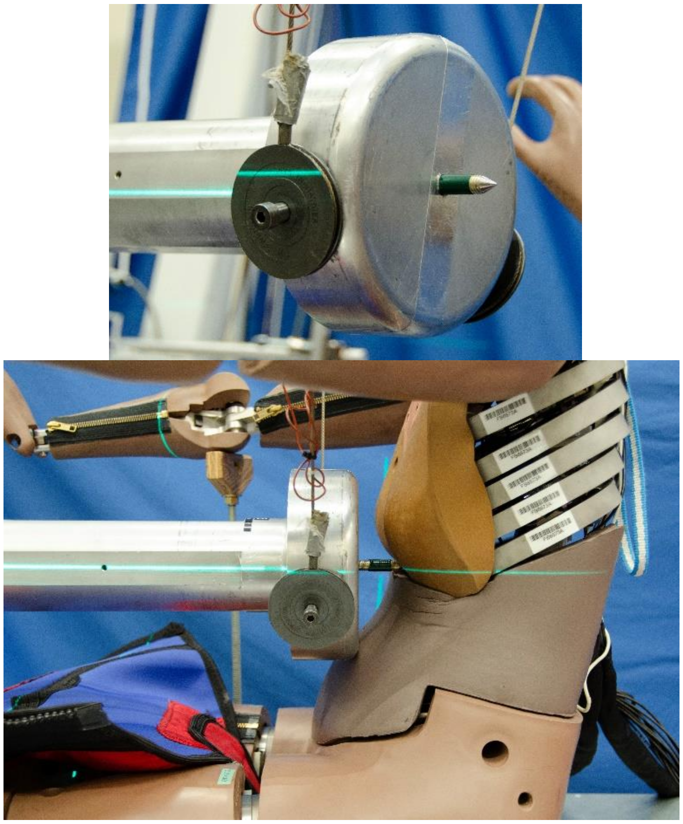


Figure 8-6. Alignment of impact location using laser and pointer tool

8.5.12 Carefully reinstall the jacket front body assembly by fastening the Velcro at the neck flap. Align the frontal (coronal) plane of the dummy perpendicular to the impact direction. Position the dummy so the chest is just touching the impact probe when the probe is at rest. Continue to reinstall the dummy's jacket by zipping the left and right side zippers. Then zipper the left and right shoulder zippers and adhere the left and right hook for the shoulders. Attach the hook portion of the crotch strap to the loop portion of the back panel assembly (Figure 8-7).

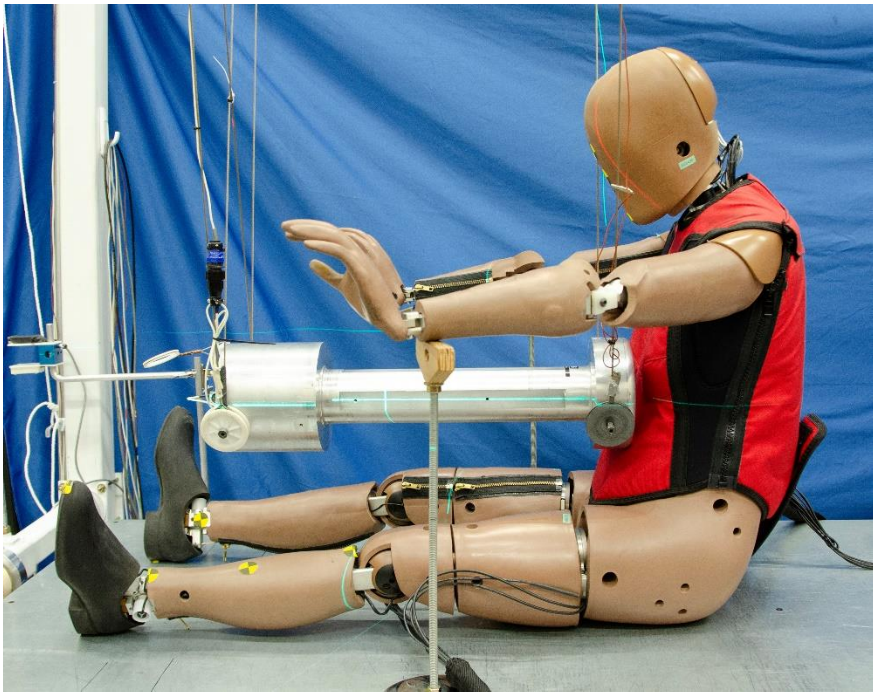


Figure 8-7. Final setup for lower thorax qualification

8.5.13 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement.

8.5.14 Record the AM channels listed in Table 8-2 (for left impacts) or Table 8-3 (for right impacts) in accordance with SAE J211-1.

8.5.15 Confirm the test setup parameters illustrated in Table 8-1.

Table 8-1. Lower Thorax Qualification Setup Parameters

Parameter	Setting
LTS Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T8	X = 0 ± 0.5º; Y = 0 ± 0.5º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 11 ± 1º
Wait Time Between Tests	At Least 30 Minutes

8.5.16 Ensure that at least 30 minutes have passed since the last upper thorax, lower thorax, or abdomen test on this ATD.

8.5.17 Conduct the test at an impact velocity of 4.30 ± 0.05 m/s.

8.5.18 Repeat 8.5 for the opposite side of the lower thorax.

8.6 Data Processing

8.6.1 With the exception of sensors used to calculate the 3D dispalcements, perform bias removal of the AM channels listed Table 8-2 by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

8.6.2 Filter channels based on CFC filter classes listed in Table 8-2 (for left impacts) or Table 8-3 (for right impacts). Do not filter any sensors used to calculate the 3D displacements.

8.6.3 Calculate time history of impact force at the contact interface (see Section 2.7).

8.6.4 Follow instruction in Section 15 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)") to calculate the lower left and lower right thorax X-axis, Y-axis, and Z-axis deflections in the LTS *local spine coordinate system*. Use CFC 180 when instructed in the calculations to filter *R* and any associated potentiometer time histories.

8.6.5 Calculate the lower left or lower right resultant thorax deflections in the LTS *local spine coordinate system*.

$$LOTH_{DR}(t) = \sqrt{D_X^2 + D_Y^2 + D_Z^2}$$

Where:

$LOTH_{DR}(t) =$ time history of lower thorax resultant deflection (L or R)

$D_X =$ time history of lower thorax X deflection (L or R)

$D_Y =$ time history of lower thorax Y deflection (L or R)

$D_Z =$ time history of lower thorax Z deflection (L or R)

Table 8-2. Required Measurement Channels for the Lower Left Thorax Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Lower left IR-TRACC tube	N/A	D0CHSTLELOTFVO0C	NA	AM	CHLL	DS	VOL
Lower left Y-axis rotational potentiometer	180	D0CHSTLELOTFANYC	YL	AM	CHLL	AD	DEG
Lower left Z-axis rotational potentiometer	180	D0CHSTLELOTFANZC	ZL	AM	CHLL	AD	DEG
Probe Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Probe Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Lower left X-axis deflection WRT LTS	N/A	D0CHSTLELOTFDSXC	XL	CM	CHLL	PP	MM
Lower left Y-axis deflection WRT LTS	N/A	D0CHSTLELOTFDSYC	YL	CM	CHLL	PP	MM
Lower left Z-axis deflection WRT LTS	N/A	D0CHSTLELOTFDSZC	ZL	CM	CHLL	PP	MM
Lower left resultant deflection WRT LTS	N/A	D0CHSTLELOTFDSRC	NA	CM	CHLL	PP	MM

Table 8-3. Required Measurement Channels for the Lower Right Thorax Qualification Test

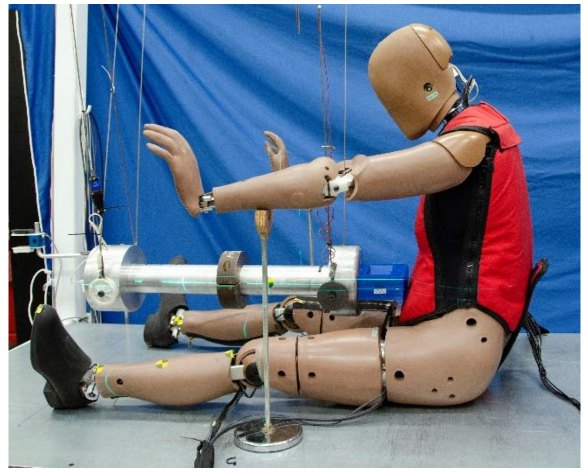
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Lower right IR-TRACC tube	N/A	D0CHSTRILOTFVO0C	NA	AM	CHRL	DS	VOL
Lower right Y-axis rotational potentiometer	180	D0CHSTRILOTFANYC	YL	AM	CHRL	AD	DEG
Lower right Z-axis rotational potentiometer	180	D0CHSTRILOTFANZC	ZL	AM	CHRL	AD	DEG
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Lower right X-axis deflection WRT LTS	N/A	D0CHSTRILOTFDSXC	XL	CM	CHRL	PP	MM
Lower right Y-axis deflection WRT LTS	N/A	D0CHSTRILOTFDSYC	YL	CM	CHRL	PP	MM
Lower right Z-axis deflection WRT LTS	N/A	D0CHSTRILOTFDSZC	ZL	CM	CHRL	PP	MM
Lower right resultant deflection WRT LTS	N/A	D0CHSTRILOTFDSRC	NA	CM	CHRL	PP	MM

8.7 Performance Specifications

Table 8-4. Lower Thorax Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.25	4.35
Peak Probe Force	N	1807	2209
Left or Right Resultant Deflection at Peak Force	mm	38.4	46.9

9 ABDOMEN QUALIFICATION



9.1 Description

The abdomen qualification test is a dynamic test performed to examine the deflection and corresponding force of the abdomen when impacted with a 16.00 kg rigid impactor (utilizing a horizontally-oriented rigid bar impactor face) at 6.10 m/s.

9.2 Materials

- Fully assembled THOR-05F ATD
- Impactor 16.00 ± 0.02 kg in mass, including rectangular impact face, instrumentation, rigid attachments, and the mass of the lower 1/3 of the suspension cables. The rectangular, horizontally-oriented impact face attached to the test probe is 140 mm by 50 mm with an edge radius of 8.0 mm (Figure 9-1).

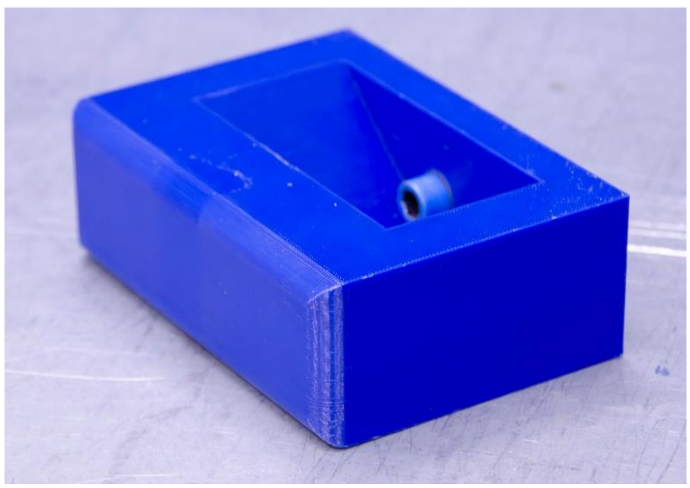


Figure 9-1. Abdomen impact face

9.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T12) to measure initial angles about “X” and “Y” axes
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about “X” and “Y” axes
- Abdomen Twin Pressure sensors (SA572-S162) in the lower left and lower right abdomen to measure abdominal pressure

9.4 Pre-Test Procedures

9.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

9.4.2 Set the LTS pitch change joint to the **slouched** position (see Section 3.1).

9.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

9.4.4 Set the arm and shoulder joint torques as described in Section 3.3.

9.5 Test Procedure

9.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

9.5.2 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward. The midsagittal plane shall be vertical within ±1 degree.

9.5.3 Support the forearms in a fully-extended orientation, palmside of the hands down, with hands angled upwards to minimize interference with the arm supports (Figure 9-2). The inability to hold this position indicates that the arm and shoulder joint torques are not set in accordance with Section 3.3.

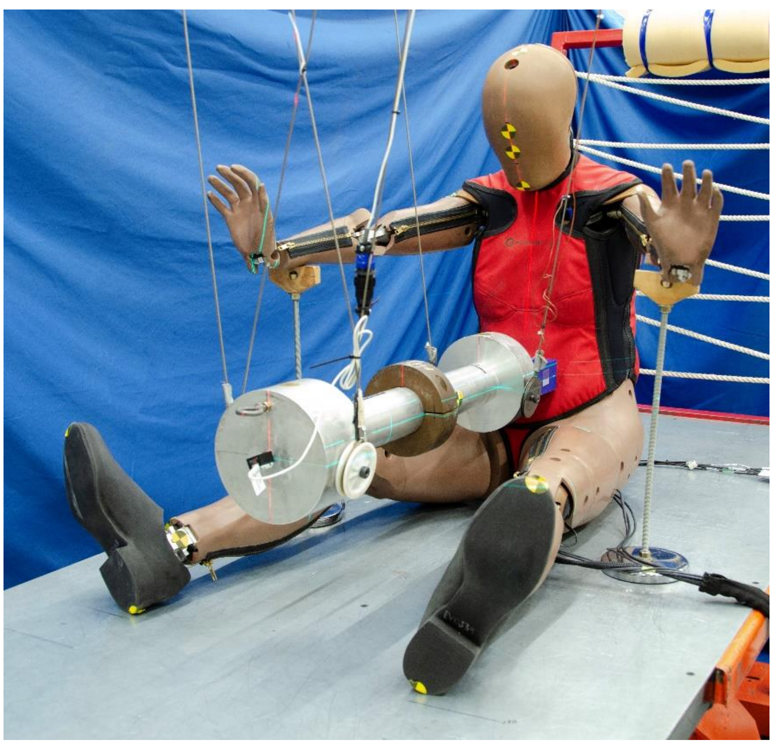


Figure 9-2. Initial setup for abdomen qualification

9.5.4 To remove the jacket, first pull the strap (474-3810) off of the Velcro on the bottom of the Back Panel Assembly (474-3910) (Figure 9-3).

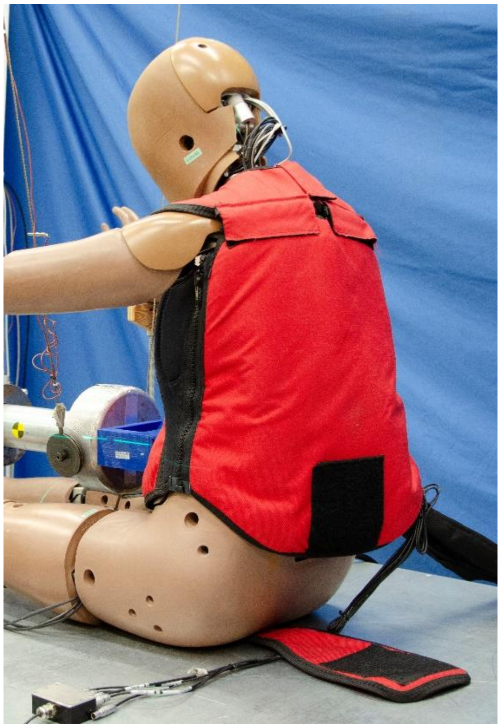


Figure 9-3. Uninstall strap from back panel assembly

9.5.5 Unzip the left and right Shoulder Zippers (474-3823) and left and right Side Zippers (474-3925). Uninstall the left and right Hook for Shoulders (474-3834) to fully remove the back panel assembly and expose the rib cage (Figure 9-4). Leave the strap in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

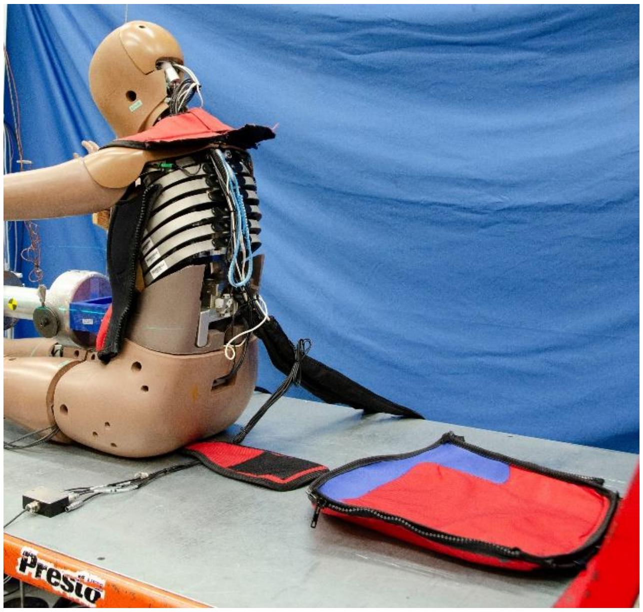


Figure 9-4. Remove back panel assembly

9.5.6 Lift the Flap for Neck (474-3833) away from the Loop Velcro for Neck Flap (474-3833B) to allow the front body assembly to be placed between the legs (Figure 9-5). Leave the front body assembly in place, under the dummy, so that it can be easily reinstalled after positioning, without lifting the dummy.

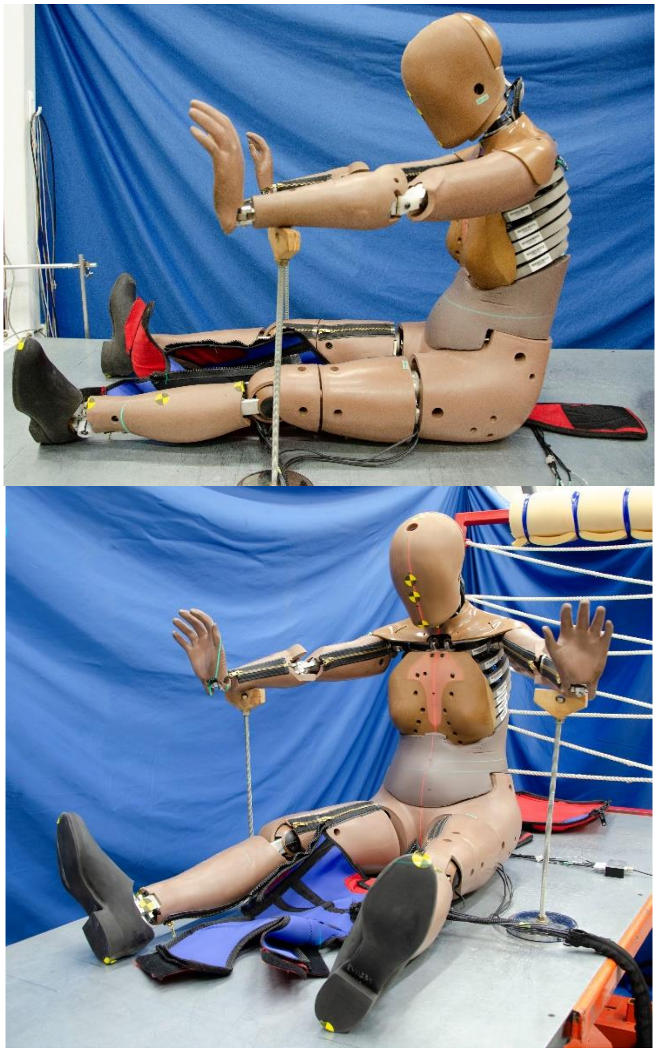


Figure 9-5. Remove front body assembly

9.5.7 Position the arms approximately equi-distant from the centerline of the probe, just far enough so that the suspension cables do not interfere with the arms when the probe contacts the target area.

9.5.8 Position the pelvis so that the pelvis tilt sensor reads 8 ± 1° (rearward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

9.5.9 Position the thorax so that the T12 tilt sensor reads 8 ± 1° (rearward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

9.5.10 Align the vertical centerline of the probe with the midsagittal plane of the dummy (Figure 9-6). The midsagittal plane can be visualized using the center of the bottom face load cell detent on the head skin, the midpoint between the 3D displacement sensor attachment bolts, the umbilicus detent on the abdomen, and the pelvis flesh at the pubic symphysis.

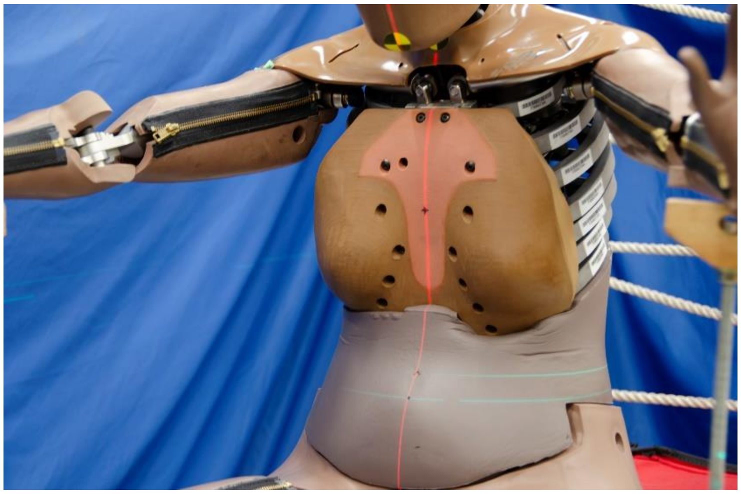


Figure 9-6. Align the midsagittal plane

9.5.11 Adjust the table height or impactor height so that the vertical center of the impact face is 20.7 ± 1.0 mm below the umbilicus detent (Figure 9-7).

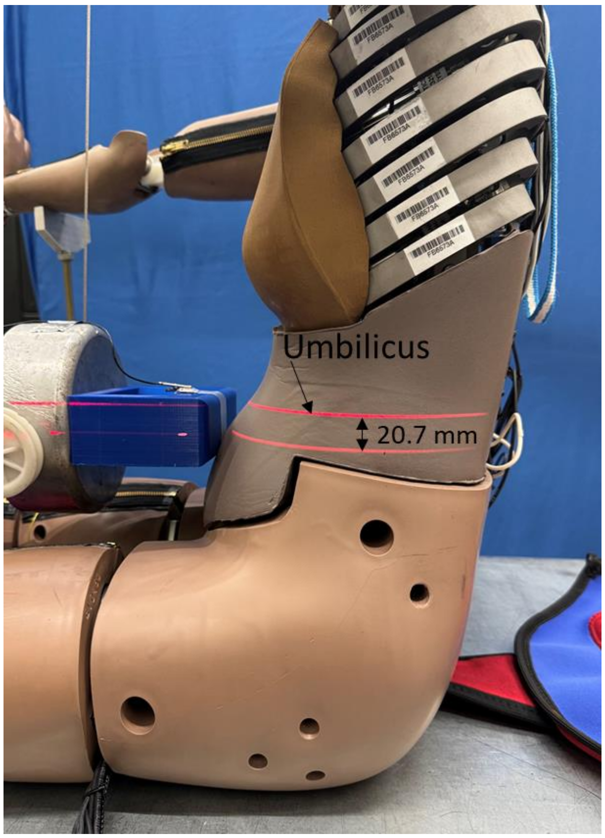


Figure 9-7. Lower abdomen impact location

9.5.12 Carefully reinstall the jacket front body assembly by fastening the Velcro at the neck flap. Align the frontal (coronal) plane of the dummy perpendicular to the impact direction. Install a right-angled guide behind the dummy's pelvis and aligned perpendicular to the line of impact to facilitate the process (Figure 9-8). Position the dummy so the abdomen is just touching the impact probe when the probe is at rest.

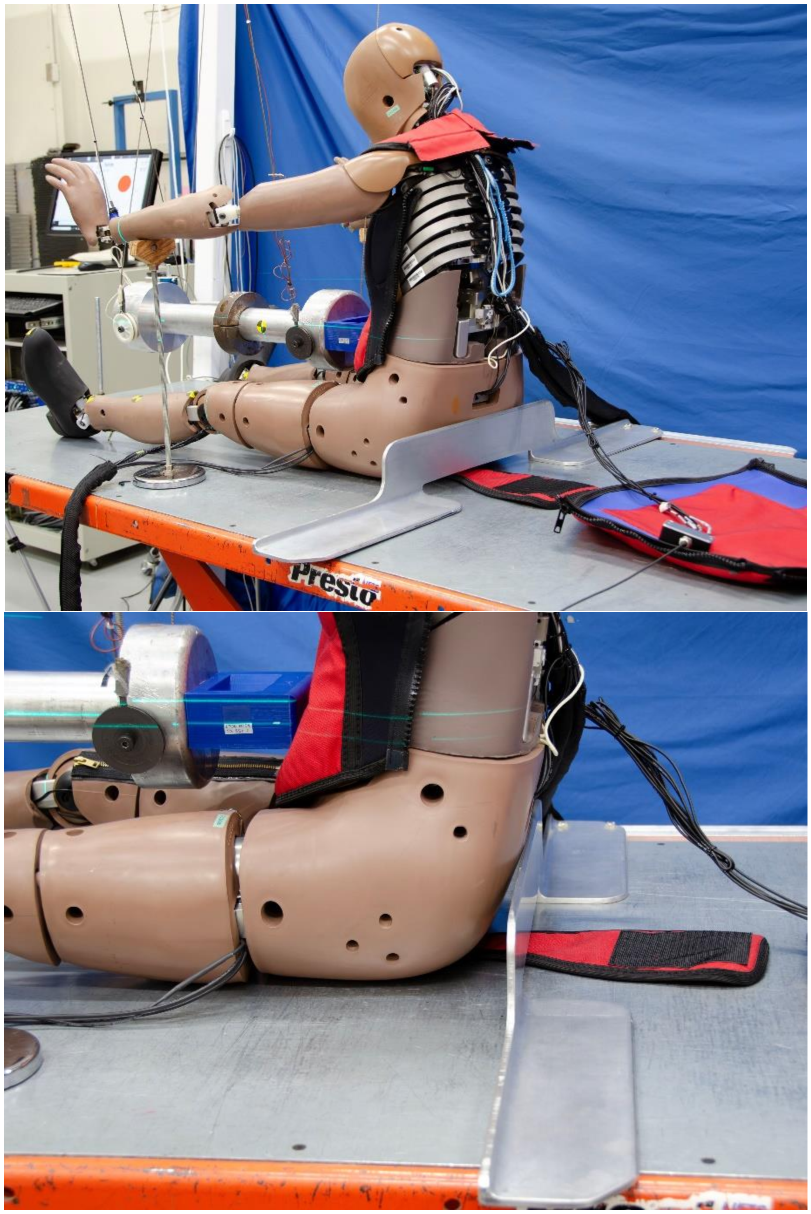


Figure 9-8. Align dummy perpendicular to impact

9.5.13 Remove the right-angled guide. Carefully reinstall the dummy's jacket by zipping the left and right side zippers. Then zipper the left and right shoulder zippers and adhere the left and right hook for the shoulders. Attach the hook portion of the crotch strap to the loop portion of the back panel assembly (Figure 9-9).

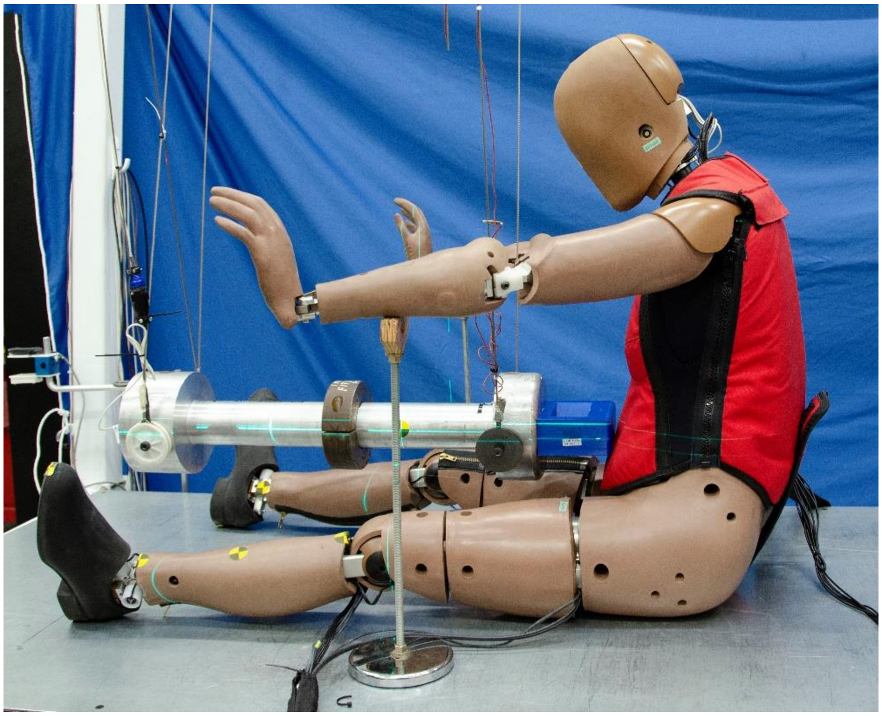


Figure 9-9. Final setup for abdomen qualification

9.5.14 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement. Ensure that the impactor bar is level, $0° \pm 0.5°$.

9.5.15 Record the AM channels listed in Table 9-2 in accordance with SAE J211-1. The pre-event bias of the abdomen pressure sensors must not be removed at any time during data collection.

9.5.16 Confirm the test setup parameters illustrated in Table 9-1.

Table 9-1. Lower Abdomen Impact Test Setup Parameters

Parameter	Setting
LTS Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T12	X = 0 ± 0.5º; Y = 8 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 8 ± 1º
Wait Time Between Tests	At Least 30 Minutes

9.5.17 Ensure that at least 30 minutes have passed since the last lower thorax or abdomen test on this ATD.

9.5.18 Conduct the test at an impact velocity of 6.10 ± 0.05 m/s.

9.6 Data Processing

9.6.1 Perform bias removal of the AM channels listed in Table 9-2 by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

9.6.2 Filter channels based on the CFC filter classes listed in Table 9-2.

9.6.3 Calculate time-history of impact force at the contact interface (see Section 2.7).

9.6.4 Calculate the absolute value of the difference between the peak left and right abdomen pressures.

Table 9-2. Required Measurement Channels for the Lower Abdomen Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT
Left abdomen pressure	600	D0ABDOLE00TFPR0B	XL	CM	ABDL	PP	KPA
Right abdomen presssure	600	D0ABDORI00TFPR0B	XL	CM	ABDR	PP	KPA

9.7 Performance Specifications

Table 9-3. Lower Abdomen Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	6.05	6.15
Peak Probe Force	N	4052	4952
Left Abdomen Peak Pressure	kPa	189	231
Right Abdomen Peak Pressure			
Difference Between Peak Left and Right Pressures	kPa		< 15

10 UPPER LEG QUALIFICATION

10.1 Description

The upper leg qualification test is a dynamic test performed to examine the response of the femur to axial impacts at the knee using a 7.26 kg rigid impactor at 3.65 m/s.

10.2 Materials

- Fully-assembled THOR-05F ATD
- Impactor 7.26 ± 0.02 kg in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables. The test probe is a 76.2 ± 0.2 mm diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 0.5 ± 0.2 mm.

10.3 Instrumentation

- Instrumentation to measure impact force (accelerometer on impactor)
- Instrumentation to measure the impact velocity
- Acetabulum load cell (Left SA572-S108, Right SA572-S109)
- Femur load cell (SA572-S63)
- A dual-axis tilt sensor (SA572-S44) attached to the pelvis to measure initial angle about "X" and "Y" axes

10.4 Pre-Test Procedures

10.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

10.4.2 Set the LTS pitch change joint to the **slouched** position (see Section 3.1).

10.4.3 Set the neck pitch change joint to the **neutral** position (see Section 3.2).

10.4.4 Adjust the knee torque settings according to the procedure in Section 3.5.

10.5 Test Procedure

10.5.1 If not already installed, install the torso jacket as described in Section 12.2 of the "THOR 5th Percentile Female (THOR-05F) Procedures for Assembly, Disassembly, and Inspection (PADI)".

10.5.2 Seat the dummy on a horizontal surface (±0.5°). Position a backer plate approximately 50 mm high behind and touching the posterior pelvis (Figure 10-6). The backer plate must be at least as long as the pelvis breadth and allow for securing it to the table. Measure the distance from the edge of the seat to the backer plate on the left and right sides until the left and right measurements are equal; adjust the plate accordingly to assure that the backer is square with, and touching, the pelvis. Securely clamp the backer plate to the table. The dummy's femurs should be extended horizontally and forward parallel to the midsagittal plane and lower legs extended vertically and downward parallel to the vertical plane (Figure 10-1). The midsagittal plane shall be vertical within ±1 degree.

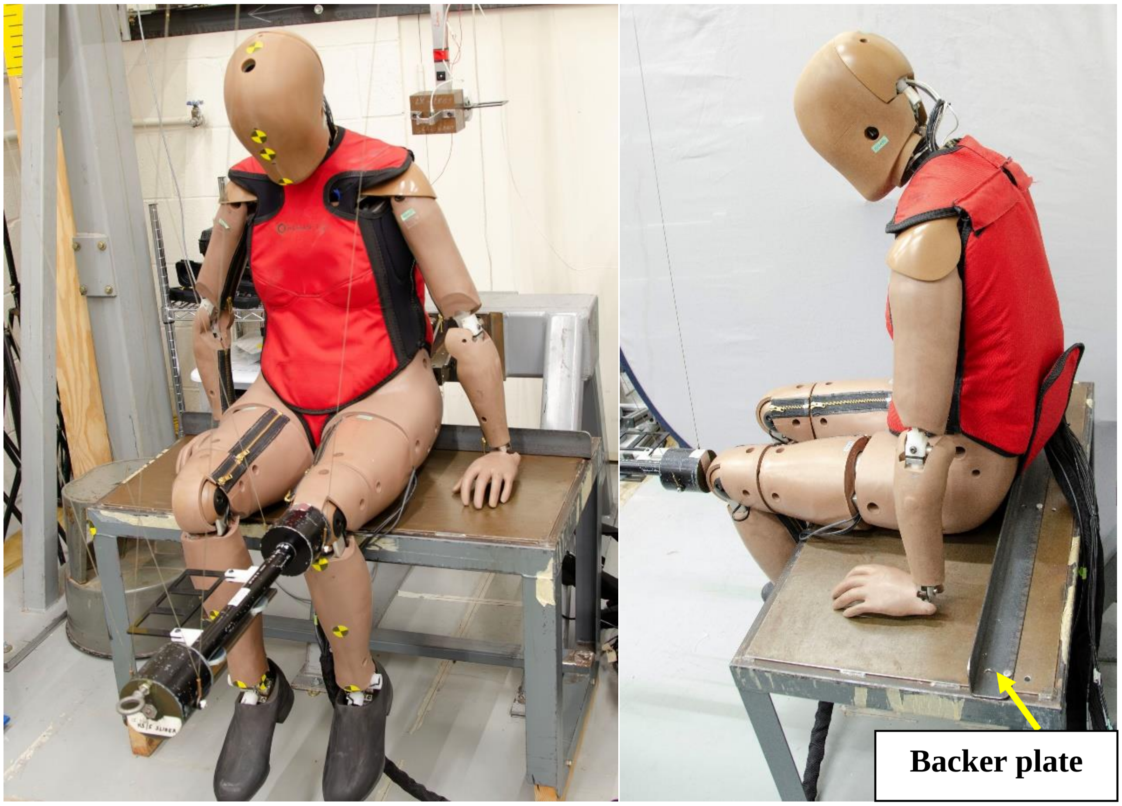


Figure 10-1. Initial setup for the upper leg qualification test.

10.5.3 Position the arms along the side of the body (Figure 10-1).

10.5.4 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5 deg in the X-axis and 5 ± 1 deg in the Y-axis.

10.5.5 With the lower legs positioned over the front edge of the seating surface, place support shim/bladder under the thigh in order to level the centerline of the femur shaft in the horizontal plane (0.0 ± 0.5 deg) (Figure 10-2). Utilizing a laser level or a straight edge with an inclinometer, measure the angle of the line between the center of the knee joint and the centerline of the femur shaft by using the boltheads, which are visible through access holes in the knee and femur flesh; the angle should be 0.0 ± 0.5 deg.

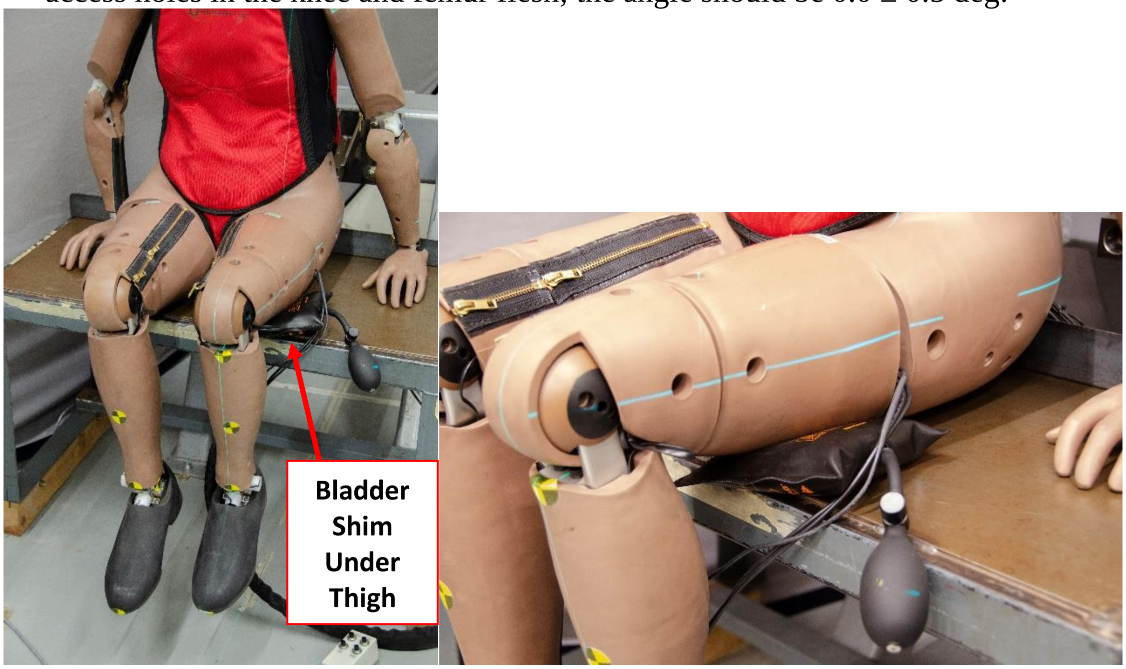


Figure 10-2. Horizontal alignment of knee and femur using laser level

10.5.6 Position the tibia at an angle of 10 ± 1° (in flexion, such that the ankle is behind the knee), as measured at the anterior aspect of the knee clevis (474-5517; Figure 10-3). The distance between the posterior surface of the tibia and the leading edge of the test seat shall be no less than 25 mm.

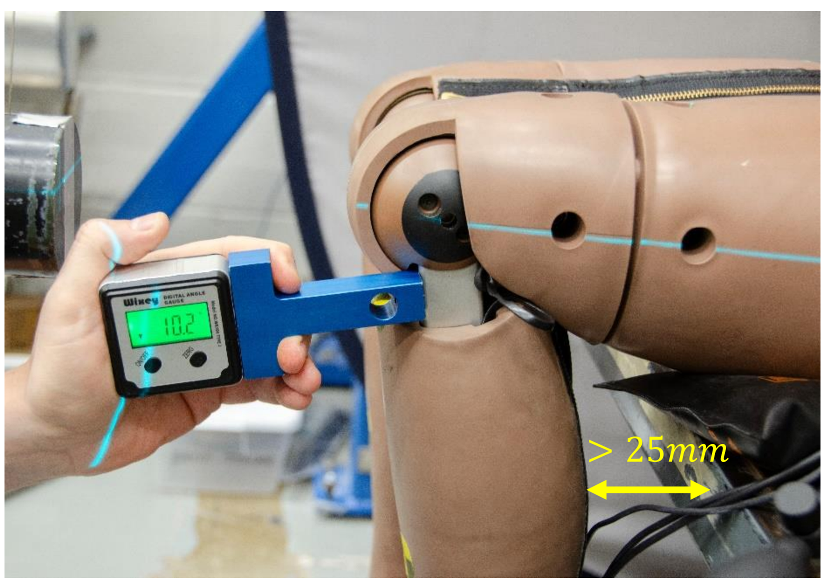


Figure 10-3. Lower leg angle measurement

10.5.6.1 Align the impact probe so that at the point of contact, the center of the probe face is touching the surface of the knee and the probe is aligned, within 0.5 deg, of the longitudinal centerline of the femur load cell (Figure 10-4). A laser level aligned with the longitudinal axis of the probe is used to position the center of the knee with the femur shaft; use the bolt access holes in the thigh flesh to align the femur.

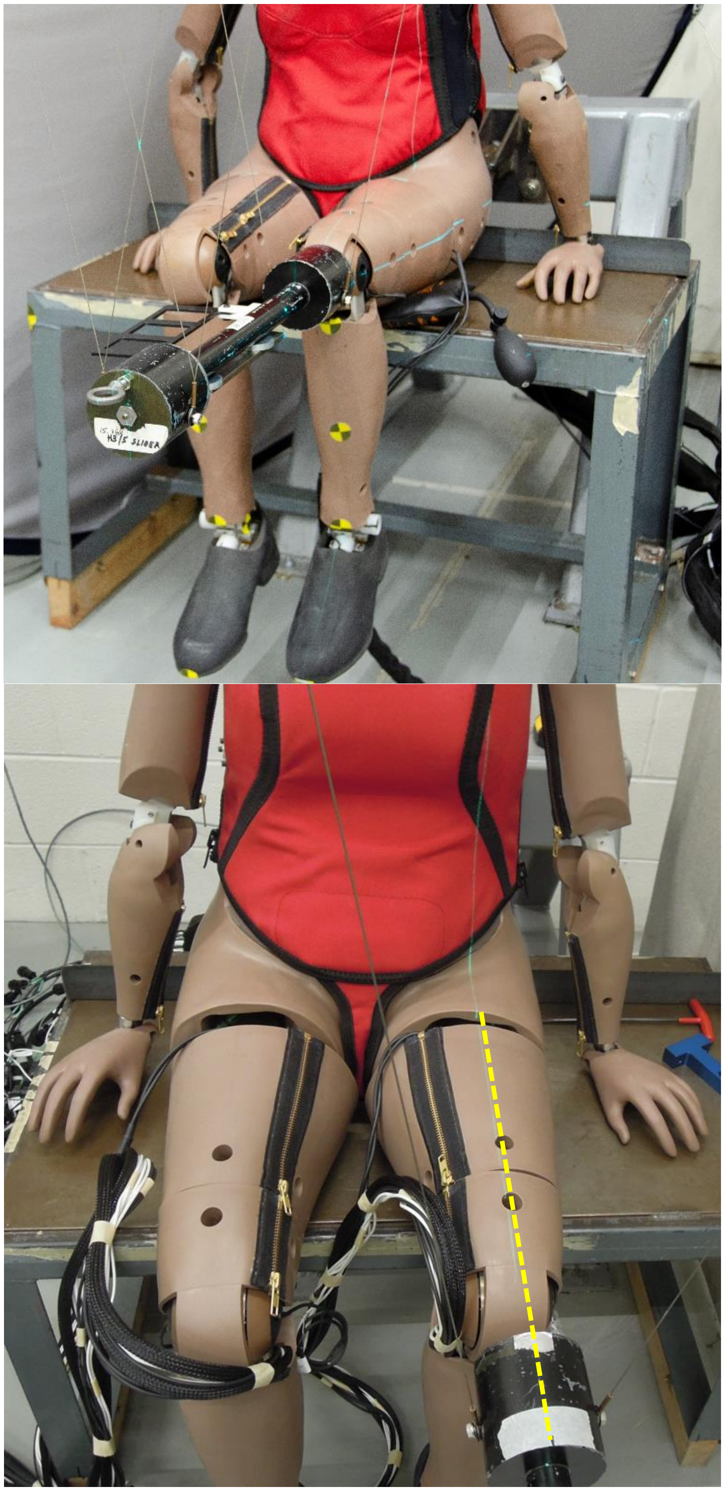


Figure 10-4. Lateral alignment of the probe

10.5.7 Position the foot and lower leg such that the center of the ankle X-axis potentiometer is in the same vertical plane as the femur centerline. This can be accomplished either by measuring the angle on the lateral side of the knee clevis (it should be 0.0 ± 0.5 deg) (Figure 10-5), or by aligning the centerline of the probe with the centerline of the lower leg through the ankle using the laser level (Figure 10-6).

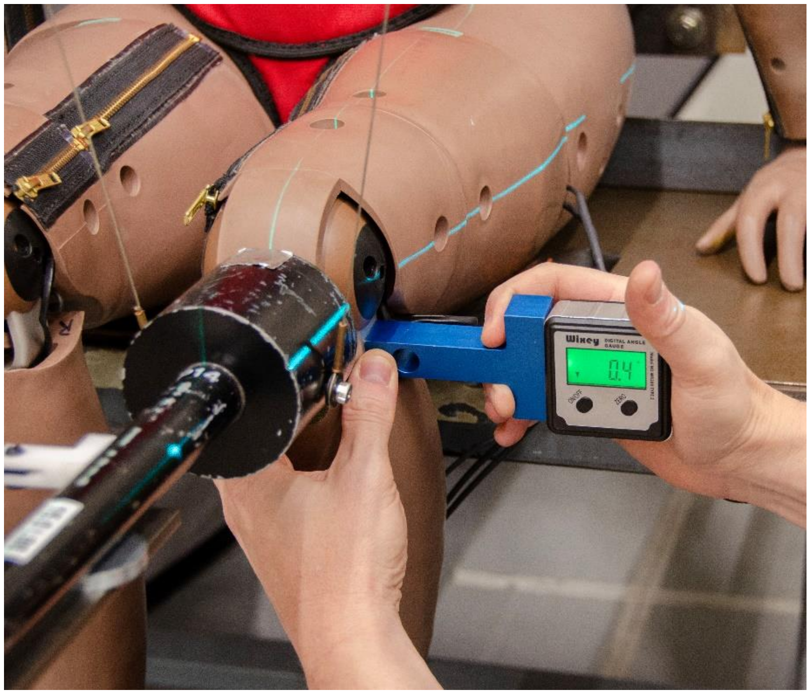


Figure 10-5. Measure angle on side of knee clvis to assure leg is vertical

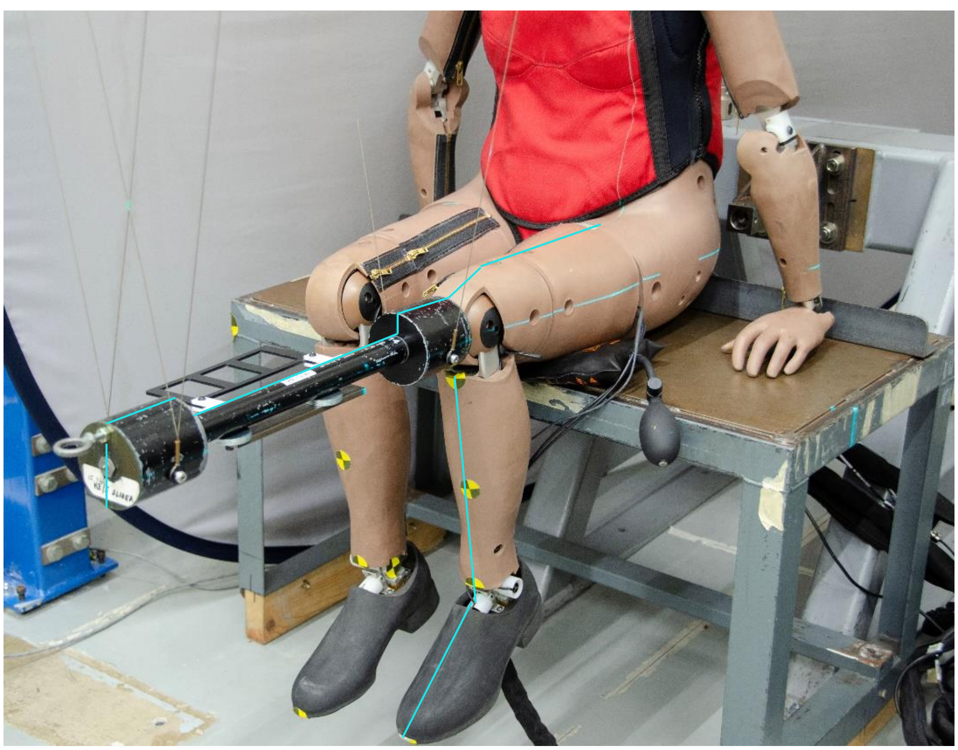


Figure 10-6. Orient lower leg along centerline of probe through ankle

10.5.8 At the point of contact, the longitudinal centerline of the impact probe must be within 0.5 deg of horizontal.

10.5.9 Constrain the motion of the impactor so that there is no lateral, vertical, or rotational movement.

10.5.10 Record the AM channels listed in Table 10-2 (for left impacts) and Table 10-3 (for right impacts) in accordance with SAE J211-1.

10.5.11 Confirm the test setup parameters illustrated in Table 10-1.

Table 10-1. Seated Knee Impact Test Setup Parameters

Parameter	Setting
Lower Thoracic Spine (LTS) Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 5 ± 1º
Wait Time Between Tests	At Least 30 Minutes

10.5.12 Ensure that at least 30 minutes have passed since the last upper leg qualification test.

10.5.13 Conduct the test at a velocity of 3.65 ± 0.05 m/s.

10.5.14 Repeat Section 10.5 for the opposite upper leg.

10.6 Data Processing

10.6.1 Perform bias removal of the AM channels listed in Table 10-2 for left impacts and Table 10-3 for right impacts by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

10.6.2 Filter channels based on the CFC filter classes listed in Table 10-2 (for left impacts) and Table 10-3 (for right impacts).

10.6.3 Calculate time-history of impact force at the contact interface (see Section 2.7).

10.6.4 Calculate resultant acetabulum force:

$$PVA_{FR}(t) = \sqrt{PVA_{FX}^2 + PVA_{FY}^2 + PVA_{FZ}^2}$$

Where:

$PVA_{FR}(t)$ = time history of acetabulum resultant force (L or R)

PVA_{FX} = time history of acetabulum X force (L or R)

PVA_{FY} = time history of acetabulum Y force (L or R)

PVA_{FZ} = time history of acetabulum Z force (L or R)

Table 10-2. Required Measurement Channels for the Left Upper Leg Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G’S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT
Left Femur Force, Z-axis	600	DOFEMRLE00TFFOZB	ZL	AM	FMRL	LC	NWT
Left Acetabulum Force, X-axis	600	D0ACTBLE00TFFOXB	XL	AM	PVAL	LC	NWT
Left Acetabulum Force, Y-axis	600	D0ACTBLE00TFFOYB	YL	AM	PVAL	LC	NWT
Left Acetabulum Force, Z-axis	600	D0ACTBLE00TFFOZB	ZL	AM	PVAL	LC	NWT
Left Acetabulum Force, Resultant	N/A	D0ACTBLE00TFFORB	RS	CM	PVAL	PP	NWT

Table 10-3. Required Measurement Channels for the Right Upper Leg Qualification Test

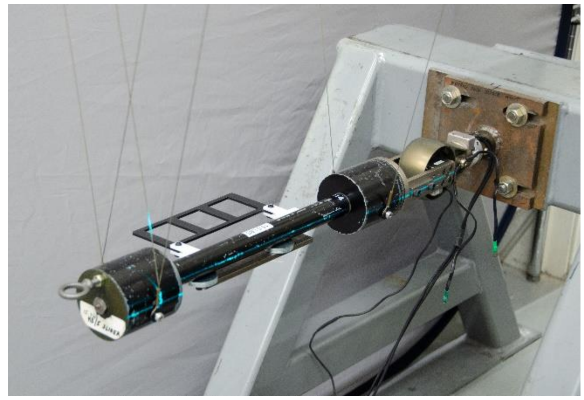
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G’S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT
Right Femur Force, Z-axis	600	DOFEMRRI00TFFOZB	ZL	AM	FMRR	LC	NWT
Right Acetabulum Force, X-axis	600	D0ACTBRI00TFFOXB	XL	AM	PVAR	LC	NWT
Right Acetabulum Force, Y-axis	600	D0ACTBRI00TFFOYB	YL	AM	PVAR	LC	NWT
Right Acetabulum Force, Z-axis	600	D0ACTBRI00TFFOZB	ZL	AM	PVAR	LC	NWT
Right Acetabulum Force, Resultant	N/A	D0ACTBRI00TFFORB	RS	CM	PVAR	PP	NWT

10.7 Performance Specifications

Table 10-4. Upper Leg Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.60	3.70
Peak Probe Force	N	7105	8684
Peak Femur Force, F_z	N	-4535	-3711
Peak Resultant Acetabulum Force	N	1829	2236

11 KNEE QUALIFICATION



11.1 Description

The knee qualification test is a dynamic test performed to examine the force-time and force-deflection of the tibia with respect to the femur at the knee joint; the knee joint is impacted with a 7.26 kg rigid impactor at 2.15 m/s.

11.2 Materials

- THOR-05F ATD knee assembly (474-5300)
- Impactor 7.26 ± 0.02 kg in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables (Section 2.6(b)2). The test probe is a 76.2 ± 0.2 mm diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 0.5 ± 0.2 mm.
- Knee slider load distribution bracket assembly (TH-474-4100)

11.3 Instrumentation

- Instrumentation to measure the impact velocity
- THOR-05F femur load cell (SA572-S63)
- Knee slider string potentiometer (SA572-S90)

11.4 Pre-Test Procedures

11.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

11.5 Test Procedure

11.5.1 Install the femur mounting plate to a rigid fixture using three of the four required ½” – 13 SAE thread nuts (Figure 11-1). Leave the nuts loosely installed so that the bracket can be adjusted in a later step.

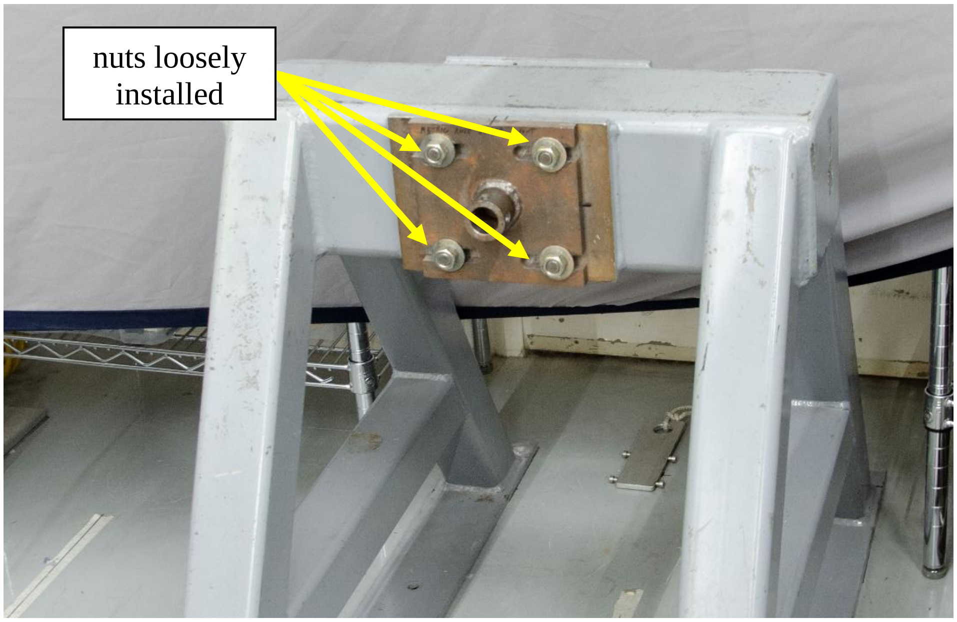


Figure 11-1. Install femur bracket to rigid fixture

11.5.2 Mount the THOR-05F femur load cell with Knee Assembly (474-5400) attached, to the femur bracket using four modified M6 BHSS and torque to 10.0 N-m (Figure 11-2).

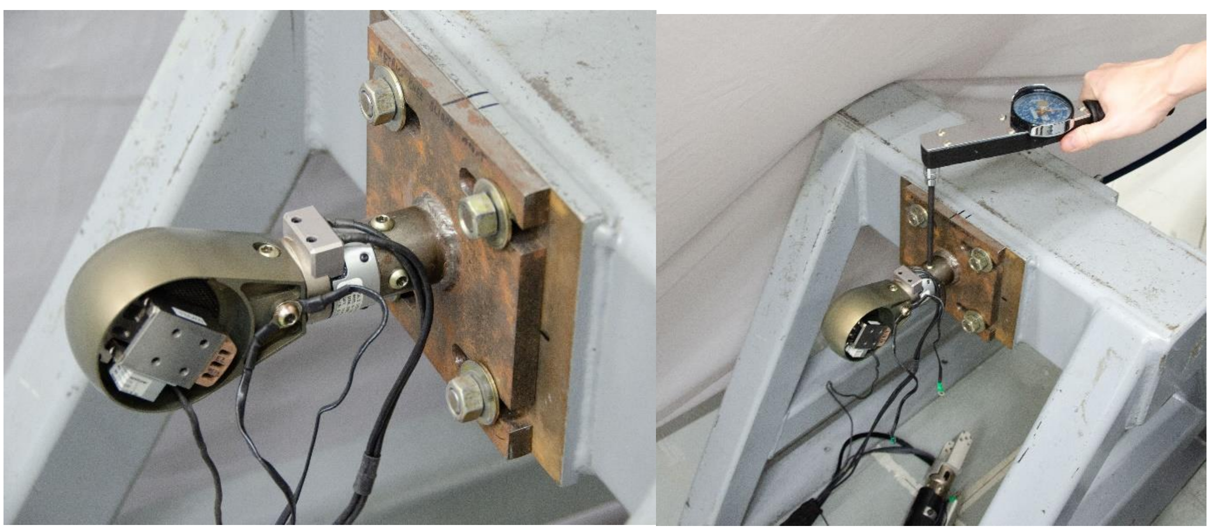


Figure 11-2. Mount femur load cell with knee assembly to rigid surface

11.5.3 Install the knee slider load distribution bracket (TH-474-4100) (Figure 11-3) to the inboard and outboard slider assemblies in the orientation shown in Figure 11-4**,** using four M4 x 0.7 FHCS on each side and torque to 2.5 N-m. Note that the knee slider distribution bracket is installed perpendicular to the orientation of the knee clevis in the fully-assembled, seated dummy. As such, orient the inboard/outboard knee slider assembly (474-5420) such that motion along the knee slider track is horizontal, parallel to the long axis of the femur load cell.

Figure 11-3. Knee slider load distribution bracket

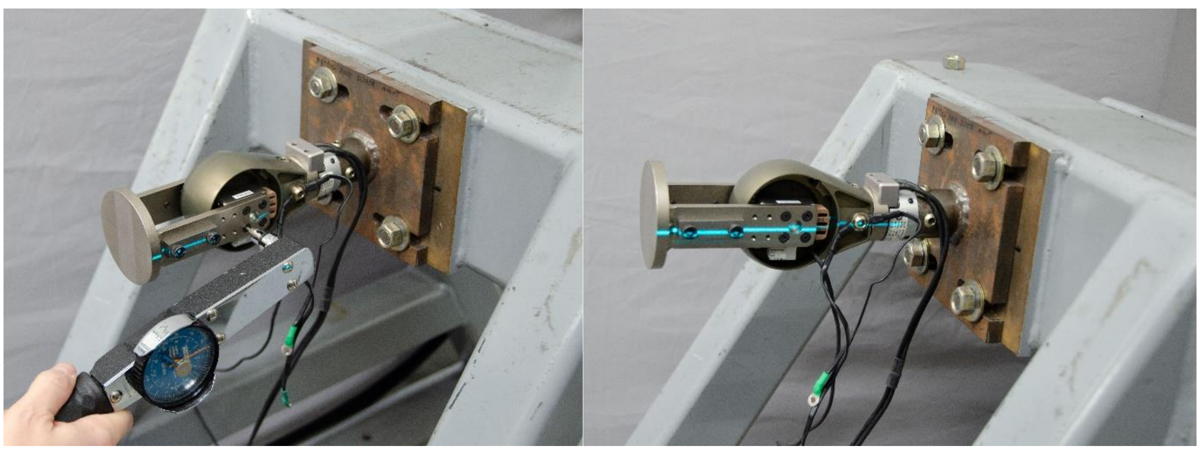


Figure 11-4. Install knee slider load distribution bracket

11.5.4 Once the knee slider load distribution bracket is installed, set the torque on the M8 shoulder bolt (5001332) to 5 N-m (Figure 11-5).

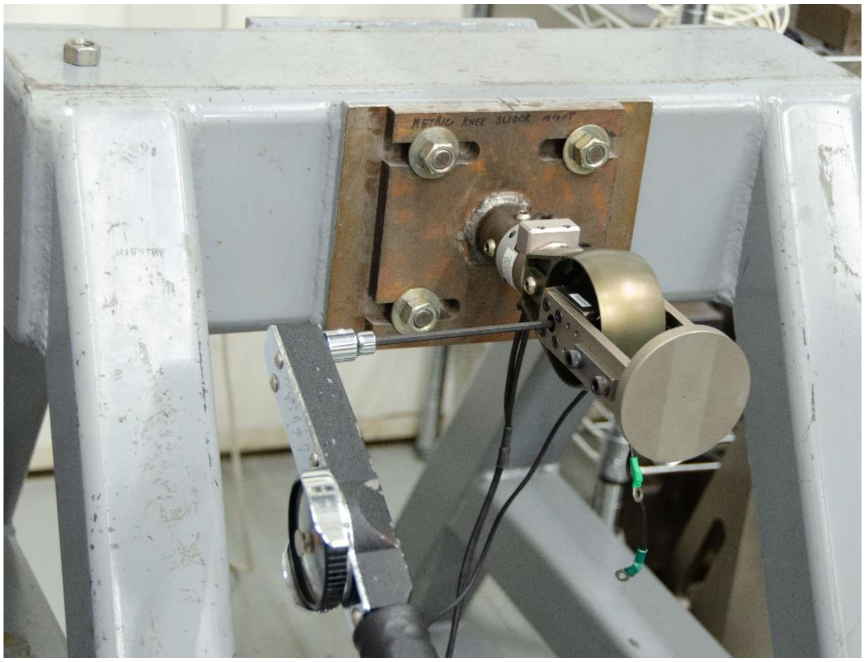


Figure 11-5. Setting knee joint bolt torque

11.5.5 Assure that the impact surface of the knee slider load distribution bracket is parallel to the impact probe by measuring the angle on the surface (90 ± 1°) (Figure 11-6).

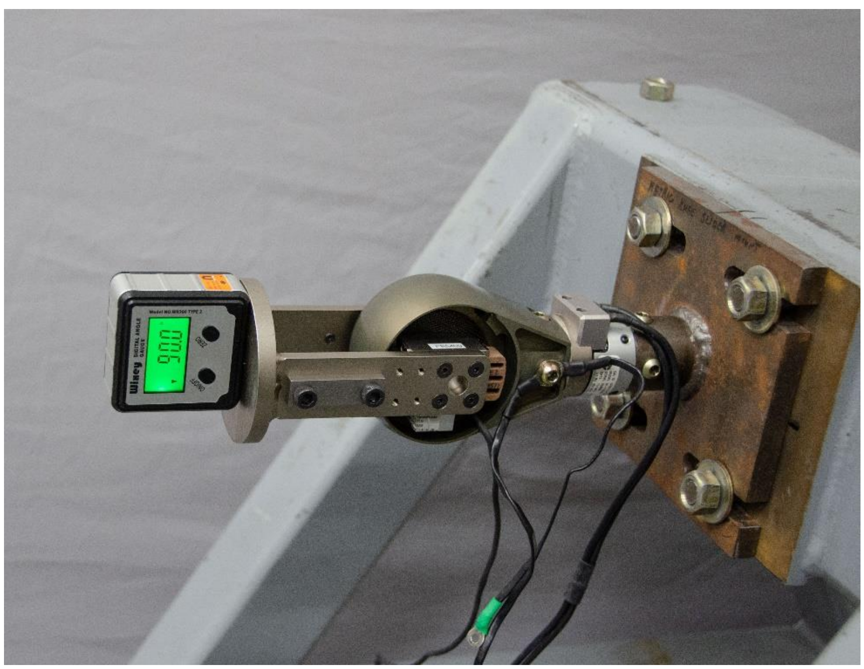


Figure 11-6. Assure impact surface is parallel to probe

11.5.6 Position the probe flush with the knee slider load distribution bracket. If the impact surface of the probe and the bracket do not align laterally, adjust the femur bracket as needed. Also check that the angle between the probe's longitudinal centerline and the centerline of the femur load cell is less than 2 deg. A laser level positioned between the centerline of the knee and the centerline of the probe both laterally and on the top surface of the probe/knee will aid in these processes (Figure 11-7). Once adjusted, tighten the four nuts on the femur mounting plate.

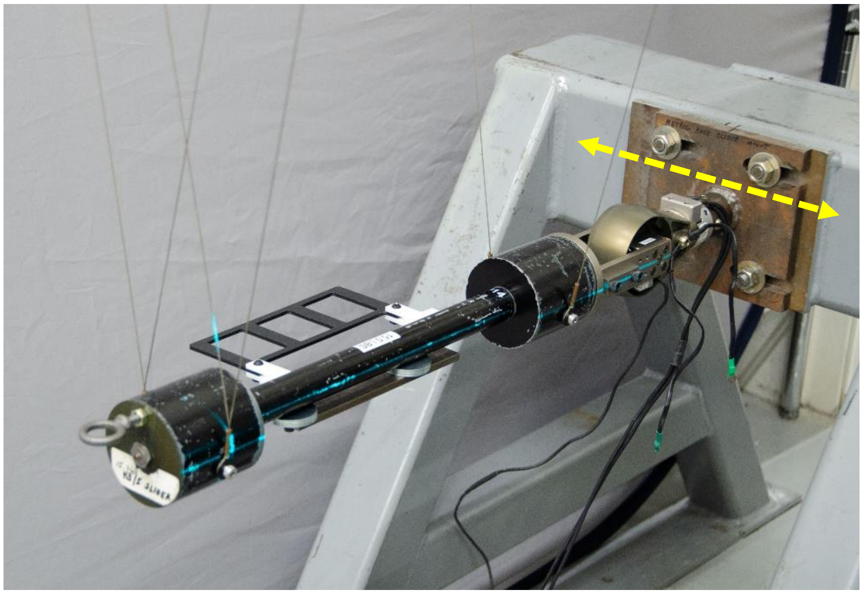


Figure 11-7. Lateral alignment of impact location

11.5.7 After alignment, confirm that the impact surfaces of the probe and knee slider load distribution bracket are flush (Figure 11-8).

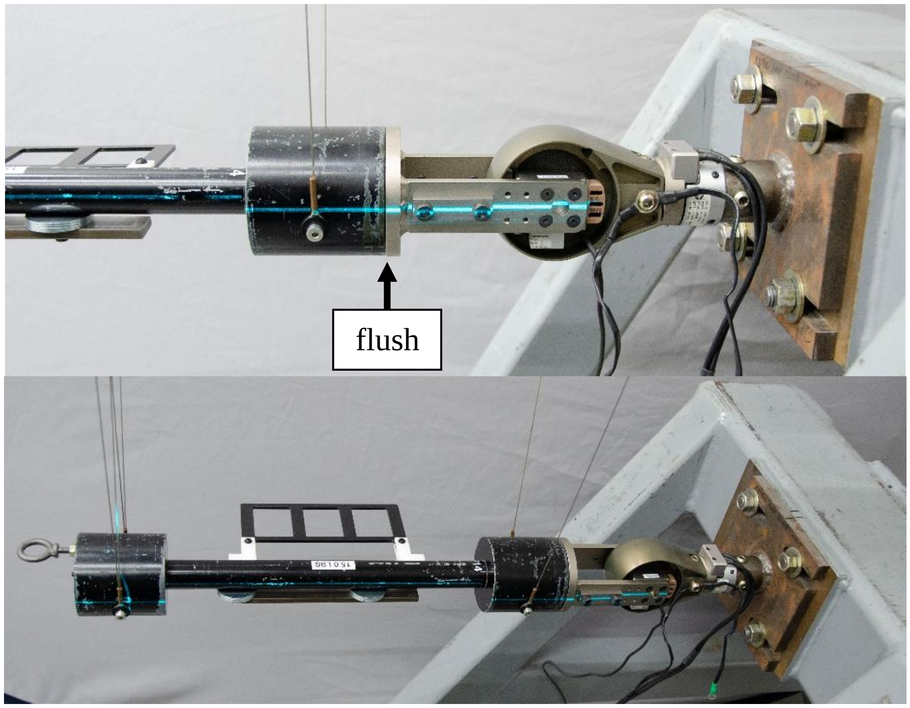


Figure 11-8. Confirm alignment of probe and knee slider load distribution bracket

11.5.8 The motion of the impactor should be constrained so that there is no lateral, vertical, or rotational movement at the time of contact between the test probe face and the load distribution bracket.

11.5.9 Record the AM channels listed in Table 11-1 (for left impacts) or Table 11-2 (for right impacts) in accordance with SAE J211-1.

11.5.10 Ensure that at least 30 minutes have passed since the last test on the upper leg or knee.

11.5.11 Conduct the test at a velocity of 2.15 ± 0.05 m/s.

11.5.12 Repeat Section 11.5 for the opposite knee.

11.6 Data Processing

11.6.1 Perform bias removal of the AM channels listed in Table 11-1 for left impacts or Table 11-2 for right impacts by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

11.6.2 Filter channels based on the CFC filter classes listed in Table 11-1 (for left impacts) or Table 11-2 (for right impacts).

Table 11-1. Required Measurement Channels for the Left Knee Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Left Femur Force, Z-axis	180	D0FEMRLE00TFFOZC	ZL	AM	FMRL	LC	NWT
Left Knee Slider Deflection	180	D0KNSLLE00TFDSXC	XL	AM	KNEL	DS	MM

Table 11-2. Required Measurement Channels for the Right Knee Qualification Test

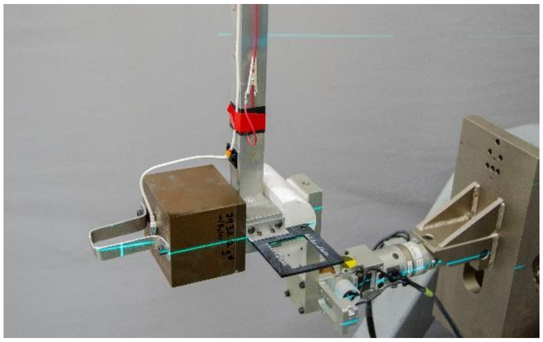
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Femur Force, Z-axis	180	D0FEMRRI00TFFOZC	ZL	AM	FMRR	LC	NWT
Right Knee Slider Deflection	180	D0KNSLRI00TFDSXC	XL	AM	KNER	DS	MM

11.7 Performance Specifications

Table 11-3. Knee Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	2.10	2.20
Minimum Femur Z-axis Force	N	-4194	-3431
Knee Deflection at Min Femur Force	mm	-15.2	-12.4

12 ANKLE INVERSION AND EVERSION QUALIFICATION



12.1 Description

The inversion and eversion ankle qualification tests are dynamic tests performed to examine the moment and rotational characteristics of the ankle when impacted with a 3.00 kg rigid impactor at 2.00 m/s to elicit inversion or eversion.

The ankle qualification consists of two impacts (one each for inversion and eversion) to a padded bracket which is temporarily attached to the ankle in place of the molded shoe. The bracket is attached such that the line of impact is offset from the longitudinal axis of the tibia, and the resulting motion of the foot exercises the inversion and eversion properties of the ankle assembly. The leg is held rigidly such that the X-Z plane of the foot and lower leg are horizontal. The impact surface of the bracket is covered with PTFE padding to reduce noise transmission through the bracket into the ankle and load cell.

12.2 Materials

- THOR-05F ATD lower leg (474-5500-1 or 474-5500-2)
- NHTSA Dynamic Impactor (TLX-9000-007, TLX-9000-006) with a ballast that achieves an *effective* mass of 3.00 ± 0.02 kg (6.61 ± 0.04 lb), which includes the mass of instrumentation, ballast, impactor face (TLX-9000-006), and a portion of the mass of the pendulum arm (TLX-9000-007) including the distal mass welded to the tube and 1/3 of the mass of the tube itself. The pendulum arm is mounted to a rigid shaft which is pivoted on low friction ball bearings. The impact surface is a rigid semi-cylinder 63.5 ± 2.5 mm in diameter and 88.9 ± 3.5 mm in length, oriented in a horizontal plane perpendicular to the direction of impact.
- Dynamic inversion/eversion bracket (TH-1603-0675)
- Rigid fixture for eversion and inversion testing

12.3 Instrumentation

- Instrumentation to measure the impact velocity
- Lower tibia load cell (SA572-S104)
- X-axis ankle potentiometer (SA572-S114)
- Y-axis ankle potentiometer (SA572-S114)
- Z-axis ankle potentiometer (SA572-S114)

12.4 Pre-Test Procedures

12.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

12.4.2 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.6.

12.5 Test Procedure

12.5.1 Follow Steps 3.6.2 through 3.6.6 to get the leg and ankle into the correct configuration for testing. Remove the tibia accelerometers if they are installed (Figure 3-28).

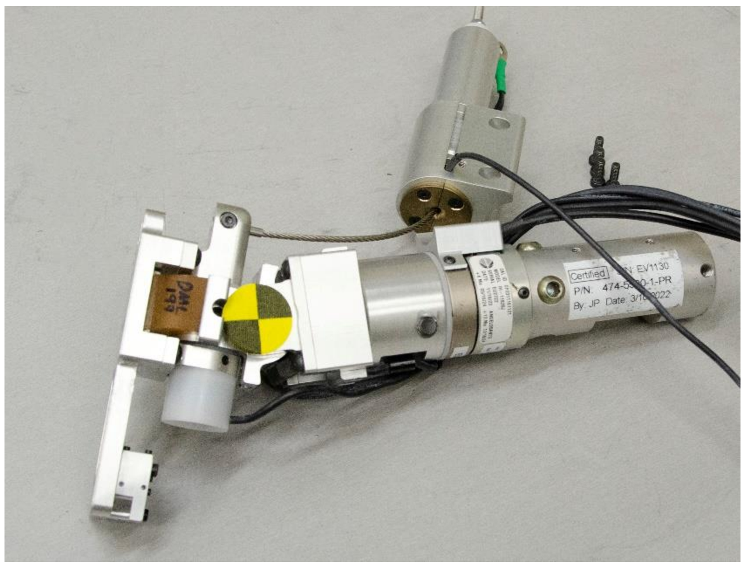


Figure 12-1. Configuration of ankle after following Sections 3.6.2 - 3.6.6

12.5.2 Remove the Achilles Cable (474-5530) by uninstalling the M3 X 0.5 X 12 SHCS from the Achilles Cable Retainer (474-5828) and sliding the Achilles cable from behind the retainer (Figure 12-2 and Figure 12-3).

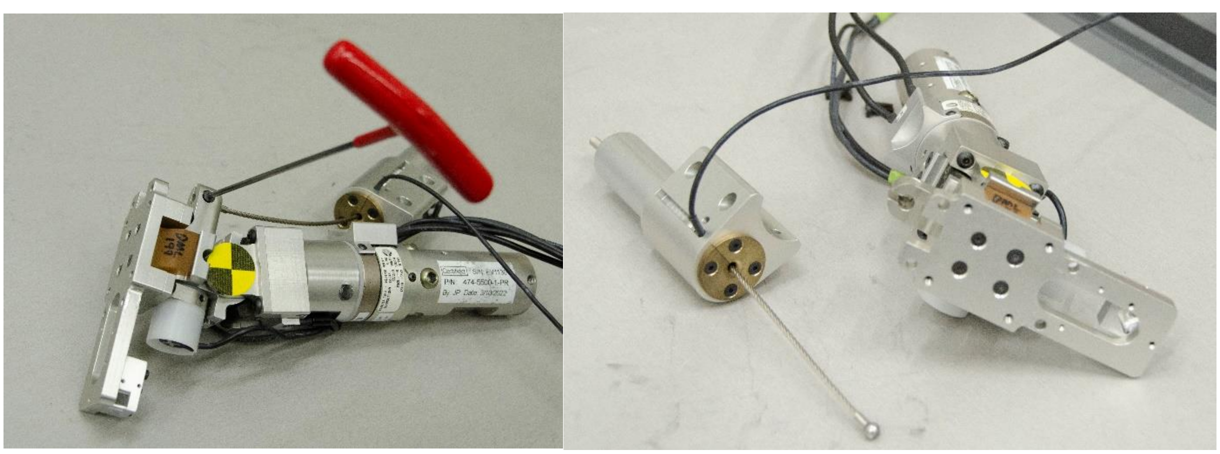


Figure 12-2. Remove Achilles cable from cable retainer

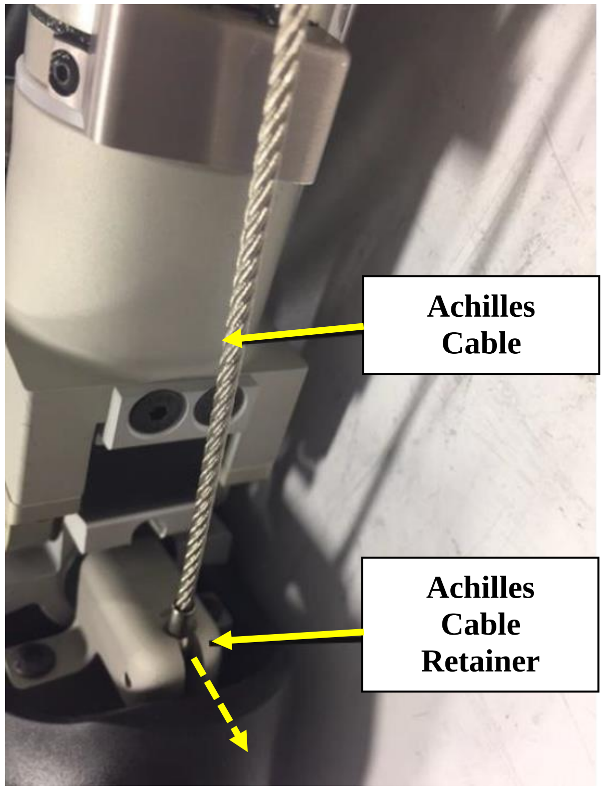


Figure 12-3. Slide the Achilles Cable out of the Achilles Cable Retainer

12.5.3 Follow the instructions in Section 3.7.4 to mount the rigid fixture for inversion/eversion tests.

12.5.4 The remainder of the procedural instructions in this Section are written for the left leg inversion test. Right leg tests for inversion are mounted in the opposite directions of their respective left leg tests. Remove the lateral inboard W50-61042 modified BHSS that attaches the Lower Tibia Shaft (474-5540) to the lower tibia load cell (Figure 12-4).

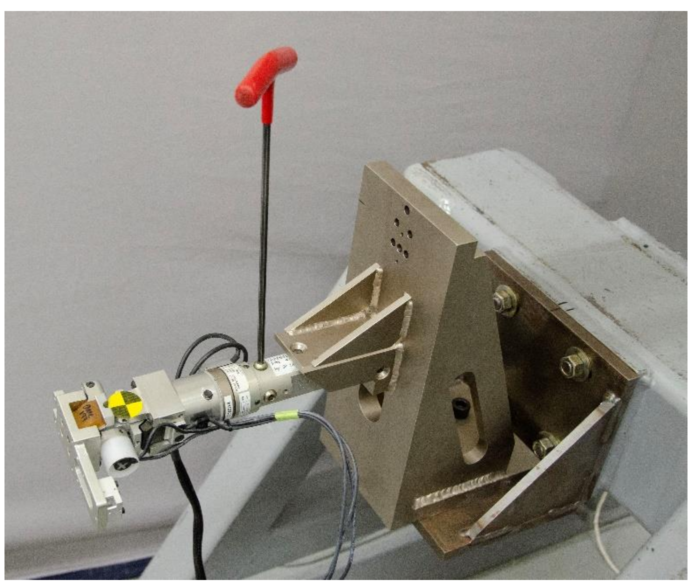


Figure 12-4. Remove lateral screw for inversion fixture installation

12.5.5 Mount the ankle assembly to the rigid fixture using four modified M6 x 1 x 20 FHCS with torque set to 10.0 ± 2.5 N-m such that the X-Z plane of the foot and lower leg are horizontal (Figure 12-5).

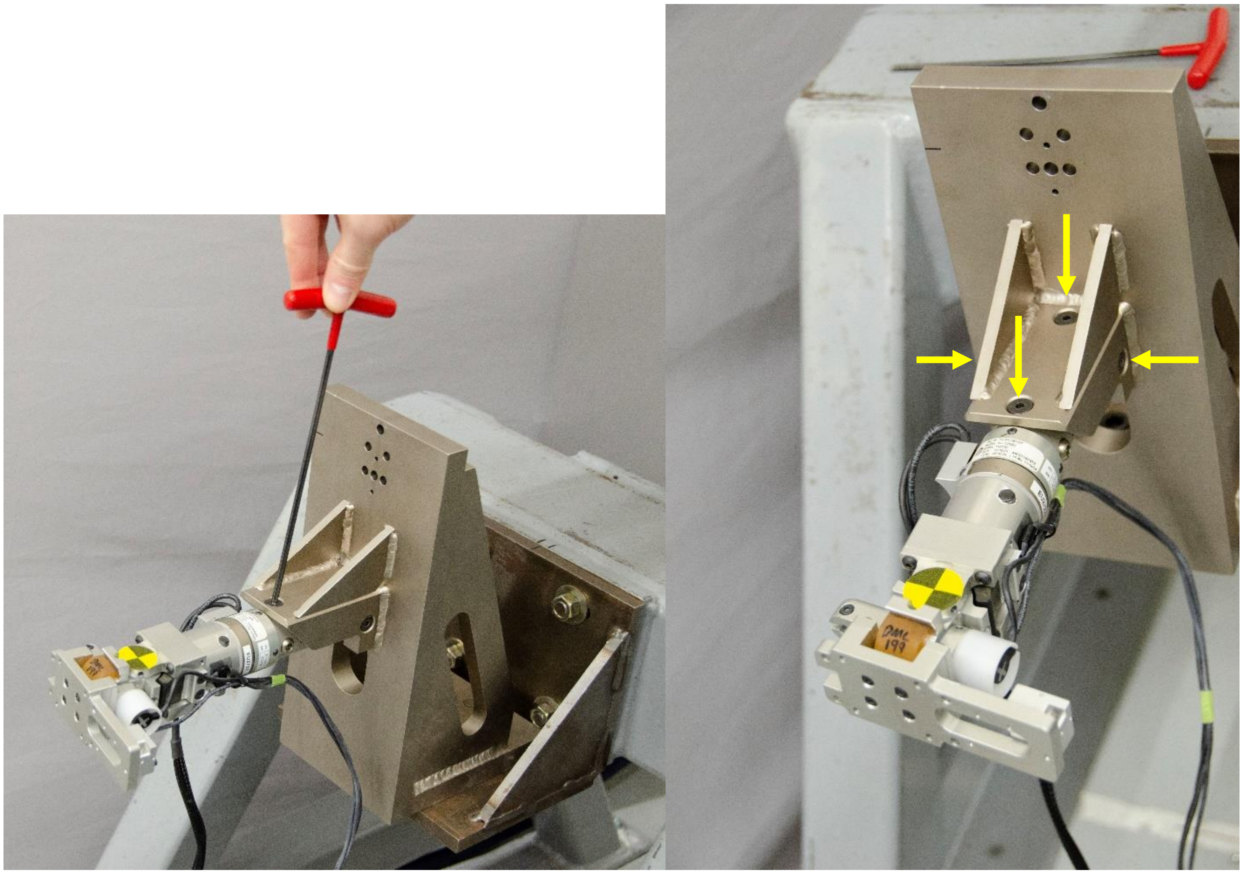


Figure 12-5. Mount ankle assembly to fixture for inversion test

12.5.6 Attach the dynamic inversion/eversion bracket (TH-1603-0675-PR) (Figure 12-6) to the Left Lower Ankle Plate (474-5806-1) using four M4 x 0.7 x 20 mm SHCS (Figure 12-7).

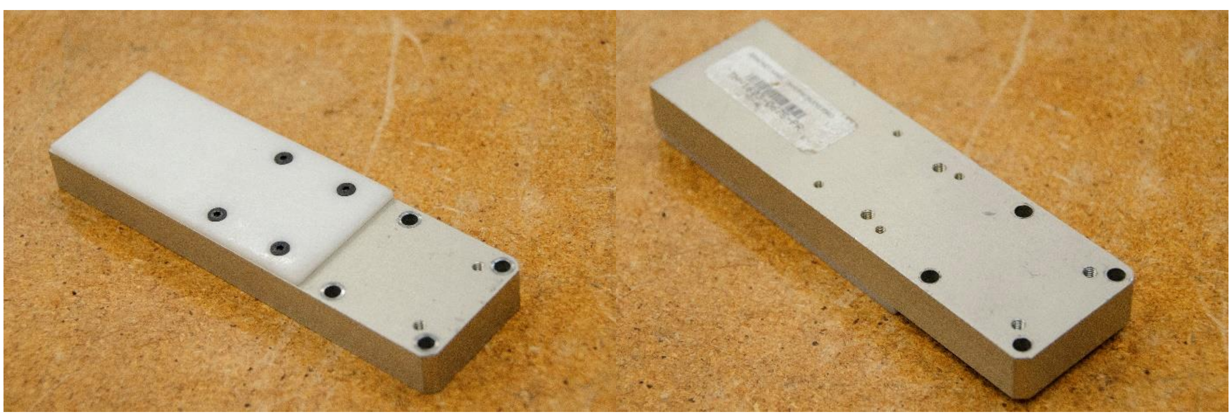


Figure 12-6. Dynamic inversion/eversion bracket

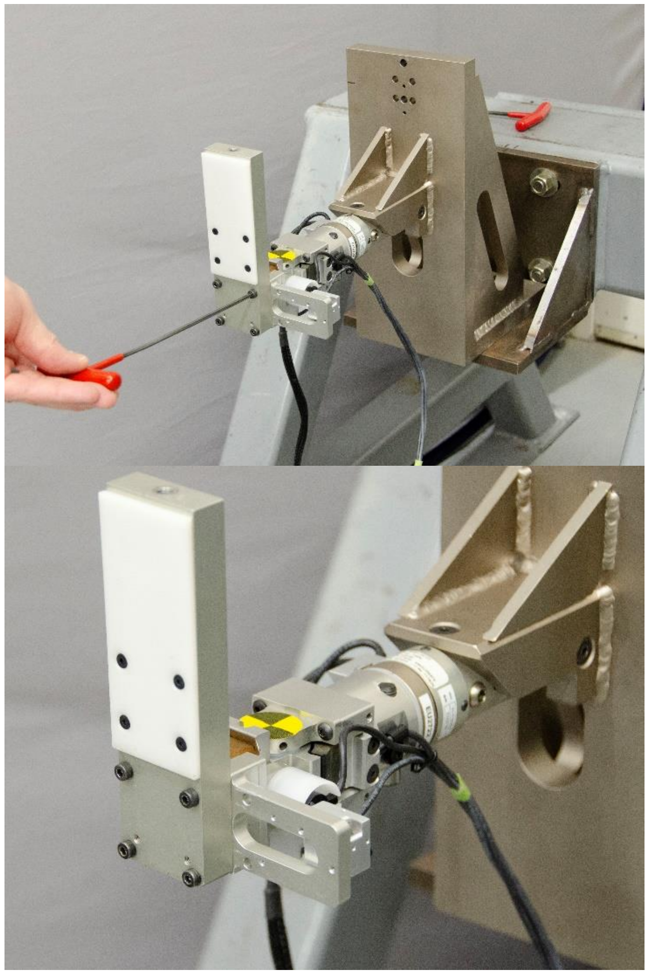


Figure 12-7. Attach inversion/eversion bracket to lower ankle plate

12.5.7 Using the zero offset values collected in Section 3.6, position the ankle Y-axis and Z-axis potentiometers to 0 ± 0.5°.

12.5.8 Adjust the position of the impactor such that the longitudinal centerline of the pendulum arm and the struck surface of the inversion/eversion bracket are vertical at impact (first contact), within ±0.5 deg (Figure 12-8). Use an inclinometer to assure that the pendulum arm is vertical; check the potentiometer settings to confirm that the inversion/eversion bracket is still zero (Section 12.5.7).

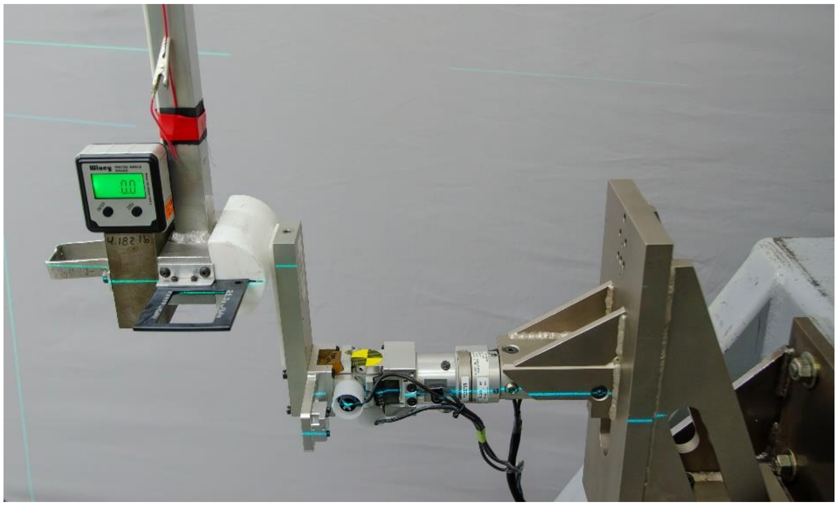


Figure 12-8. Set the pendulum and inversion/eversion bracket vertical at contact

12.5.9 The point of impact is set 110.0 ± 2.5 mm above the ankle X-axis pivot point (Figure 12-9). Recheck the Y-axis and Z-axis zeroes (Section 12.5.7) prior to testing.

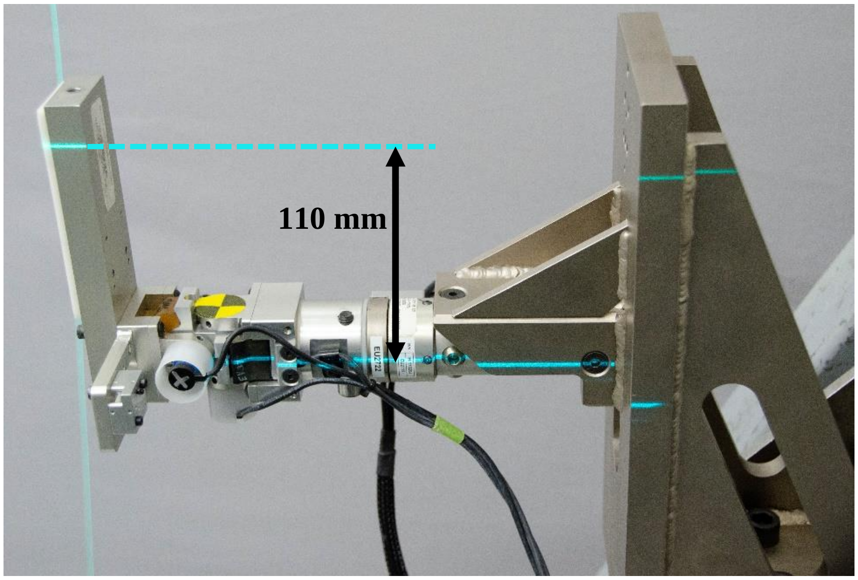


Figure 12-9. Set impact location for left leg inversion test

12.5.10 Record the AM channels listed in Table 12-1 (for left impacts) or Table 12-2 (for right impacts) in accordance with SAE J211-1.

12.5.11 Ensure that at least 30 minutes have passed since the last test on the lower leg.

12.5.12 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 2.00 ± 0.05 m/s.

12.5.13 To perform an eversion test, first, remove the screws that attach the leg to the rigid test fixture (Section 12.5.5). Rotate the lower leg 180 deg about its longitudinal axis, then remove, rotate, and reinstall the dynamic inversion/eversion bracket (Section 12.5.6) (Figure 12-10).

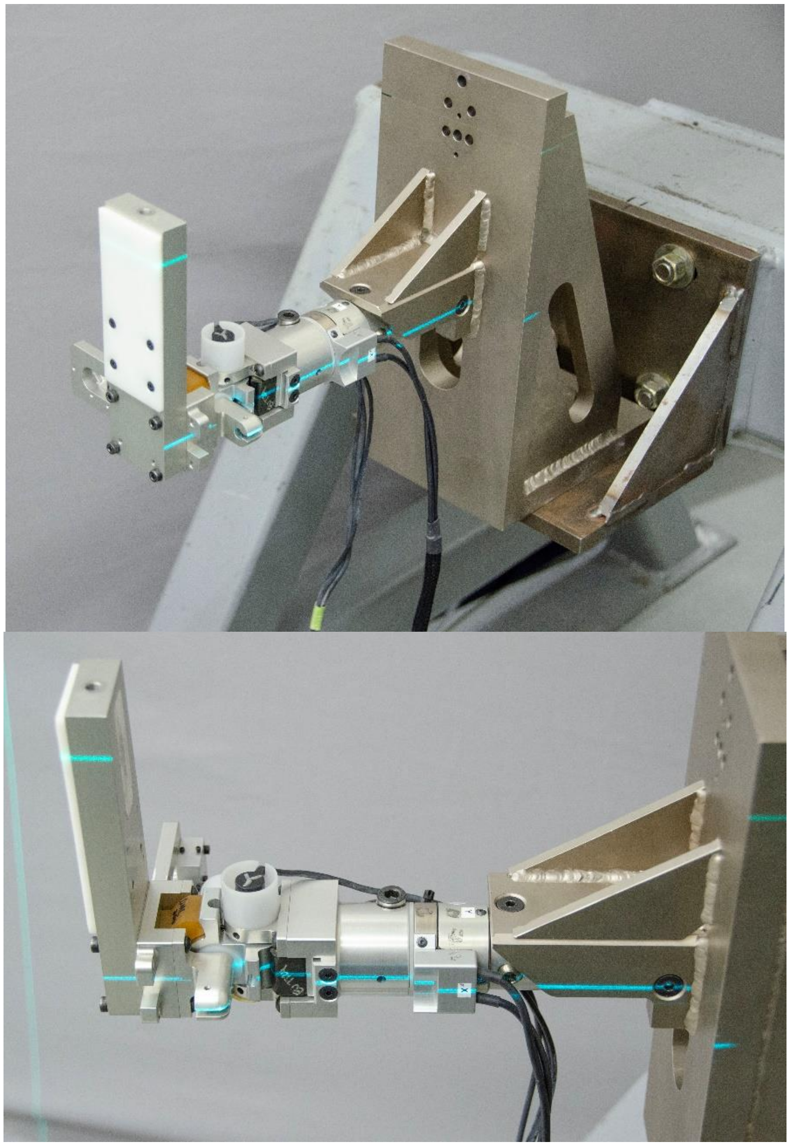


Figure 12-10. Setup for left leg eversion test

12.5.14 Right leg tests for both inversion and eversion are mounted in the opposite directions of their respective left leg tests.

12.6 Data Processing

12.6.1 With the exception of the ankle rotational potentiometer channels, perform bias removal of the AM channels listed in Table 12-1 for left impacts or Table 12-2 for right impacts by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

12.6.2 Filter channels based on the CFC filter classes listed in Table 12-1 (for left impacts) or Table 12-2 (for right impacts).

12.6.3 Calculate ankle resistive moment:

Left: $$M_{ANKL}(t) = M_{x_{TBLL}} + \left[0.1014m \times F_{y_{TBLL}}\right]$$

Right: $$M_{ANKR}(t) = M_{x_{TBLR}} + \left[0.1014m \times F_{y_{TBLR}}\right]$$

Where:

$M_{ANK[LR]} =$ time history of calculated ankle resistive moment [L or R]

$M_{x_{TBL[LR]}} =$ time history of X moment measured at the lower [L or R] tibia load cell

$F_{y_{TBL[LR]}} =$ time history of Y measured at the lower [L or R] tibia load cell

Table 12-1. Required Measurement Channels for the Left Ankle Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Left Lower Tibia Shear Force, Y-axis	600	D0TIBILELOTFFOYB	YL	AM	TBLL	LC	NWT
Left Lower Tibia Axial Force, Z-axis	600	D0TIBILELOTFFOZB	ZL	AM	TBLL	LC	NWT
Left Lower Tibia Moment, X-axis	600	D0TIBILELOTFMOXB	XL	AM	TBLL	LC	NWM
Left Ankle Rotation, X-axis	180	D0ANKLLE00TFANXC	XL	AM	ANKL	AD	DEG
Left Ankle Resistive Moment	N/A	D0ANKLLE00TFMOXB	XL	CM	ANKL	PP	NWM

Table 12-2. Required Measurement Channels for the Right Ankle Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Lower Tibia Shear Force, Y-axis	600	D0TIBIRILOTFFOYB	YL	AM	TBRL	LC	NWT
Right Lower Tibia Axial Force, Z-axis	600	D0TIBIRILOTFFOZB	ZL	AM	TBRL	LC	NWT
Right Lower Tibia Moment, X-axis	600	D0TIBIRILOTFMOXB	XL	AM	TBRL	LC	NWM
Right Ankle Rotation, X-axis	180	D0ANKLRI00TFANXC	XL	AM	ANKR	AD	DEG
Right Ankle Resistive Moment	N/A	D0ANKLRI00TFMOXB	XL	CM	ANKR	PP	NWM

12.7 Performance Specifications

Table 12-3. Left Ankle Inversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F_z	N	-349	-286
Minimum Ankle X-axis Resistive Moment	Nm	-31.4	-25.7
Minimum Ankle X-axis Rotation	deg	-30.6	-25.0

Table 12-4. Right Ankle Inversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F_z	N	-349	-286
Maximum Ankle X-axis Resistive Moment	Nm	25.7	31.4
Maximum Ankle X-axis Rotation	deg	25.0	30.6

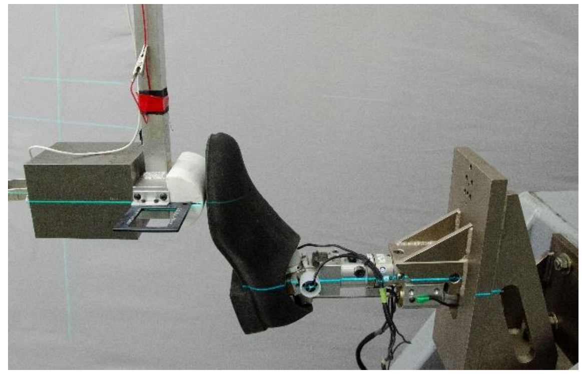
Table 12-5. Left Ankle Eversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F_z	N	-353	-289
Maximum Ankle X-axis Resistive Moment	Nm	26.2	32.0
Maximum Ankle X-axis Rotation	deg	24.8	30.3

Table 12-6. Right Ankle Eversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F_z	N	-353	-289
Minimum Ankle X-axis Resistive Moment	Nm	-32.0	-26.2
Minimum Ankle X-axis Rotation	deg	-30.3	-24.8

13 BALL OF FOOT QUALIFICATION



13.1 Description

The ball of foot qualification test is a dynamic test performed to examine the force, moment, and rotational characteristics of the ankle when impacted with a 8.52 kg rigid impactor at 2.00 m/s to elicit dorsiflexion.

13.2 Materials

- THOR-05F ATD lower leg (474-5500-1 or 474-5500-2)
- NHTSA Dynamic Impactor (TLX-9000-007, TLX-9000-006) with a ballast that achieves an *effective* mass of 8.52 ± 0.02 kg (18.78 ± 0.04 lb), which includes the mass of instrumentation, ballast, impactor face (TLX-9000-006), and a portion of the mass of the pendulum arm (TLX-9000-007) including the distal mass welded to the tube and 1/3 of the mass of the tube itself. The pendulum arm is mounted to a rigid shaft which is pivoted on low friction ball bearings. The impact surface is a rigid semi-cylinder 63.5 ± 2.5 mm in diameter and 88.9 ± 3.5 mm in length, oriented in a horizontal plane perpendicular to the direction of impact.
- Rigid fixture for ball of foot testing

13.3 Instrumentation

- Instrumentation to measure the impact velocity
- THOR-05F lower tibia load cell (SA572-S104)
- X-axis ankle potentiometer (SA572-114)
- Y-axis ankle potentiometer (SA572-114)
- Z-axis ankle potentiometer (SA572-114)
- Achilles cable load cell (SA572-S126)

13.4 Pre-Test Procedures

13.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C (69 to 72 °F) and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

13.4.2 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.6.

13.4.3 If not yet carried out on the lower leg being used for this test, conduct the Achilles Cable Adjustment Procedure described in Section 3.7.

13.5 Test Procedure

13.5.1 Follow the steps in Sections 3.6.2, 3.6.3 and 3.6.6 to get the leg and ankle into the correct configuration for testing (Figure 13-1). Note that the lower Achilles spring housing and and molded shoe are not removed (Sections 3.6.4 and 3.6.5). Remove the tibia accelerometers if they are installed, along with the front W50-61042 modified BHSS that attaches the lower tibia shaft to the lower tiba load cell in order to mount the leg into the rigid fixture.

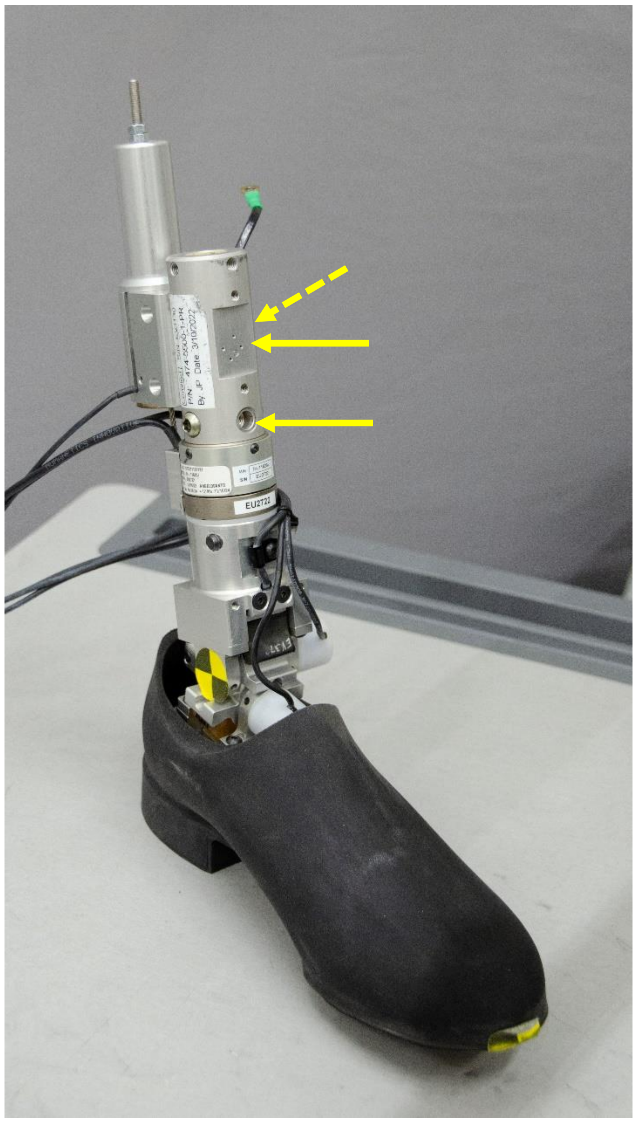


Figure 13-1. Configuration of ankle for ball of foot qualification tests

13.5.2 Follow the instructions in Section 3.7.4 to mount the rigid fixture for ball of foot tests.

13.5.3 Mount the lower leg assembly to the rigid fixture with toe pointing upward using four modified M6 x 1 x 20 FHCS (Figure 13-2).

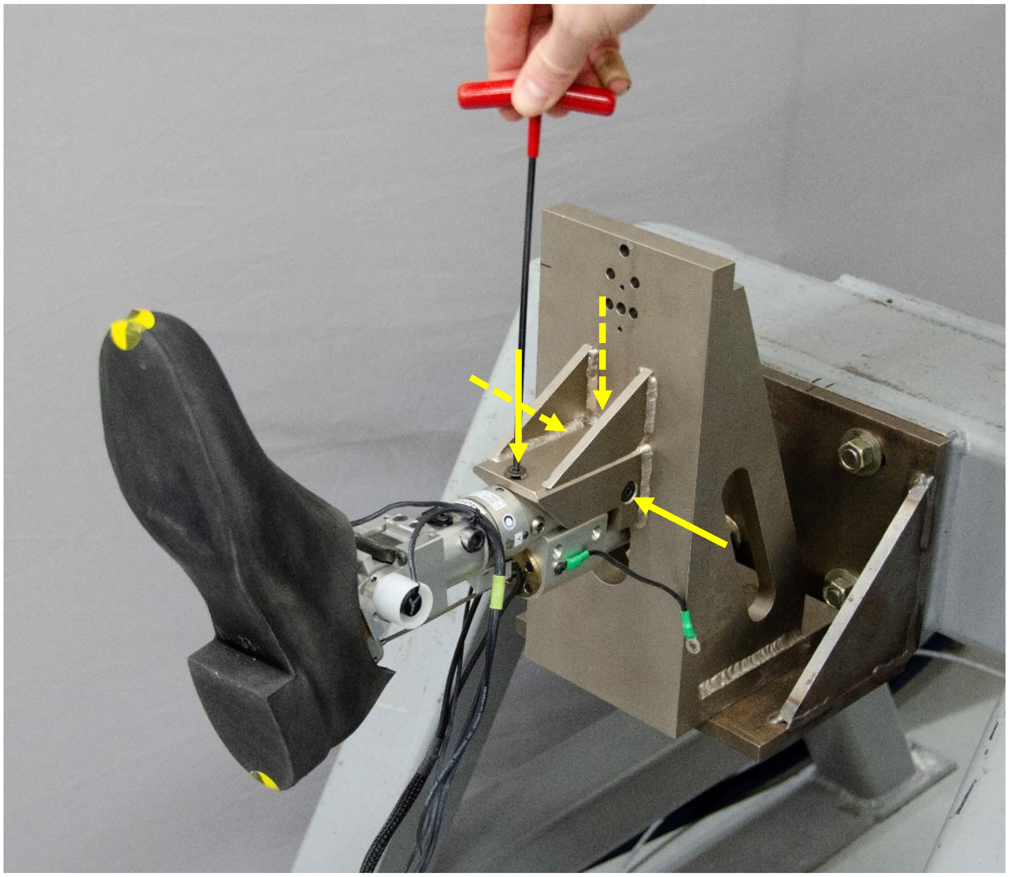


Figure 13-2. Mount lower leg to rigid fixture for ball of foot tests

13.5.4 Using the zero offset values collected in Section 3.6, position the ankle X-axis and Z-axis rotations to 0° ± 0.5°; the foot should be at rest about the Y-axis of rotation.

13.5.5 Using an inclinometer, adjust the position of the impactor such that the longitudinal centerline of the pendulum arm is vertical at impact (first contact), within ±0.5 deg (Figure 13-3). Check the potentiometer settings to confirm that the foot is still zero about the X-axis and Z-axis (Section 13.5.4).

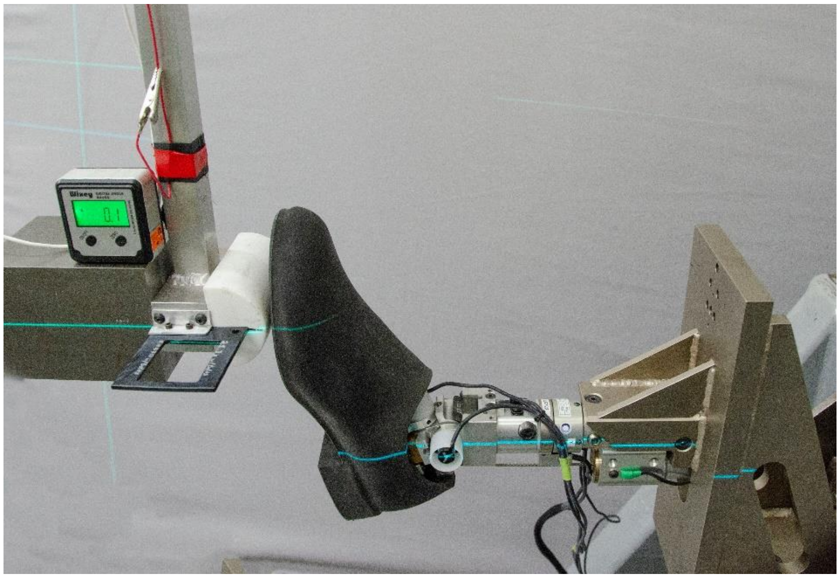


Figure 13-3. Set the pendulum vertical at impact

13.5.6 The point of impact on the ball of the foot is 110.0 ± 2.5 mm above the ankle Y-axis pivot point (Figure 13-4). The final setup is shown in Figure 13-5. Ensure there is no material (contact tape) between the impactor face and the bottom of the shoe.

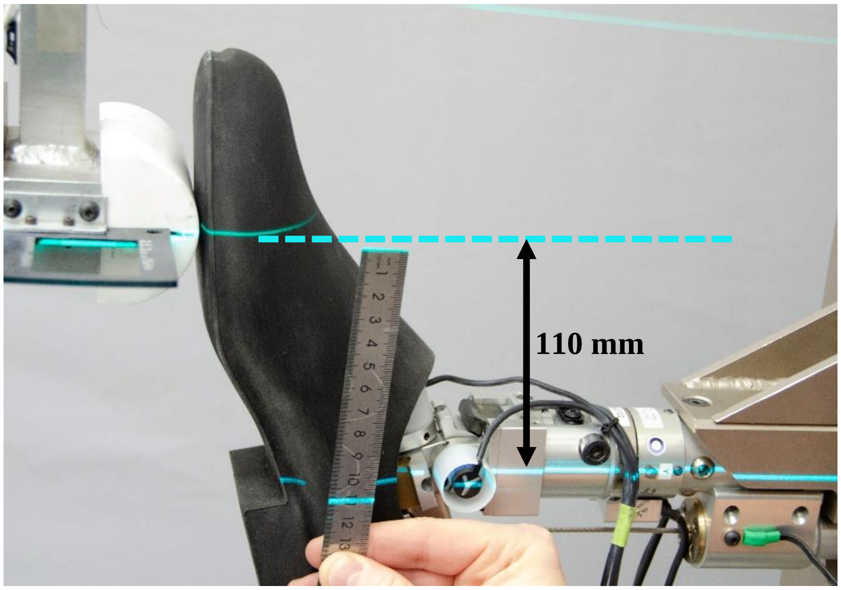


Figure 13-4. Set impactor location for ball of foot test

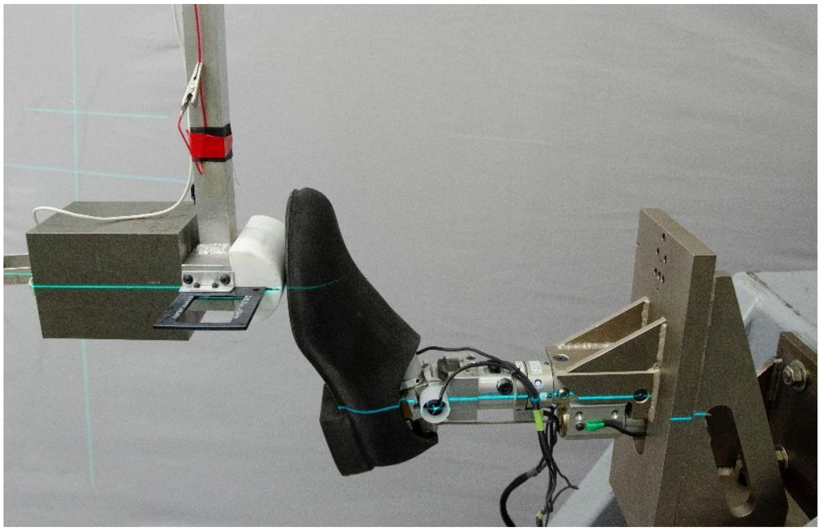


Figure 13-5. Ball of foot setup

13.5.7 Record the "as measured (AM)" channels listed in Table 13-1 (for left impacts) or Table 13-2 (for right impacts) in accordance with SAE J211-1.

13.5.8 Ensure that at least 30 minutes have passed since the last test on the lower leg.

13.5.9 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 2.00 ± 0.05 m/s.

13.5.10 Repeat Section 13.5 for the opposite leg.

13.6 Data Processing

13.6.1 With the exception of the ankle rotational potentiometer channel, perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 13-1 for left impacts and Table 13-2 for right impacts) by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

13.6.2 Filter channels based on the CFC filter classes listed in Table 13-1 (for left impacts) or Table 13-2 (for right impacts).

13.6.3 Calculate ankle resistive moment:

Left: $$M_{ANKL} = M_{y_{TBLL}} - [0.0864m \times F_{x_{TBLL}}]$$

Right: $$M_{ANKR} = M_{y_{TBLR}} - [0.0864m \times F_{x_{TBLR}}]$$

Where:

$M_{ANK[LR]} =$ calculated ankle resistive moment [left or right] time history

$M_{y_{TBL[LR]}}$ = measured Y moment time history measured at the lower [L or R] tibia load cell

$F_{x_{TBL[LR]}} =$ measured X force time history measured at the lower [L or R] tibia load cell

Table 13-1. Required Measurement Channels for the Left BOF Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Left Lower Tibia Shear Force, X-axis	600	D0TIBILELOTFFOXB	XL	AM	TBLL	LC	NWT
Left Lower Tibia Axial Force, Z-axis	600	D0TIBILELOTFFOZB	ZL	AM	TBLL	LC	NWT
Left Lower Tibia Moment, Y-axis	600	D0TIBILELOTFMOYB	YL	AM	TBLL	LC	NWM
Left Ankle Rotation, Y-axis	180	D0ANKLLE00TFANYC	YL	AM	ANKL	AD	DEG
Left Ankle Resistive Moment	N/A	D0ANKLLE00TFMOYB	YL	CM	ANKL	PP	NWM

Table 13-2. Required Measurement Channels for the Right BOF Qualification Test

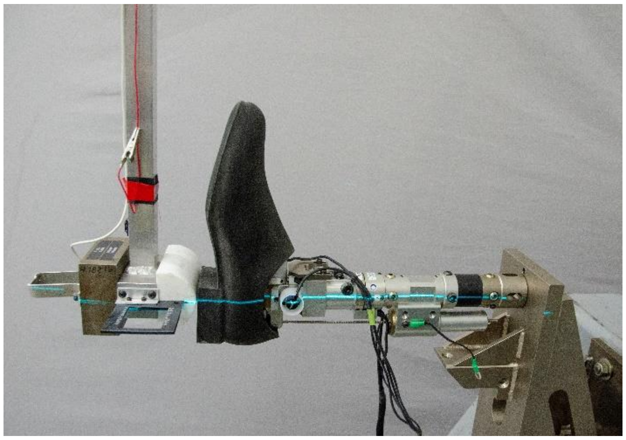
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Lower Tibia Shear Force, X-axis	600	D0TIBIRILOTFFOXB	XL	AM	TBRL	LC	NWT
Right Lower Tibia Axial Force, Z-axis	600	D0TIBIRILOTFFOZB	ZL	AM	TBRL	LC	NWT
Right Lower Tibia Moment, Y-axis	600	D0TIBIRILOTFMOYB	YL	AM	TBRL	LC	NWM
Right Ankle Rotation, Y-axis	180	D0ANKLRI00TFANYC	YL	AM	ANKR	AD	DEG
Right Ankle Resistive Moment	N/A	D0ANKLRI00TFMOYB	YL	CM	ANKR	PP	NWM

13.7 Performance Specifications

Table 13-3. Ball of Foot Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F_z after 10 ms	N	-1020	-835
Maximum Ankle Y-axis Resistive Moment	Nm	42.9	52.4
Maximum Ankle Y-axis Rotation (in dorsiflexion)	deg	30.6	37.3

14 HEEL QUALIFICATION



14.1 Description

The heel qualification test is a dynamic test performed to examine the force-time response of the heel when impacted with a 3.00 kg rigid impactor at 4.00 m/s.

14.2 Materials

- THOR-05F ATD lower leg (474-5500-1 or 474-5500-2)
- NHTSA Dynamic Impactor (TLX-9000-007, TLX-9000-006) with a ballast that achieves an *effective* mass of 3.00 ± 0.02 kg (6.61 ± 0.04 lb), which includes the mass of instrumentation, ballast, impactor face (TLX-9000-006), and a portion of the mass of the pendulum arm (TLX-9000-007) including the distal mass welded to the tube and 1/3 of the mass of the tube itself. The pendulum arm is mounted to a rigid shaft which is pivoted on low friction ball bearings. The impact surface is a rigid semi-cylinder 63.5 ± 2.5 mm in diameter and 88.9 ± 3.5 mm in length, oriented in a horizontal plane perpendicular to the direction of impact.
- Ankle external positioning bracket (TH-1603-0680)
- Rigid fixture for heel of foot testing

14.3 Instrumentation

- Pendulum accelerometer
- Instrumentation to measure the impact velocity
- THOR-05F lower tibia load cell (SA572-S104)
- X-axis ankle potentiometer (SA572-114)
- Y-axis ankle potentiometer (SA572-114)
- Z-axis ankle potentiometer (SA572-114)

14.4 Pre-Test Procedures

14.4.1 Soak the ATD in a controlled environment with a temperature of 20.6 to 22.2 °C and a relative humidity from 10 to 70% for at least 4 hours prior to a test. The test environment should have the same temperature and humidity requirements as the soak environment.

14.4.2 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.6.

14.4.3 If not yet carried out on the lower leg being used for this test, conduct the Achilles Cable Adjustment Procedure described in Section 3.7.

14.5 Test Procedure

14.5.1 Follow the steps in Sections 3.6.2 and 3.6.3 to get the leg and ankle into the correct configuration for testing (Figure 13-1). Note that the leg requires the Tibia Compliant Bushing (474-5508) and the Upper Tibia Load Cell Structural Replacement (474-5550).

Figure 14-1. Leg configuration for heel test

14.5.2 Mount the leg to the rigid fixture with the toe pointing upward (Figure 14-2) using four M6 X 16 SHCS.

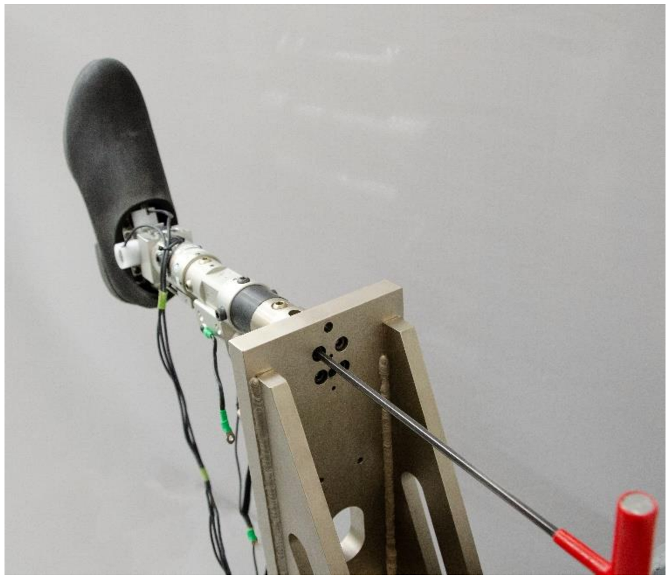


Figure 14-2. Install leg to rigid fixture for heel test

14.5.3 Install the external positioning bracket (TH-1603-0680) to hold the ankle in the proper orientation for test (Figure 14-3). Position the bracket over the Upper Ankle Adapter (474-5820-1 (left), 474-5820-2 (right)) with the bottom of the U-shaped bracket closest to the shoe (Figure 14-4; install two M4 x 0.7 x 10LG SHCS through the bracket and into the upper ankle adapter.

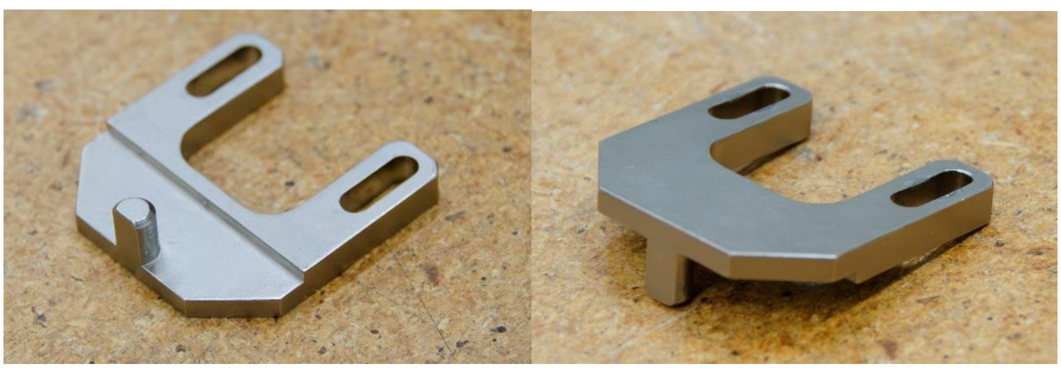


Figure 14-3. External positioning bracket used in heel tests

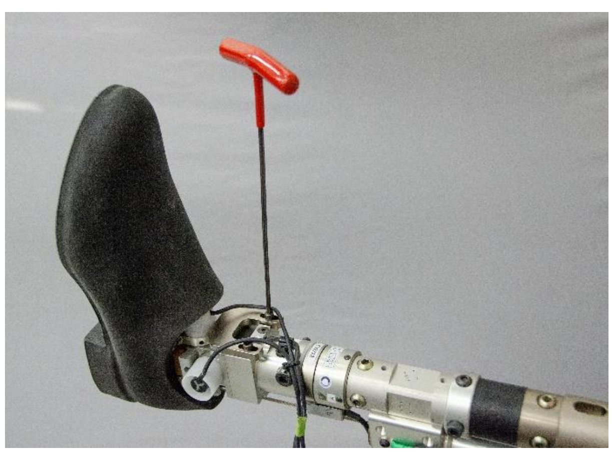


Figure 14-4. Install external positioning bracket for heel impact tests

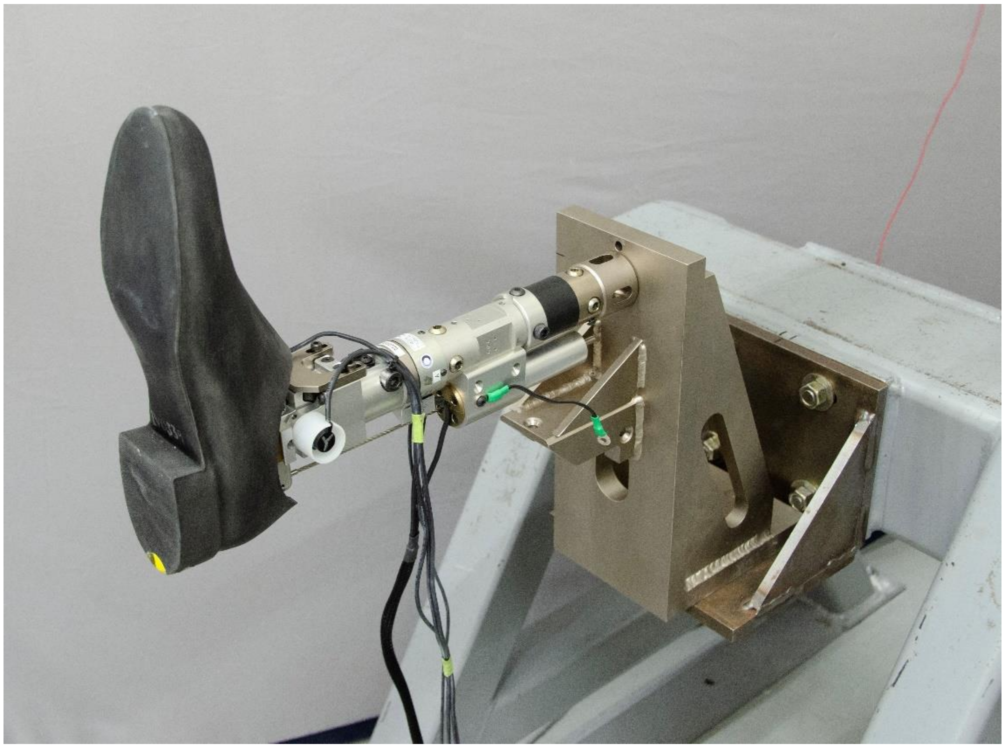


Figure 14-5. External positioning bracket installed for heel impact test

14.5.4 Using the zero offset values collected in Section 3.6, orient the foot at 0° ± 0.5° about all three axes.

14.5.5 Adjust the position of the impactor so that the longitudinal centerline of the pendulum arm is vertical at impact, within ±0.5° (Figure 14-6).

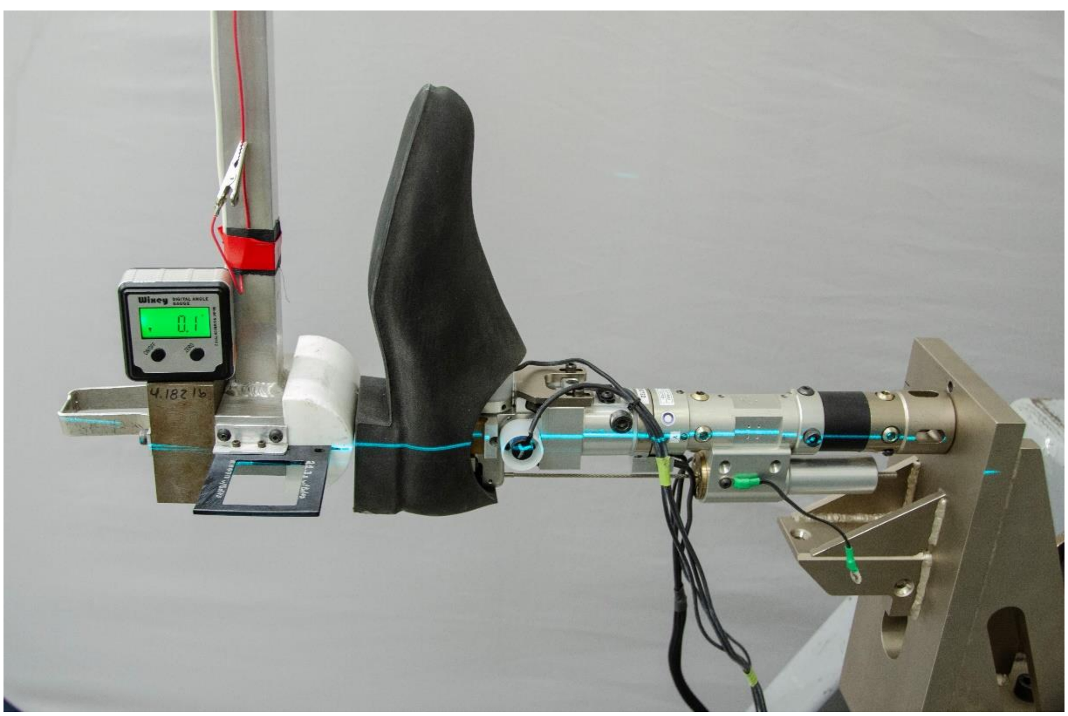


Figure 14-6. Set pendulum to vertical

14.5.6 The point of impact is aligned with the longitudinal axis of the tibia within ±1 mm; the longitudinal axis of the tibia is defined as the horizontal line crossing the centers of the ankle Y-axis pivot point, plunger retaining bolt (474-5512), and the modified BHSC (W50-61042) attaching the tibia compliant bushing assembly to the rigid fixture (Figure 14-7).

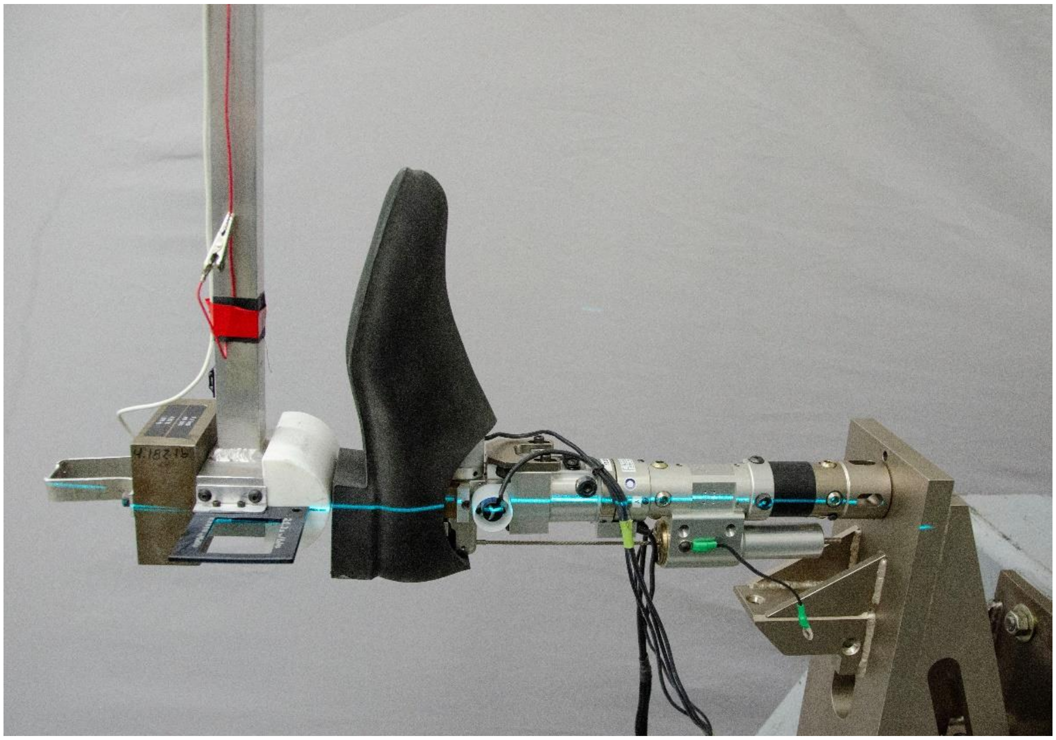


Figure 14-7. Alignment of the impactor for heel impact test

14.5.7 Record the "as measured (AM)" channels listed in Table 14-1 (for left impacts) or Table 14-2 (for right impacts) in accordance with SAE J211-1.

14.5.8 Ensure that at least 30 minutes have passed since the last test on the lower leg.

14.5.9 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 4.00 ± 0.05 m/s.

14.5.10 Repeat Section 14.5 for the opposite leg.

14.6 Data Processing

14.6.1 Perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 14-1 for left impacts or Table 14-2 for right impacts) by subtracting the average value of the data samples over the period between (0.050 s) and (0.010 s) prior to contact.

14.6.2 Filter channels based on the CFC filter classes listed in Table 14-1 (for left impacts) or Table 14-2 (for right impacts).

14.6.3 Calculate time-history of impact force at the contact interface (see Section 2.7).

Table 14-1. Required Measurement Channels for the Left Heel Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Left Lower Tibia Axial Force, Z-axis	600	D0TIBILELOTFFOZB	ZL	AM	TBLL	LC	NWT
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT

Table 14-2. Required Measurement Channels for the Right Heel Qualification Test

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Lower Tibia Axial Force, Z-axis	600	D0TIBIRILOTFFOZB	ZL	AM	TBRL	LC	NWT
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT

14.7 Performance Specifications

Table 14-3. Heel Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.95	4.05
Maximum Probe Force	N	3447	4212
Minimum Lower Tibia F_z	N	-2220	-1816

APPENDIX A. TEST FIXTURES

A- 1. Summary of Test Fixtures for THOR-05F Qualification Tests

Test Fixture Description [± 0.02 kg, ± 0.25 mm]	Reference	Section(s)	Title
Lower leg zero bracket	TH-1603-0671	3.6	Ankle Rotary Potentiometer Zeroing Procedure
Rigid fixture for ankle/foot testing	DL472-4100	3.7, 12, 13, 14	Ankle Inversion and Eversion Qualification, Ball of Foot Qualification, Heel of Foot Qualification, Achilles Cable Adjustment Procedure
Dynamic inversion/eversion bracket	TH-1603-0675	3.7, 12	Ankle Inversion and Eversion Qualification, Achilles Cable Adjustment Procedure
Rigid disk impactor 19.20 kg, 152.4 mm diameter disk	Section 4.2 herein	4	Head Qualification
Rigid disk impactor 10.70 kg, 152.4 mm diameter disk	Section 5.2 herein	5	Face Qualification
THOR neck twist fixture	DL472-1000	6.7	Neck Torsion Test
Neck pendulum	CFR Title 49, §572.33(c)3 (Figure 22)	6.7, 6.8, 6.9, 6.10	Neck Torsion Test, Neck Frontal Flexion Test, Neck Extension Test, Neck Lateral Flexion Test
Rigid disk impactor 13.97 kg, 152.4 mm diameter disk	CFR Title 49, §572.137(c)(7)	7, 8	Upper Thorax Qualification, Lower Thorax Qualification
Lower abdomen probe face assembly	Section 9.2 herein	9	Abdomen Qualification
Rigid disk impactor 7.26 kg, 76.2 mm diameter disk	Sections 10.2 & 11.2 herein	10, 11	Upper Leg Qualification, Knee Qualification
Knee slider load distribution bracket assembly	DL472-5000	11	Knee Qualification
Dynamic impactor, 3.00 kg	TLX-9000-007, TLX-9000-006	12, 14	Ankle Inversion and Eversion Qualification, Heel Qualification
Dynamic impactor, 8.52 kg	TLX-9000-007, TLX-9000-006	13	Ball of Foot Qualification
External positioning bracket	TH-1603-0680	14	Heel Qualification

APPENDIX B. POLARITY

Sensor	Direction	Motion	SAE-J211 Polarity
Head Accel	Ax	Impact rear of head in forward didrection	+
	Ay	Impact left side of head in rightward direction	+
	Az	Impact top of head in downward direction	+
Redundant Head Accel	Ax	Impact rear of head in forward didrection	+
	Ay	Impact left side of head in rightward direction	+
	Az	Impact top of head in downward direction	+
Head CG Angular Rate Sensor	ωx	Rotate right ear toward right shoulder	+
	ωy	Rotate chin toward sternum	-
	ωz	Rotate chin toward right shoulder	+
Upper Neck Load Cell	Fx	Move head rearward, chest forward	+
	Fy	Move head leftward, chest rightward	+
	Fz	Move head upward, chest downward	+
	Mx	Rotate left ear toward left shoulder	+
	My	Rotate chin toward sternum	+
	Mz	Rotate chin toward left shoulder	+
Lower Neck Load Cell	Fx	Move head rearward, chest forward	+
	Fy	Move head leftward, chest rightward	+
	Fz	Move head upward, chest downward	+
	Mx	Rotate left ear toward left shoulder	+
	My	Rotate chin toward sternum	+
	Mz	Rotate chin toward left shoulder	+
Front Neck Spring	Fz	Rotate head rearward	+
Rear Neck Spring	Fz	Rotate chin toward chest	+
O.C. Rotary Pot	θ_y	Rotate chin toward chest	-
Face Load Cells	Fx	Hold back of head, push face rearward	-
T1 Accelerometer	Ax	Impact rear of thorax in forward direction	+
	Ay	Impact left side of thorax in rightward direction	+
	Az	Impact top of thorax in downward direction	+
Mid Sternum Accelerometer	Ax	Impact rear of thorax in forward direction	+
T8 Accelerometer	Ax	Impact rear of thorax in forward direction	+
	Ay	Impact left side of thorax in rightward direction	+
	Az	Impact top of thorax in downward direction	+
T12 Accelerometer	Ax	Impact rear of thorax in forward direction	+
	Ay	Impact left side of thorax in rightward direction	+
	Az	Impact top of thorax in downward direction	+

Sensor	Direction	Motion	SAE-J211 Polarity
T12 Load Cell	Fx	Move chest rearward, pelvis forward	+
	Fy	Move chest leftward, pelvis rightward	+
	Fz	Move chest upward, pelvis downward	+
	Mx	Rotate left shoulder toward left hip	+
	My	Rotate sternum towards front of legs	+
	Mz	Rotate left shoulder rearward and right shoulder forward	+
T12 Angular Rate Sensor	ωx	Rotate thorax rightward	+
	ωy	Rotate thorax rearward	+
	ωz	Rotate left shoulder forward and right shoulder rearward	+
Left Clavicle Load Cell (External Load Cell)	Fx - Medial	Push center of clavicle bone rearward towards spine	-
	Fz - Medial	Push center of clavicle bone downward towards pelvis	+
	Fx - Lateral	Push center of clavicle bone rearward towards spine	-
	Fz - Lateral	Push center of clavicle bone downward towards pelvis	+
Right Clavicle Load Cell (External Load Cell)	Fx – Medial	Push center clavicle bone rearward towards spine	-
	Fz - Medial	Push center of clavicle bone downward towards pelvis	+
	Fx - Lateral	Push center of clavicle bone rearward towards spine	-
	Fz - Lateral	Push center of clavicle bone downward towards pelvis	+
Abdomen pressure sensor (APTS)	P	Compress abdomen	+
Pelvis CG Accelerometer	Ax	Impact rear of pelvis in forward direction	+
	Ay	Impact left side of pelvis in rightward direction	+
	Az	Impact top of pelvis in downward direction	+
Pelvis CG ARS	ωx	Move left leg upward and right leg downward	+
	ωy	Lift both legs up	+
	ωz	Move upper legs rightward	+
L Acetabular LC	Fx	Move femur forward, pelvis rearward	-
	Fy	Move femur rightward, pelvis leftward	-
	Fz	Move femur upward, pelvis downward	+
R Acetabular LC	Fx	Move femur forward, pelvis rearward	+
	Fy	Move femur rightward, pelvis leftward	+
	Fz	Move femur upward, pelvis downward	-

Sensor		Direction	Motion	SAE-J211 Polarity
L ASIS		Fx	Push towards back of pelvis	-
		My	Push top of ASIS towards back of pelvis	+
R ASIS		Fx	Push towards back of pelvis	-
		My	Push top of ASIS towards back of pelvis	+
Left Femur Load Cell		Fx	Move knee upward, upper femur downward	+
		Fy	Move knee rightward, upper femur leftward	+
		Fz	Move knee forward, femur rearward	+
		Mx	Push knee leftward, hold upper femur	+
		My	Push knee upward, hold upper femur	+
		Mz	Rotate tibia leftward, hold pelvis	+
Right Femur Load Cell		Fx	Move knee upward, upper femur downward	+
		Fy	Move knee rightward, upper femur leftward	+
		Fz	Move knee forward, femur rearward	+
		Mx	Push knee leftward, hold upper femur	+
		My	Push knee upward, hold upper femur	+
		Mz	Rotate tibia leftward, hold pelvis	+
Left	Knee Shear Displacement	Dx	Hold femur, move tibia forward	+
	Upper Tibia Load Cell	Fx	Move tibia forward, knee rearward	+
		Fy	Move tibia rightward, knee leftward	+
		Fz	Move tibia downward, knee upward	+
		Mx	Push tibia leftward, hold knee	+
		My	Push tibia forward, hold knee	+
	Lower Tibia Load Cell	Fx	Move ankle forward, knee rearward	+
		Fy	Move ankle rightward, knee leftward	+
		Fz	Move ankle downward, knee upward	+
		Mx	Push ankle leftward, hold knee	+
		My	Push ankle forward, hold knee	+
	Tibia Accelerometer	Ax	Impact back of tibia in forward direction	+
		Ay	Impact left of tibia in rightward direction	+
	Achilles Load Cell	Fz	Hold tibia, move toes upward	+
	Ankle Rotation	θ_x	Hold tibia, push right side of foot to the left	+
		θ_y	Hold tibia, pull toe upward	+
		θ_z	Hold tibia, push toe rightward	+
	Foot Acceleration	Ax	Impact back of foot in forward direction	+
		Ay	Impact left of foot in rightward direction	+
		Az	Impact top of foot in downward direction	+

Sensor		Direction	Motion	SAE-J211 Polarity
Right	Knee Shear Displacement	Dx	Hold femur, move tibia forward	+
	Upper Tibia Load Cell	Fx	Move tibia forward, knee rearward	+
		Fy	Move tibia rightward, knee leftward	+
		Fz	Move tibia downward, knee upward	+
		Mx	Push tibia leftward, hold knee	+
		My	Push tibia forward, hold knee	+
	Lower Tibia Load Cell	Fx	Move ankle forward, knee rearward	+
		Fy	Move ankle rightward, knee leftward	+
		Fz	Move ankle downward, knee upward	+
		Mx	Push ankle leftward, hold knee	+
		My	Push ankle forward, hold knee	+
	Tibia Accelerometer	Ax	Impact back of tibia in forward direction	+
		Ay	Impact left of tibia in rightward direction	+
	Achilles Load Cell	Fz	Hold tibia, move toes upward	+
	Ankle Rotation	θ_x	Hold tibia, push right side of foot to the left	+
		θ_y	Hold tibia, pull toe upward	+
		θ_z	Hold tibia, push toe rightward	+
	Foot Acceleration	Ax	Impact back of foot in forward direction	+
		Ay	Impact left of foot in rightward direction	+
		Az	Impact top of foot in downward direction	+
Upper Left 3D IR-TRACC		Dx	Push front of rib where 3D IR-TRACC mounts inward toward spine	-
		Ry	Push front of rib where 3DIR-TRACC mounts downward	-
		Rz	Push front of rib where 3D IR-TRACC mounts rightward	+
Upper Right 3D IR-TRACC		Dx	Push front of rib where 3D IR-TRACC mounts inward toward spine	-
		Ry	Push front of rib where 3D IR-TRACC mounts downward	-
		Rz	Push front of rib where 3D IR-TRACC mounts rightward	+

Sensor	Direction	Motion	SAE-J211 Polarity
Lower Left 3D IR-TRACC	Dx	Push front of rib where 3D IR-TRACC mounts inward toward spine	-
	Ry	Push front of rib where 3D IR-TRACC mounts downward	-
	Rz	Push front of rib where 3D IR-TRACC mounts rightward	+
Lower Right 3D IR-TRACC	Dx	Push front of rib where 3D IR-TRACC mounts inward toward spine	-
	Ry	Push front of rib where 3D IR-TRACC mounts downward	-
	Rz	Push front of rib where 3D IR-TRACC mounts rightward	+

APPENDIX C. CHANGE LOG

Date	Description