THOR 50th Percentile Male (THOR-50M)

Qualification Procedures Manual

SEPTEMBER 2018

This manual includes content provided under contracts DTNH22-13-D-00269 (Transportation Research Center, Inc.), DTNH22-99-C-07007 (GESAC, Inc.) and DTNH22-07-00070 (Humanetics Innovative Solutions, Inc.) administered by the National Highway Traffic Safety Administration, U.S. Department of Transportation.

THOR-50M QUALIFICATION PROCEDURES MANUAL

TABLE OF CONTENTS

THOR-50M QUALIFICATION PROCEDURES MANUAL

1 INTRODUCTION

This manual describes the qualification procedures for the NHTSA advanced frontal 50th percentile male anthropomorphic (ATD) known as the **T**est Device for **H**uman **O**ccupant **R**estraint, referred to as THOR-50M throughout this manual. The intent of this manual is to define the performance characteristics of a THOR-50M. This manual supersedes the THOR-NT Certification Manual Revision 2005.2[1], and it should be noted that some of the requirements have been updated based on changes made during the Mod Kit project[2]. These qualification tests ensure that the components are functioning properly, and are also intended to monitor the response of components that may have a tendency to deteriorate over time.

These qualification procedures are simplified versions of biofidelity tests, relaxing the need for specialized instrumentation or test equipment. These tests are configured to use internal instrumentation to evaluate both the instrumentation and the response of the ATD. These qualification tests are to be carried out on each THOR ATD to ensure agreement with the design specification before use to ensure repeatable and reproducible crash testing.

The performance specifications for the qualification tests were determined during a repeatability and reproducibility study consisting of five tests in each mode for three THOR-50M ATDs (serial numbers DL9207, DO9798, and DO9799), which meet the specifications of the THOR-50M Drawing Package (August 2018 version). Each of the three dummies were tested at NHTSA's Vehicle Research and Test Center. In addition, DO9799 was tested under contract at two other laboratories (Humanetics Innovative Solutions; Calspan Corporation), providing five sets of data for generating the performance requirements (unless noted otherwise within the procedure). The performance requirements were calculated using the mean plus or minus 10% of the peak for the specified measured or calculated channels. These performance requirements may be updated once additional data are available from other dummies and other test laboratories.

While not always feasible, an attempt was made to measure each instrument used in the calculation of injury criteria and to assess the performance at a severity level similar to that experienced during a vehicle crash test. The set of injury criteria considered to meet this

---

[1] National Highway Traffic Safety Administration, "THOR Certification Manual, Revision 2005.2," Report No: GESAC-05-04, U.S. Department of Transportation, Washington, DC, March 2005.

[2] Ridella, S., Parent, D., "Modifications to Improve the Durability, Usability, and Biofidelity of the THOR-NT Dummy," 22nd ESV Conference, Paper No. 11-0312, 2011.

objective are those used in the assessment of THOR-50M response in the oblique moving deformable barrier test mode[3].

The recommended order of operations is shown in Figure 1-1. First, the component tests are carried out on the sub-assemblies (head/neck assembly, knee assembly, and lower leg assembly). If resources allow, these tests can be carried out in parallel. After the component tests are completed, the full dummy is assembled and the full body qualification tests are conducted. Alternatively, neck component tests (Figure 1-2, Box A1) and full dummy qualification tests (Figure 1-2, Box A2) can be carried out in parallel with the lower extremity qualification tests by using an alternate pair of lower legs (either THOR or Hybrid III lower legs can be used), then the qualified THOR lower legs can be installed once both groups of tests are complete. Note that in this alternative arrangement, the neck qualification tests would still need to be carried out first to allow proper adjustment of the neck spring cables.

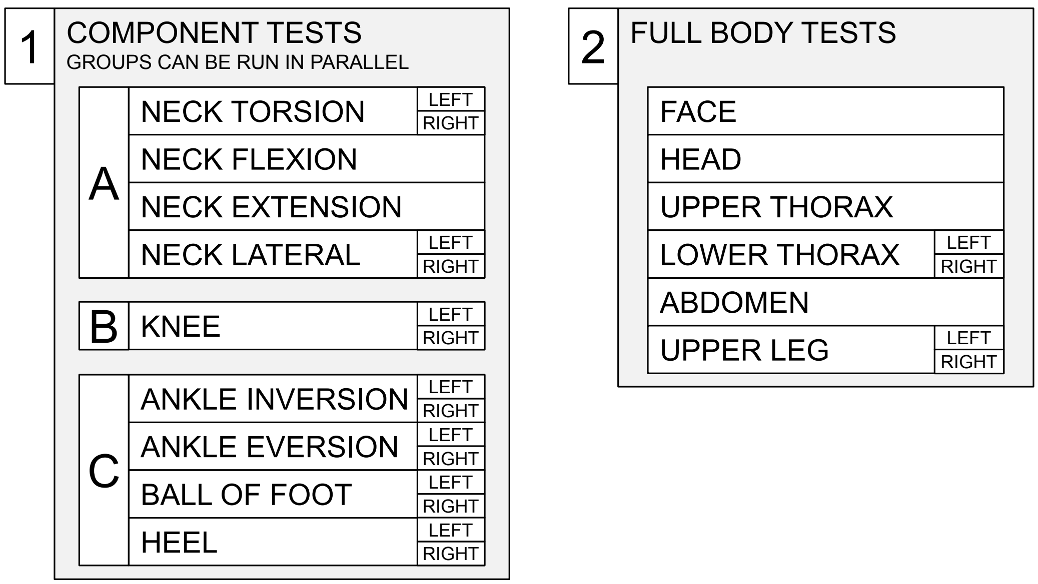


Figure 1-1. Recommended order of operations for qualification procedures.

[3] Saunders, J., Parent, D., Ames, E., "NHTSA Oblique Crash Test Results: Vehicle Performance and Occupant Injury Risk Assessment in Vehicles with Small Overlap Countermeasures," 24th ESV Conference, Paper No. 15-0108, 2015.

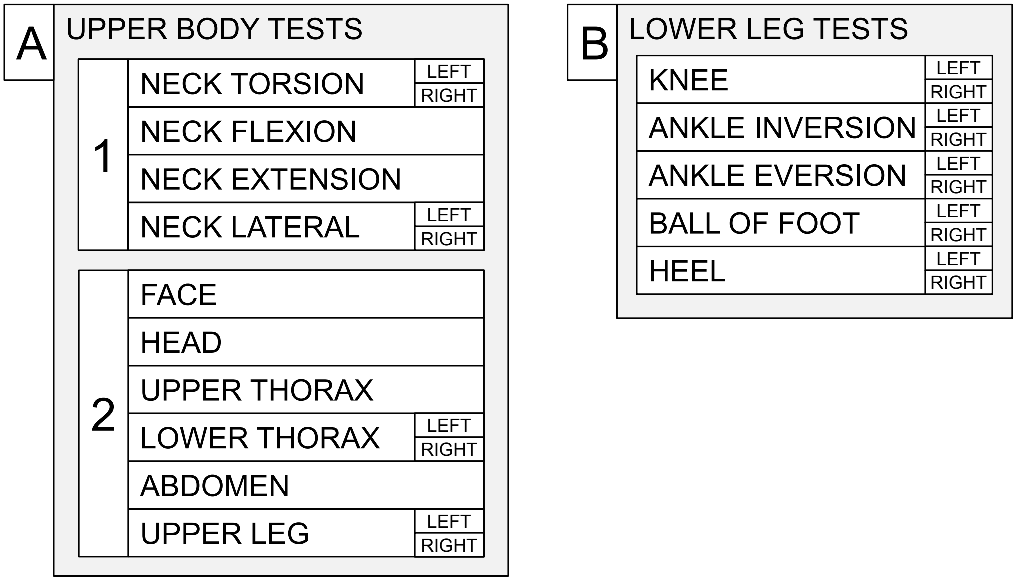


Figure 1-2. Alternative order of operations for qualification procedures.

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	23.36	152.4 disk
	Face Impact Test	6.73	13.0	152.4 disk
Neck	Neck Left Torsion	5.00	Neck Pendulum	
	Neck Right Torsion	5.00		
	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	23.36	152.4 disk
	Left Thorax Impact	4.30	23.36	152.4 disk
	Right Thorax Impact	4.30	23.36	152.4 disk
Abdomen	Abdomen Impact	3.30	32.0	177.8 x 50.8 Rectangular Bar
Femur/Knee	Left Upper Leg Impact	2.60	5.00	76.2 disk
	Right Upper Leg Impact	2.60	5.00	76.2 disk
	Left Knee Impact	2.20	12.00	76.2 disk
	Right Knee Impact	2.20	12.00	76.2 disk
Lower Extremity[4]	Left Ankle Inversion	2.00	NHTSA Dynamic Impactor	
	Right Ankle Inversion	2.00		
	Left Ankle Eversion	2.00		
	Right Ankle Eversion	2.00		
	Left Ball of Foot Impact	5.00		
	Right Ball of Foot Impact	5.00		
	Left Heel Impact	4.00		
	Right Heel Impact	4.00		

[4] Qualification procedures for the lower extremities include photos of the molded shoe (472-7815-1 and 472-7815-2); several qualification procedures were prepared prior to the introduction of the molded shoe and instead depict the molded foot. As the results of these qualification procedures are not affected by the foot/shoe configuration, please disregard the foot/shoe configuration shown in the test setup photographs of the face, lower thorax, abdomen, and upper leg body regions.

2 GENERAL DATA COLLECTION GUIDELINES

2.1 Sign conventions

The sign conventions in this manual are intended to conform to the requirements of SAE Information Report SAE J1733 (Section 2.4(a)2). For polarity information specific to the THOR ATD, see the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

2.2 Signal conditioning

This manual specifies filtering of data channels using Channel Frequency Class (CFC) definitions. For more information on the required filter definitions, please see Appendix C of the March 2014 update to SAE J211-1 (Section 2.4(a)1).

Filter classes were selected using the following hierarchy: first, if the given sensor requires a filter class due to its mechanical or electrical specifications, follow recommendations from the manufacturer; otherwise, if the given sensor is also recorded in a similar qualification test for the Part 572 Subpart E 50th percentile male ATD, follow the sensor specifications in 49 CFR 572.36; otherwise, follow the recommendations provided in SAE J211-1.

2.3 Naming conventions

To facilitate interoperability, the ISO-MME channel code naming convention is recommended. For each test, the recommended channel names for the measured and calculated channels are described in both the ISO-MME (based on the 2015-04-15 proposed codes (Section 2.4(b)1)) and NHTSA Entrée Version 5 naming conventions.

2.4 Normative Documents

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

References include:

(a) SAE International, 400 commonwealth Drive, Warrendale, PA, 15096. Most current revision applies.

   1) SAE J211-1, Instrumentation for impact test – Part 1: Electronic Instrumentation.

   2) SAE J1733, Sign Convention for Vehicle Crash Testing.

   3) SAE J2570, Performance specifications for anthropomorphic test device transducers.

   4) SAE J2876_201505, Low Speed Knee Slider Test Procedure for the Hybrid III 50th Male Dummy.

(b) ISO

1) ISO-MME Task Force, 2015-04-15 proposed mnemonic codes for the THOR-50M.

(c) 49 CFR Part 572

1) Section 572.33, Subpart E, Hybrid III Test Dummy, Neck.

2) Section 572.36, Subpart E, Hybrid III Test Dummy, Test conditions and instrumentation.

(d) NHTSA Website, www.nhtsa.gov

1) THOR-50M Drawing/Parts List.

2) THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI).

3) Entrée Version 5.

2.5 Impact Force Calculation

In many of the test procedures, the response to be evaluated requires calculation of impact force at the contact interface. This can be measured in either of two ways:

2.5.1 With a single linear accelerometer along the line of impact. In this case, impact force is calculated using the following equation:

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

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

2.5.2 With an in-line load cell measuring axial force and a linear accelerometer along the line of impact. In this case, the mass in front of the load cell, including half the load cell mass, must be measured or calculated to determine the inertial correction to the load cell reading. The impact force is calculated using the following equation:

$$F_{IMP}(t) = -F_{LC}(t) + m_f \cdot a_{IMP}(t)$$

where

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

$F_{LC}(t)$ = measured impactor load cell force time-history

m_f = mass in front of the load cell

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

2.6 Measured Channels

Throughout these procedures, sensor channels denoted as "As Measured" (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 "Calculated Measure" (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 (472-3670), representing erect, neutral, slouched, and super-slouched postures. 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 Anthropometry of Motor Vehicle Occupants (AMVO)[5] seated posture for a 50th percentile male 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. If desired or convenient, remove the jacket completely.

3.1.2 Locate the M12 x 1.75 x 60 mm SHCS on the right side of the lower spine, as indicated in Figure 3-1.

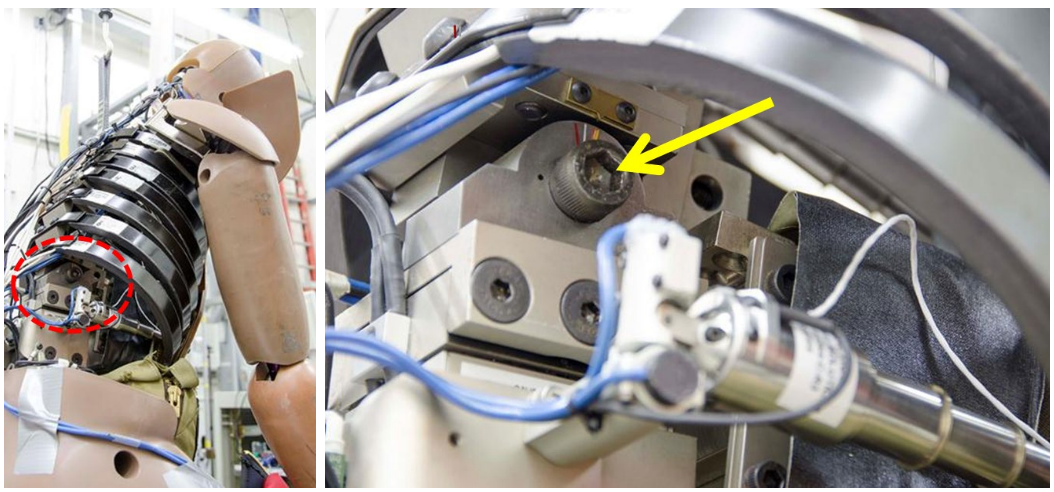


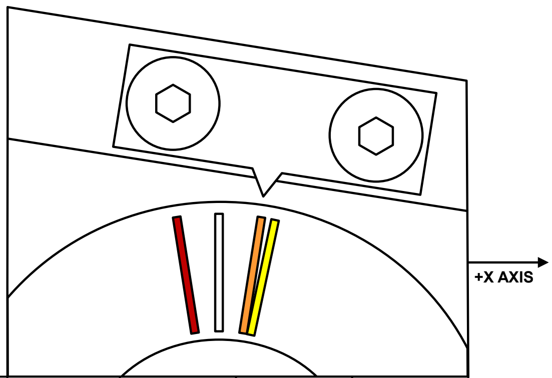
Figure 3-1. Lumbar spine pitch change mechanism adjustment SHCS (M12).

3.1.3 Loosen the M12 x 1.75 x 60 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 and Figure 3-3.

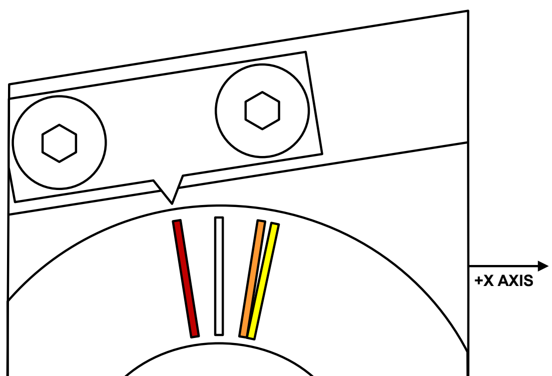
---

[5] 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.



COLOR	RED	WHITE	ORANGE	YELLOW
POSTURE	ERECT	NEUTRAL	SLOUCHED	SUPER SLOUCHED
ANGLE	-9°	0°	9°	12°

Figure 3-2. Lumbar spine pitch change assembly (472-3670) posture settings. Diagram indicates the "slouched" position.



COLOR	RED	WHITE	ORANGE	YELLOW
POSTURE	ERECT	NEUTRAL	SLOUCHED	SUPER SLOUCHED
ANGLE	-9°	0°	9°	12°

Figure 3-3. Lumbar spine pitch change assembly (472-3670) posture settings (diagram shows "erect" position).

3.1.5 Re-tighten the M12 x 1.75 x 60 mm SHCS and torque to 68.0 N-m (50.5 ft-lbf).

3.2 Neck Pitch Change Mechanism

The neck pitch change mechanism connects the lower neck load cell to the upper thoracic spinebox (472-3620). It allows adjustment of the angle of the base of the neck in 3 degree increments. There are two scribe lines marked on the right sprocket, which rotates with the neck, and one scribe line settings marked on left sprocket, which is fixed to the upper thoracic spine. A neutral setting is achieved by aligning the fixed scribe line with the inferior scribe line on the right sprocket, as shown in Figure 3-4. 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 50th percentile male occupant.

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

3.2.1 Unzip the zippers on the right shoulder and the right side of the jacket. If desired or convenient, remove the jacket completely.

3.2.2 Locate the M10 x 1.5 x 55 mm SHCS on the right side of the upper thoracic spine, as indicated in Figure 3-4. If the dummy is fully assembled, the SHCS can be accessed by inserting an M10 T-handle between ribs #2 and #3, through the access hole in the upper thoracic spinebox, and into the head of the adjustment bolt (Figure 3-5, left).

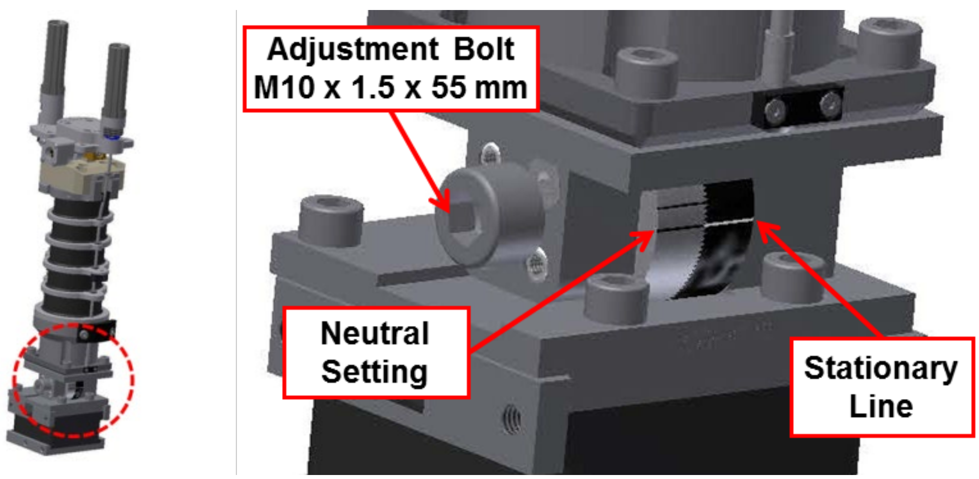


Figure 3-4. Neck pitch change assembly (472-3630) posture setting (diagram shows "neutral" position).

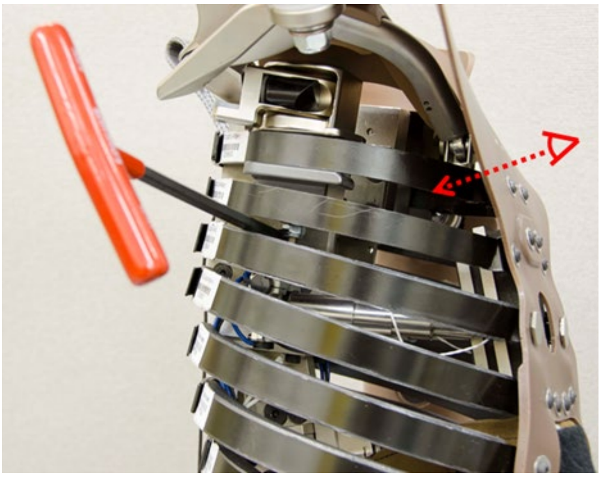


Figure 3-5. Access to the neck pitch change mechanism through the upper thoracic spinebox.

Figure 3-6. View of neck pitch change joint scribe lines through ribcage.

3.2.3 Unscrew the M10 x 1.5 x 55 mm SHCS bolt at least two complete turns (720 degrees) to disengage the sprockets.

3.2.4 Manipulate the neck to achieve the desired posture setting. The default position ("neutral" as shown in Figure 3-4 right and Figure 3-6) is achieved by aligning the lower/inferior scribe line on the sprocket attached to the neck with the scribe line on the fixed sprocket. If the dummy is fully-assembled, the scribed lines can be viewed by looking between ribs #1 and #2 from the front of the dummy (see direction indicated in Figure 3-5 and expected view in Figure 3-6).

3.2.5 Re-tighten the M10 x 1.5 x 55 mm SHCS and torque to 50.8 N-m (37.5 ft-lbf).

3.3 Arm and Shoulder Joint Torque Settings

3.3.1 Position the left hand as shown in Figure 3-7. Adjust the torque of the M12 x 1.75 x 30 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. Repeat for right hand.

Figure 3-7. Wrist orientation for setting joint torque to 1G.

3.3.2 Position the left lower arm as shown in Figure 3-8**.** Adjust the torque of the M12 x 30 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 right elbow.

Figure 3-8. Elbow orientation for setting joint torque to 1G.

3.3.3 Disconnect both clavicles at the shoulder by removing the modified M8 bolt (472-3891, Figure 3-9). Do not remove the cable ties which hold the shoulder pad to the clavicle.

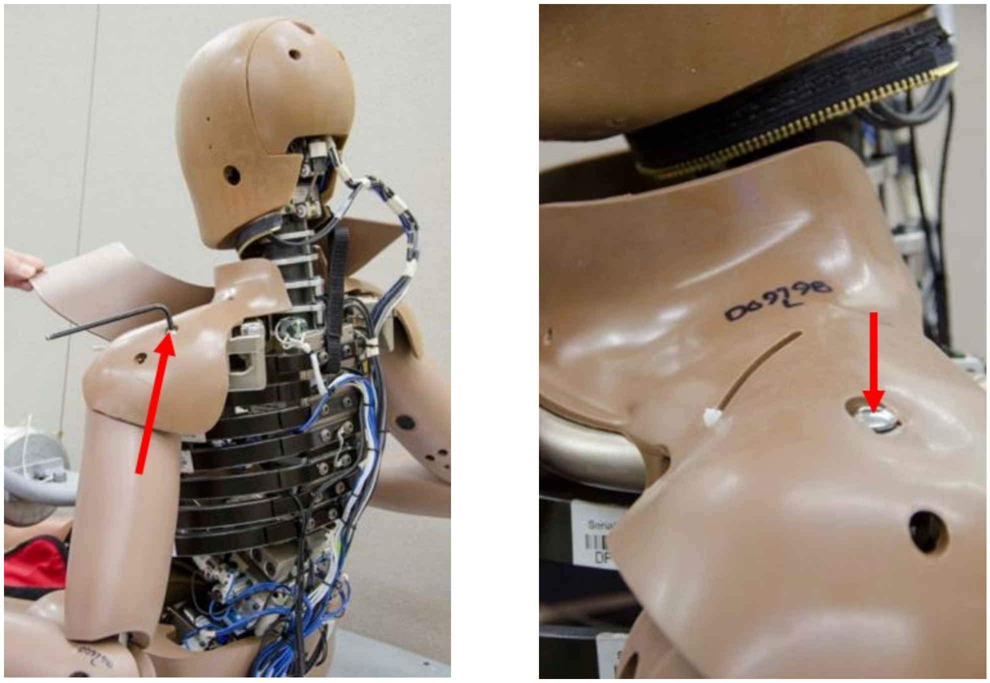


Figure 3-9. Disconnect both left and right clavicles at shoulders (shoulder pad cable ties may be left intact).

3.3.4 Locate the M10 x 20mm SHSS attaching the left upper humerus assembly (472-6200) to the arm clevis (472-3831). This screw may be located through either the anterior or posterior hole in the upper arm flesh (472-6270), as indicated in Figure 3-10. With the elbow bent at 90° as shown in Figure 3-8, rotate upper arm about the X-axis shoulder joint until the arm is in the horizontal plane. Adjust the torque of the M10 bolt such that the arm remains in this position under its own mass but falls once any additional mass or force is added. Repeat for right arm.

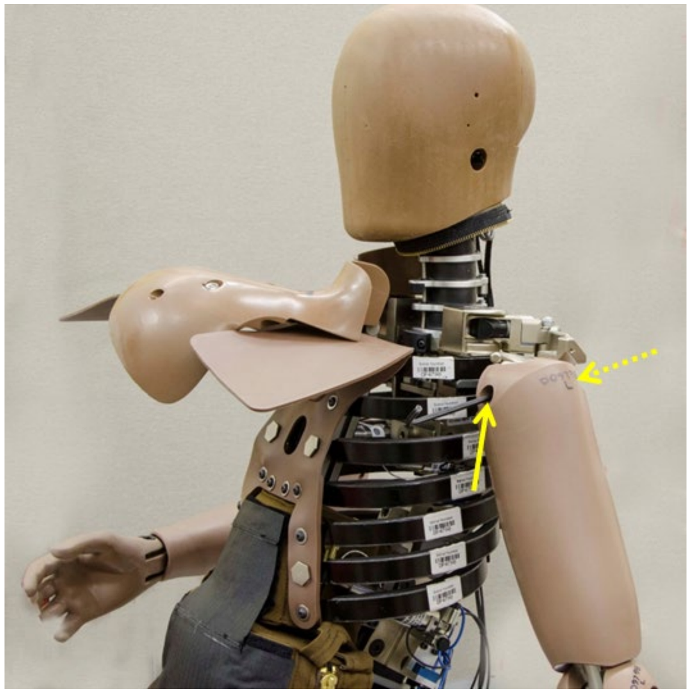


Figure 3-10. Upper arm orientation for setting joint torque about shoulder X-axis to 1G.

3.3.5 Set the torque on the M8 locknut connecting the left shoulder support assembly (472-3813) to the left arm link (472-3829) to 15 N-m (Figure 3-11). Repeat for right arm.

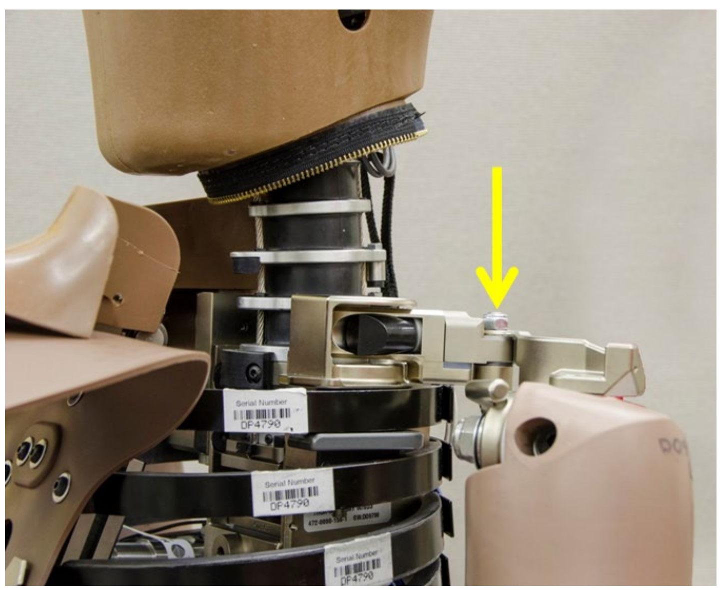


Figure 3-11. Locknut on joint connecting shoulder support assembly to arm link.

3.3.6 Locate the M12 x 1.75 mm locknut at the medial aspect of the left arm clevis assembly (472-3831), indicated by arrow in Figure 3-12. Straighten the elbow, extend the arm fully forward in the horizontal plane, and rotate the lower arm about the global X-axis to prevent bending at the elbow joint. Adjust the torque on the M12 nut such that the arm remains in this position under its own mass but falls once any additional mass or force is added. If this cannot be achieved, inspect the tabbed washer (472-3838) and replace if damaged. Repeat for right arm.

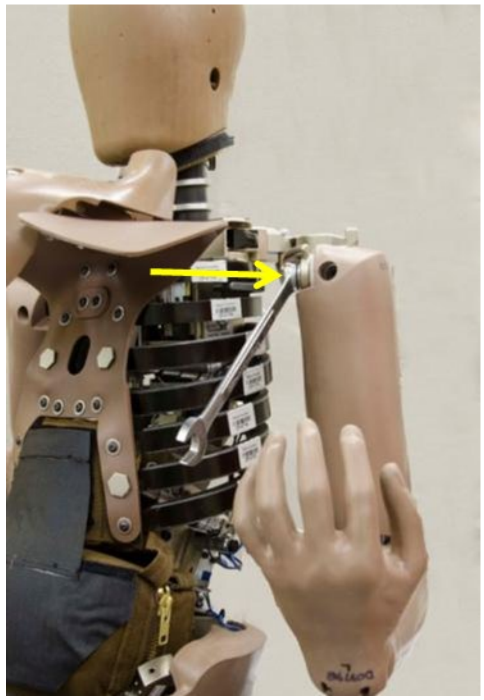


Figure 3-12. Upper arm orientation for setting joint torque about shoulder Y-axis to 1G.

3.3.7 Remove the left forward range of motion (ROM) buffer cover (472-3816) to reveal the locknut behind it (Figure 3-13). Repeat for right arm.

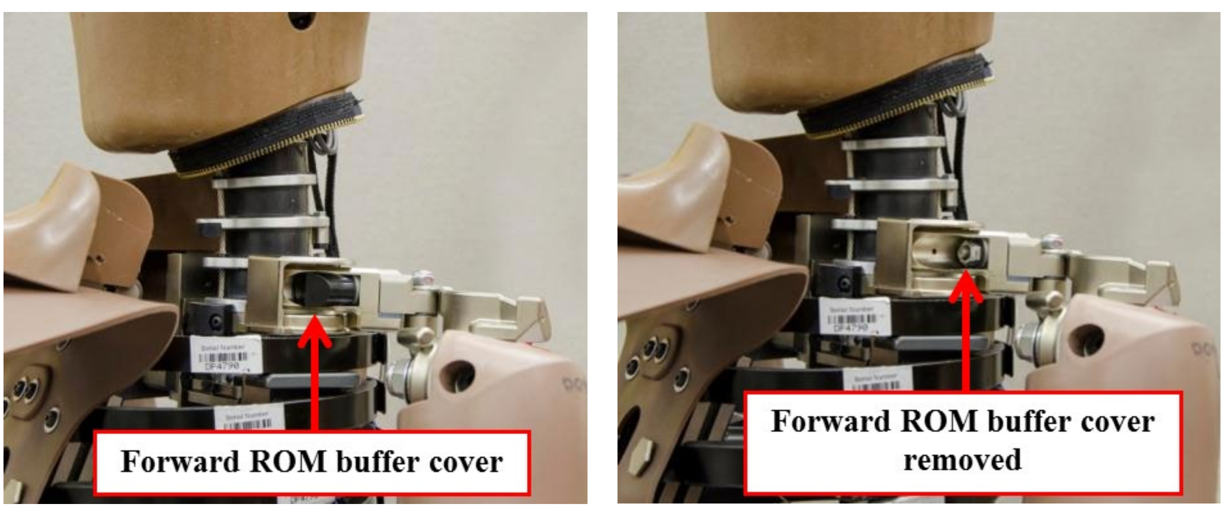


Figure 3-13. Removal of shoulder forward ROM buffer cover to reveal nut.

3.3.8 Set the torque on the M8 x 1.25 mm nut under the forward ROM buffer to 10 N-m (Figure 3-14). Repeat for right arm.

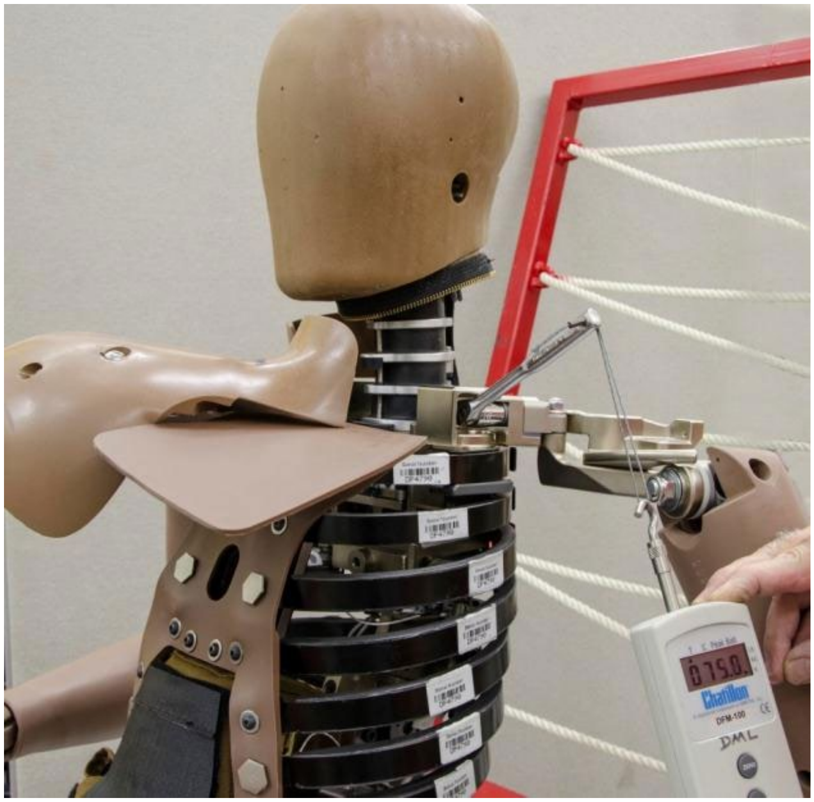


Figure 3-14. Shoulder pivot joint torque setting.

3.3.9 Reinstall the forward ROM buffer (472-3816) so that the line formed between the two beveled surfaces of the ROM buffer is vertical, and the beveled surface faces away from the body of the shoulder support (472-3814), as shown in Figure 3-15. Repeat for right arm.

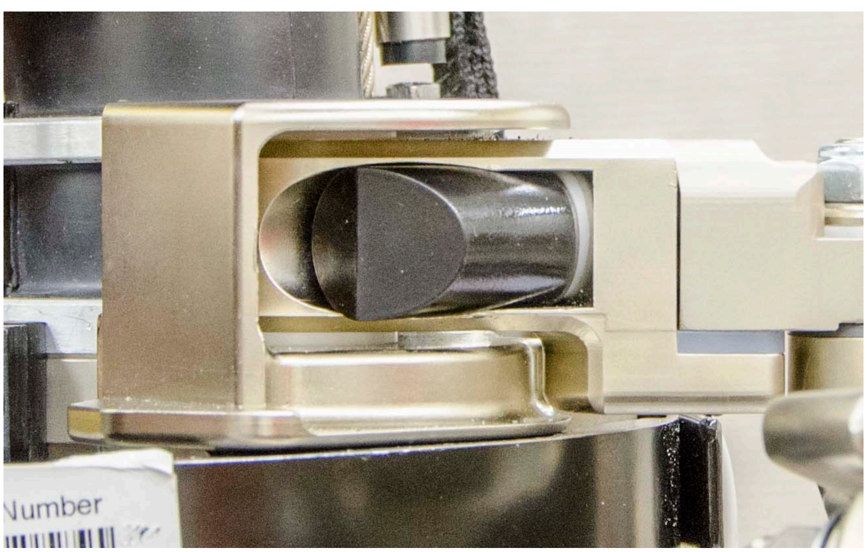


Figure 3-15. Reinstallation of forward ROM buffer.

3.3.10 Reinstall the left and right clavicles by replacing the modified M8 bolts (472-3891) on both the left and right shoulders (Figure 3-9).

3.4 Ankle Rotary Potentiometer Zeroing Procedure

Before conducting any of the dynamic impact tests, it is necessary to determine the voltage 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 voltage values, along with the rotational calibration values in degrees per volt (which should be supplied by the manufacturer or determined experimentally), are later used to determine the angular position of the foot relative to the tibia.

Materials: THOR-50M lower leg assembly (472-7000), lower leg zero bracket (DL472-3500), leg mounting bracket (DL472-4100) mounted to a rigid surface.

Procedure:

3.4.1 Ensure that ankle potentiometers are installed so that they will not pass through the deadband during testing. Rotate the shaft until the potentiometer output voltage is approximately 0 volts so that the potentiometer is near mid-range.

3.4.2 Remove the tibia skin (472-7370) and the two M6 x 1 x 16 BHCS which attach the tibia guard (472-7115) to the lower leg assembly (Figure 3-16).

Figure 3-16. Remove tibia guard.

3.4.3 Remove the four M6 x 1 x 12 FHCS (two per side) which attach the Achilles spring tube assembly to the rear of the lower tibia tube (Figure 3-17).

Figure 3-17. Remove Achilles spring tube assembly.

3.4.4 Separate the ankle assembly from the leg by removing the four modified M6 BHSS (W50-61042) attaching the lower tibia tube assembly (472-7310) to the lower tibia load cell (Figure 3-18). Set the rest of the lower leg mechanical assembly (472-7300) aside.

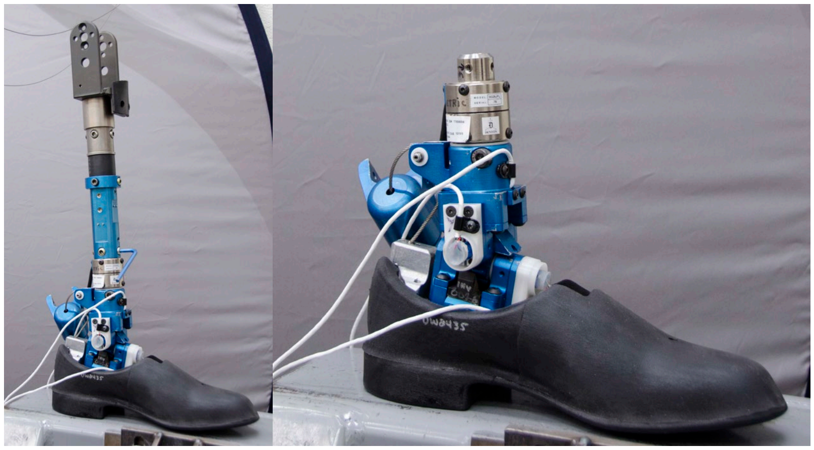


Figure 3-18. Separate the ankle assembly fom the lower tibia load cell.

3.4.5 Mount the Lower Leg Mounting Bracket Assembly (472-4100) to a rigid surface (Figure 3-19).

Figure 3-19. Install the lower leg mounting bracket.

3.4.6 Mount the ankle assembly to the leg mounting bracket using four modified M6 BHSS (W50-61042) with torque set to 10.0 ± 2.5 N-m (7.4 ± 1.8 ft-lbf). Ensure that the toe is pointing upward (Figure 3-20). Secure the Achilles spring tube assembly to the leg mounting bracket using four M6 x 12mm FHCS.

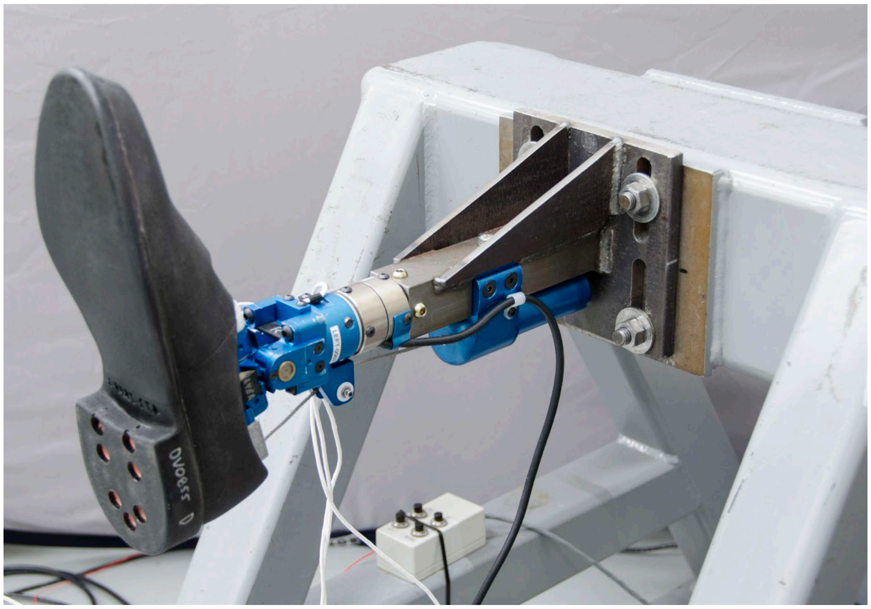


Figure 3-20. Attach lower leg and Achilles tube to bracket.

3.4.7 Remove the four FHCS which attach the molded shoe to the ankle (Figure 3-21).

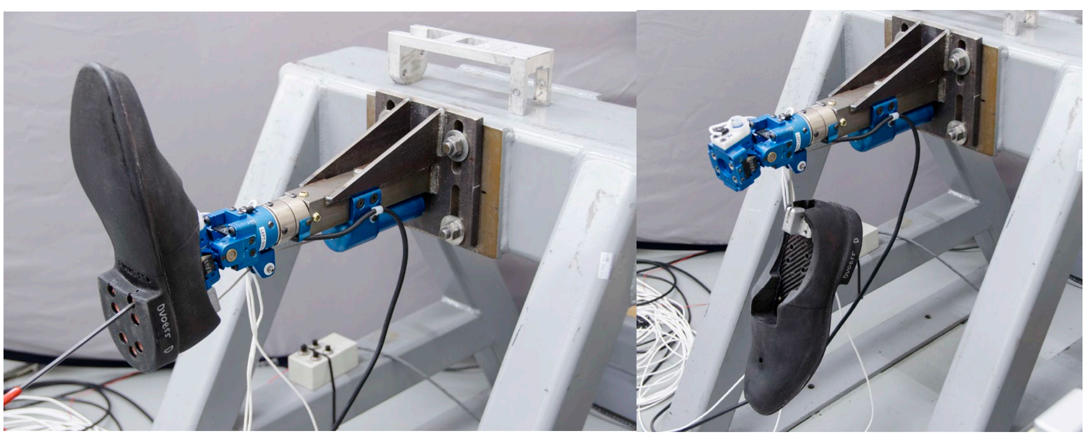


Figure 3-21. Remove the molded shoe.

3.4.8 Attach the lower leg zero bracket (DL472-3500) to the base of the ankle using two M8 x 16 mm SHSS and to the leg mounting bracket using two M6 x 20 mm SHCS, one on each side (Figure 3-22 and Figure 3-23).

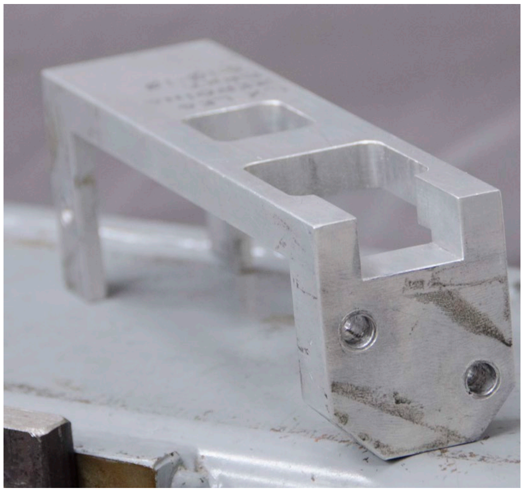


Figure 3-22. Lower leg zero bracket.

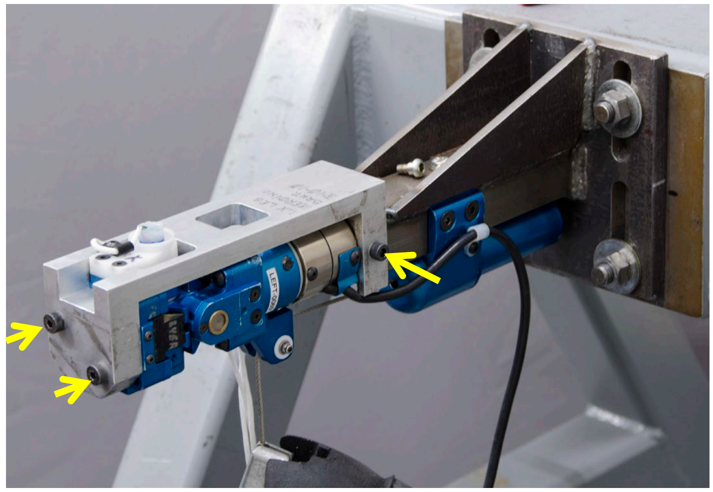


Figure 3-23. Attachment of lower leg zero bracket to leg mounting bracket.

3.4.9 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		

3.4.10 If the Achilles Cable Adjustment Procedure will be conducted immediately following this procedure, follow the steps below. Otherwise, this procedure is now complete.

3.4.11 Remove the ankle zero bracket by removing the two M8 x 16 mm SHSS and two M6 x 20 mm SHCS (Figure 3-23). Hold the ankle assembly in place while removing the ankle zero bracket, and install four modified M6 BHSS (W50-61042) to anchor the lower tibia load cell to the leg mounting bracket.

3.4.12 Attach the molded shoe to the ankle by installing four FHCS through the bottom of the heel of the shoe. Ensure that the Achilles spring cable is anchored to the lower Achilles mounting post.

3.4.13 Proceed to Section 3.5.3 in the Achilles Cable Adjustment Procedure.

3.5 Achilles Cable Adjustment Procedure

The THOR-50M lower leg assembly was designed with an adjustable Achilles tendon cable 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 spring cable tension using a fixture that is integrated with the same leg mounting bracket used in other lower leg qualification tests.

Materials: THOR-50M lower leg assembly (472-7000), Achilles fixture complete assembly (DL472-4000) mounted to a rigid surface.

Instrumentation: tension load cell, Y-axis ankle rotational potentiometer

Procedure:

3.5.1 Ensure that the ankle Y-axis potentiometer is installed such that it will not pass through the deadband during testing. Rotate the shaft until the potentiometer output voltage is approximately 0 volts so that the potentiometer is near mid-range.

3.5.2 Assemble the leg to the lower mounting bracket assembly (Section 3.4.2 through Section 3.4.6).

3.5.3 Attach the load cell mounting assembly (DL472-4200) to the top of the leg mounting bracket using two flat M6 washers and M6-1 x 20 mm hex head cap screws (Figure 3-24).

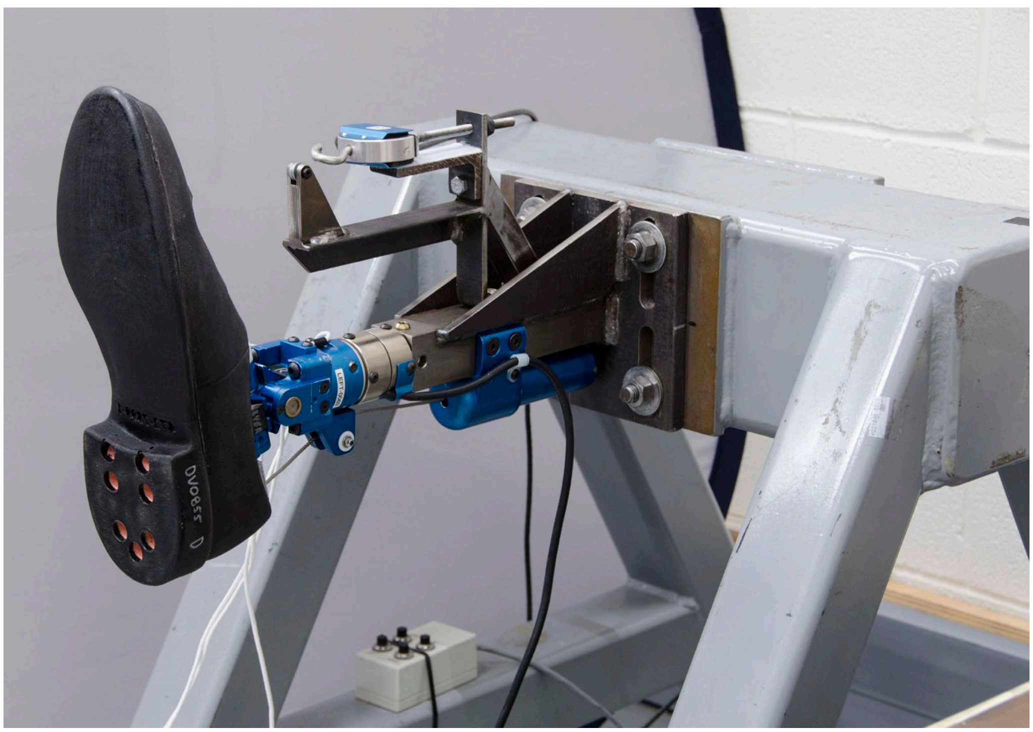


Figure 3-24. Lower leg assembled to Achilles fixture.

3.5.4 Position the leg to the zero reference values for the X axis and Z axis (Section 3.4.9) by adjusting the lower leg about each axis until the reference value is achieved (±0.5°).

3.5.5 Zero the initial value of the tension load cell. Do not zero the ankle Y axis potentiometer. Instead, apply any necessary corrections developed in Section 3.4 to the ankle Y axis potentiometer in the Ankle Rotary Potentiometer Zeroing Procedure.

3.5.6 Screw the pull wire assembly (DL472-4203) into the molded shoe (Figure 3-24). Attach the loop end of the pull wire to the wire hook connected to the tension load cell (DL472-4204). Ensure that the pull wire is centered in the groove of the pulley.

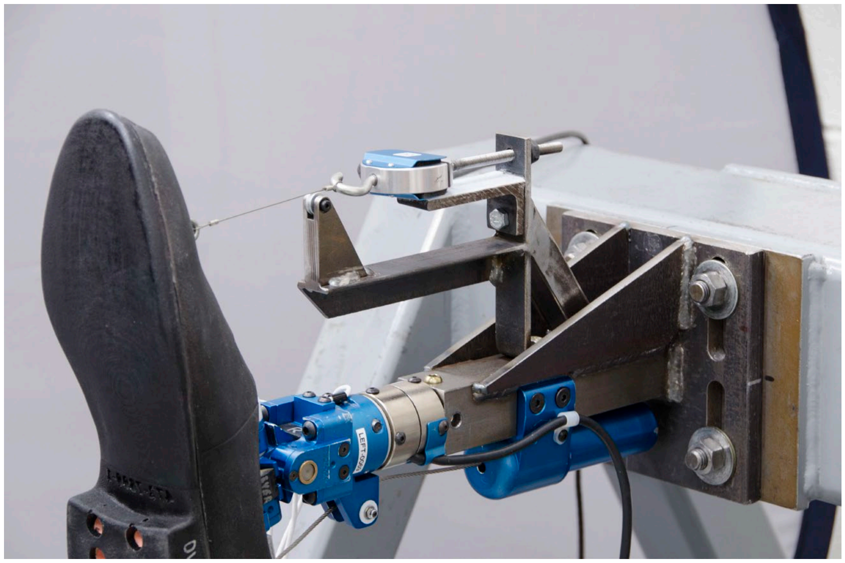


Figure 3-25. Install pull wire assembly.

3.5.7 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.

3.5.8 Connect the Y axis ankle potentiometer and the tension load cell to a data acquisition system. Set the system to record approximately 35 seconds of data, collected at 500Hz and record data from the following procedure.

3.5.9 Using a drill with a (long) hex nut bit, tighten the ¼-28 hex flange nut on the draw screw (Figure 3-26) 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, with the flanged hex nut and thrust bearing touching the mounting bracket assembly. Reverse the direction of the drill to unload the tension on the pull wire completely.

Figure 3-26. Collecting force and angle data to determine Achilles load.

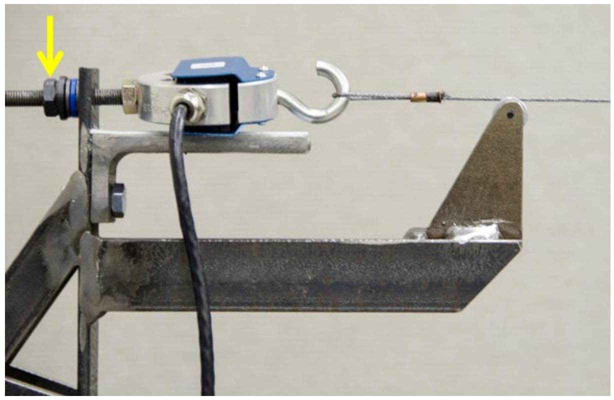


Figure 3-27. Location of adjustment nut on draw screw when Achilles is fully loaded.

3.5.10 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 77.8 ± 4.4 N (17.5 ± 1.0 lbf), this procedure is complete. Otherwise, proceed to the next step.

3.5.11 The Achilles spring tension must be adjusted if it does not meet the tension criteria. First detach the Achilles spring tube from the leg mounting bracket by removing the four M6 x 12mm FHCS. Locate the jam nuts at the top of the spring tube (Figure 3-28). If the tension is higher than the prescribed target tension, loosen both M5 hex jam nuts and move them slightly up the Achilles cable, 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, 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 at least 1.5 N-m. Secure the Achilles spring tube assembly to the leg mounting bracket using four M6 x 12mm FHCS, and return to Section 3.5.9; repeat the procedure as necessary, adjusting tension until the 77.8 ± 4.4 N (17.5 ± 1.0 lbf) is achieved (Section 3.5.10).

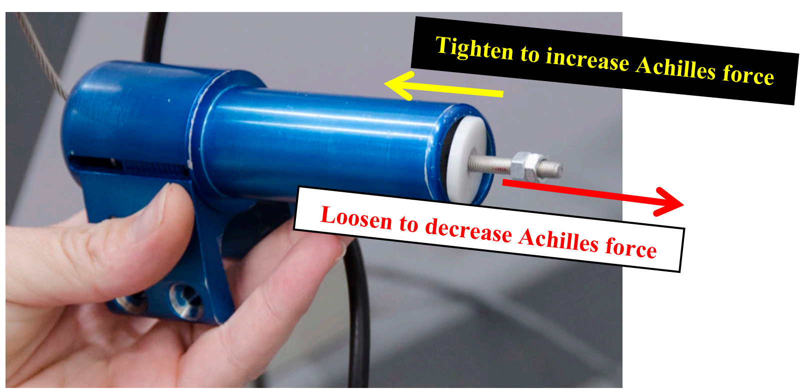
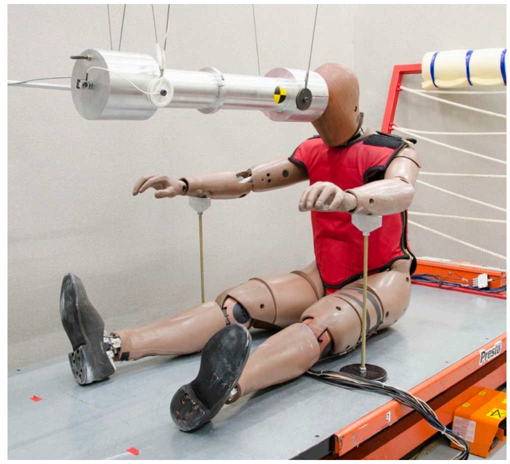


Figure 3-28. Adjusting tension on the Achilles.

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 23.36 kg rigid impactor at 2.00 m/s.

4.2 Materials

- ☐ Fully-assembled THOR-50M ATD (472-0000)
- ☐ Impactor 23.36 ± 0.02 kg (51.50 ± 0.05 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables (Section 2.4(c)2). The test probe is a 152.40 ± 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 ± 0.2 mm (0.50 ± 0.01 in).

4.3 Instrumentation

- ☐ Instrumentation to measure impact force (accelerometer on impactor or a load cell / accelerometer combination if using a linear impactor)
- ☐ Instrumentation to measure the impact velocity
- ☐ Head center of gravity tri-axial accelerometers
- ☐ A dual-axis tilt sensor attached to head accelerometer mounting plate assembly (472-1200) 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 Inspect the head assembly for wear, tears, or other damage; if necessary take appropriate action to refurbish the part (Section 2.4(d)2).

4.4.2 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.

4.4.3 Set the lower thoracic spine (LTS) pitch change joint to the **slouched** position (see Section 3.1).

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

4.5 Test Procedure

4.5.1 Before positioning the dummy for the test, mark the point of impact on the head skin (472-1321). The impact point is 30 mm above the horizontal edge of the skull representing the brow line (Figure 4-1, right). Transferred to the face skin, the brow line is 17 mm superior to the Nasion detent on the head skin (472-1321), so the impact point can be located by measuring along the surface of the head skin to a point that is 47 ± 0.5 mm above the center of the Nasion (Figure 4-1, left). With a flexible ruler, measure to a point that is 47 ± 0.5 mm superior to the center of the Nasion detent along the contour of the midsagittal plane of the head skin, and mark this point on the head skin (Figure 4-2).

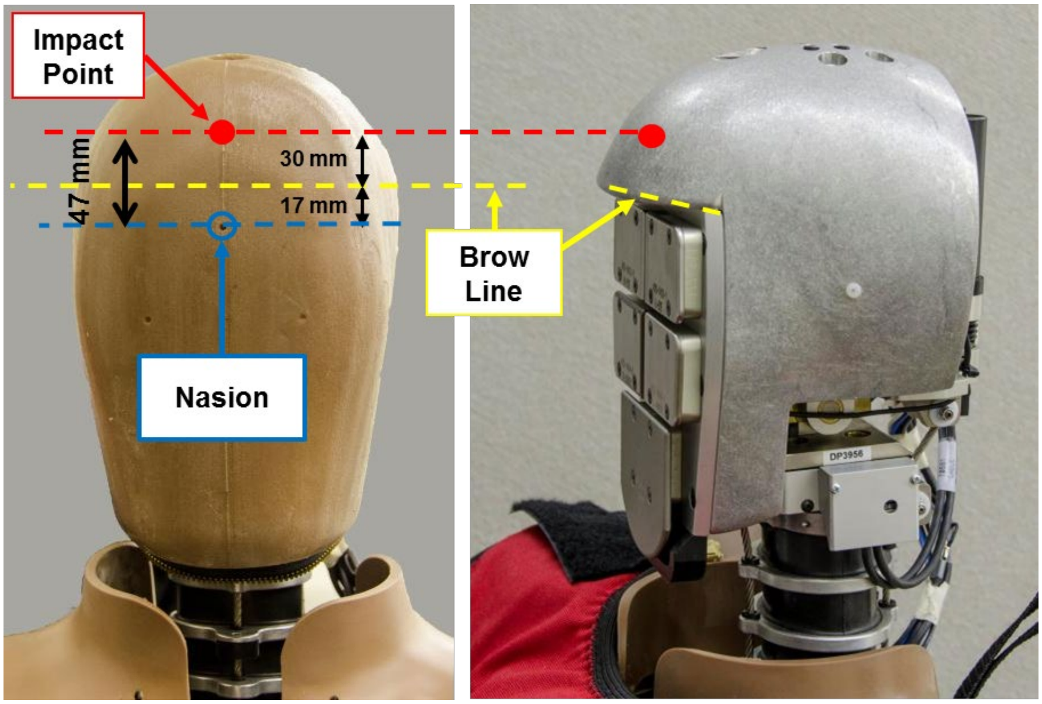


Figure 4-1. Impact location relative to Nasion detent on head skin.

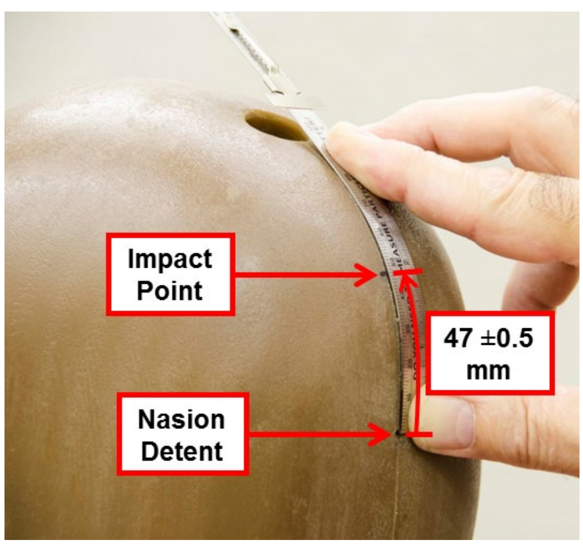


Figure 4-2. Measurement and marking of impact point on head skin.

4.5.2 If not currently installed, reinstall the torso jacket (a.k.a. Front/Rear Panel Assembly, Jacket).

4.5.3 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward parallel to the midsagittal plane. The midsagittal plane shall be vertical within ±1 degree (Figure 4-3).

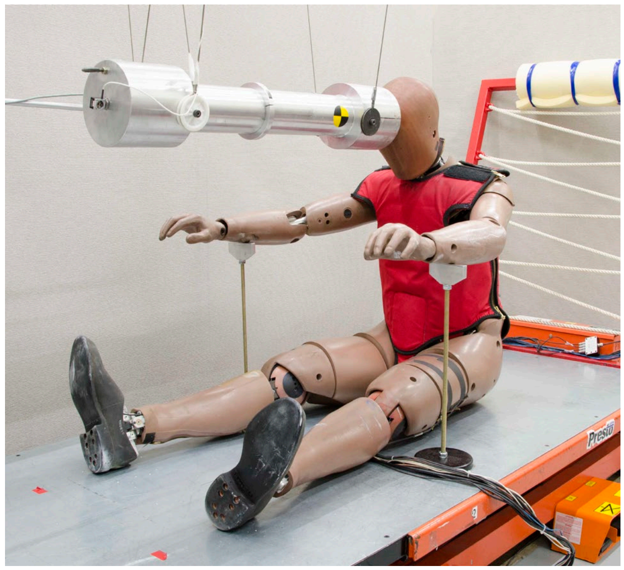


Figure 4-3. Initial setup for head qualification test.

4.5.4 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 4-3). If this cannot be achieved, or the torso cannot be stabilized in the following two steps, repeat the Arm and Shoulder Joint Torque Settings procedure in Section 3.3 before proceeding.

4.5.5 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5° in the X-axis and 13 ±1° in the Y-axis.

4.5.6 Set the head so that the angle measured by the head CG tilt sensor is 0 ± 0.5° in the X-axis and -29 ± 1° in the Y-axis (Figure 4-4).

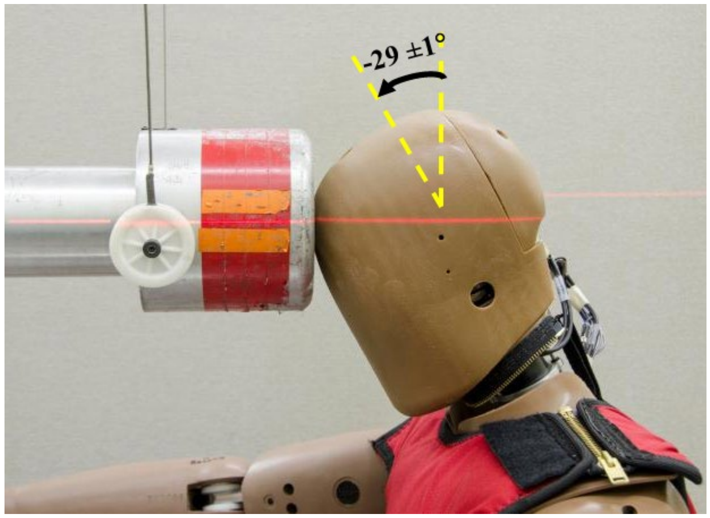


Figure 4-4. Angle of head and alignment with impactor.

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

4.5.8 Adjust the table height or impactor height so that the center of the impactor face is aligned with the point marked on the head skin in Step 4.5.1 (Figure 4-6). 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.

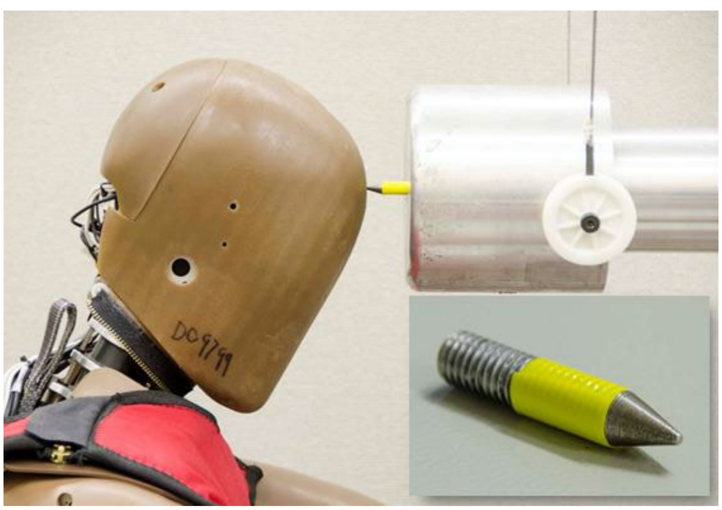


Figure 4-5. Use of a pointer tool to set impactor location.

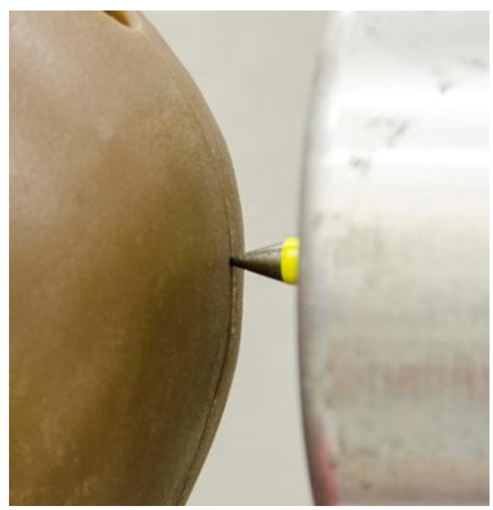


Figure 4-6. Alignment of impactor with impact point marked on head skin.

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

4.5.10 If not already unzipped, unzip the top shoulder portion of the jacket to allow the shoulder alignment marks to be viewed (Figure 4-7). Manipulate the upper arm in the anterior-posterior orientation until the interface between the rear ROM buffer (472-3816) and shoulder support (472-3814) is aligned with the scribe mark on the spring housing cover. If this cannot be achieved, repeat the procedures in Section 3.3 before proceeding.

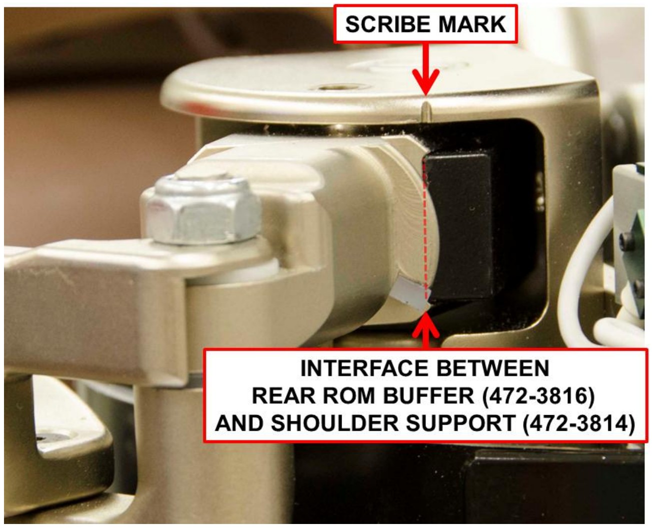


Figure 4-7. Align scribe mark to interface between rear ROM buffer and shoulder support.

4.5.11 Carefully reinstall the jacket by zipping the shoulders of the jacket.

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

4.5.13 Record the “as measured (AM)” channels listed in

4.5.14 Table 4-2 in accordance with SAE J211-1.

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

Table 4-1. Head Impact Test Setup Parameters

Parameter	Setting
Lower Thoracic Spine (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 ± 0.5°; Y = 13 ± 1°
Wait Time Between Tests	At Least 60 Minutes

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

4.5.17 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 measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 4-2) by subtracting the average value of the data samples over the period between (.050 s) and (.010 s) prior to contact.

4.6.2 Filter channels based 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 2.5).

4.6.4 Calculate head CG resultant acceleration:

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

Where:

$$HDCG_R(t) = \text{time} - \text{history of head CG resultant acceleration}$$

$$HDCG_X = \text{time} - \text{history of head acceleration, X} - \text{axis}$$

$$HDCG_Y = \text{time} - \text{history of head acceleration, Y} - \text{axis}$$

$$HDCG_Z = \text{time} - \text{history of head acceleration, Z} - \text{axis}$$

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

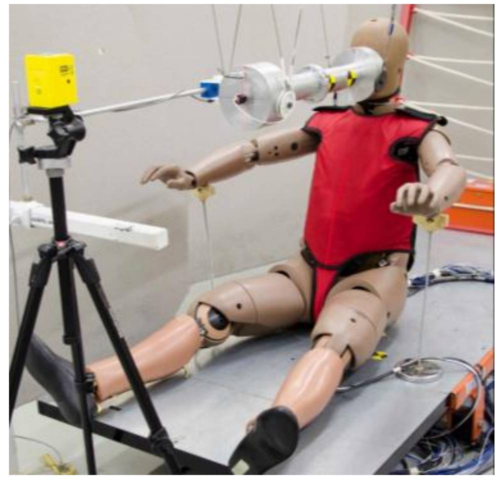
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Head CG Accelerometer, X-axis	1000	D0HEAD0000THACXA	XL	AM	HDCG	AC	G'S
Head CG Accelerometer, Y-axis	1000	D0HEAD0000THACYA	YL	AM	HDCG	AC	G'S
Head CG Accelerometer, Z-axis	1000	D0HEAD0000THACZA	ZL	AM	HDCG	AC	G'S
Head CG Resultant Acceleration	N/A	D0HEAD0000THACRA	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	5022	6138
Peak Head CG Resultant Acceleration	g	105.3	128.7

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 13.00 kg impactor at a velocity of 6.73 m/s.

5.2 Materials

- ☐ Fully-assembled THOR-50M ATD
- ☐ Impactor 13.00 ± 0.02 kg (28.66 ± 0.02 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables (Section 2.4(a)4). The test probe is a 152.70 ± 0.25 mm (6.01 ± 0.01 in) diameter rigid cylinder. The impacting surface must have a flat, right angle face with an edge radius of 12.7 ± 0.2 mm (0.50 ± 0.01 in).
- ☐ Erect posture abdomen foam insert (472-0011)

5.3 Instrumentation

- ☐ Instrumentation to measure impact force (accelerometer on impactor or a load cell / accelerometer combination if using a linear impactor)
- ☐ Instrumentation to measure the impact velocity
- ☐ Head center of gravity tri-axial accelerometers
- ☐ A dual-axis tilt sensor attached to head accelerometer mounting plate assembly (472-1200) 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 Remove head cap (472-1110) by removing four M6 x 1 x 16 mm SHCS.

5.4.2 Remove the head skin assembly (472-1320) by first spreading the posterior portion away from the groove at the rear of the skull assembly (Figure 5-1), then pulling the top of the head skin forward and down (Figure 5-2).

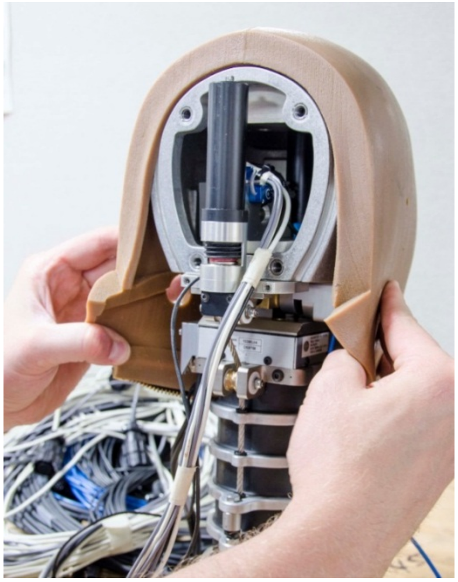


Figure 5-1. Separation of head skin from grooves at posterior of skull assembly.

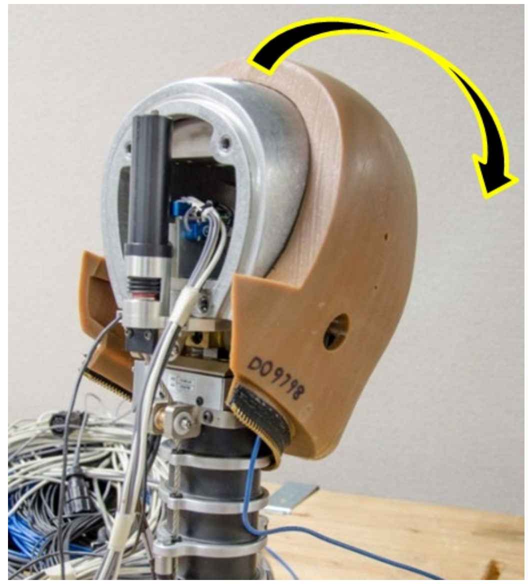


Figure 5-2. Removal of head skin from skull assembly

5.4.3 Inspect the face skin, face foam, and head skin for wear, tears, or other damage; if necessary take appropriate action to refurbish the part (Section 2.4(d)2).

5.4.4 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.

5.4.5 Set the lower thoracic spine (LTS) pitch change joint to the **erect** position (see Section 3.1).

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

5.5 Test Procedure

5.5.1 Ensure that at least 24 hours have passed *with the head skin removed* since Step 5.4.2.

5.5.2 Ensure that the face foam (472-1401) is positioned in the head skin assembly (472-1320). Install head skin assembly by positioning in front of and below skull and moving over the skull in an up-and-back motion until the head skin posterior flaps are positioned along the posterior groove of the skull.

5.5.3 Install the head cap (472-1110) using four M6 x 1 x 16 mm SHCS torqued to 20.3 N-m (15.0 ft-lbf).

5.5.4 Before positioning the dummy for the test, mark the point of impact on the head skin (472-1321). The impact point is centered between the cheek and chin plates on the face (Figure 5-3, right). Transferred to the head skin, this point is 68 ± 0.5 mm inferior of the Nasion detent (Figure 5-3, left). With a flexible ruler, measure to a point that is 68 ±0.5 mm inferior to the center of the Nasion detent along the contour of the midsagittal plane of the head skin, and mark this point on the head skin (Figure 5-4).

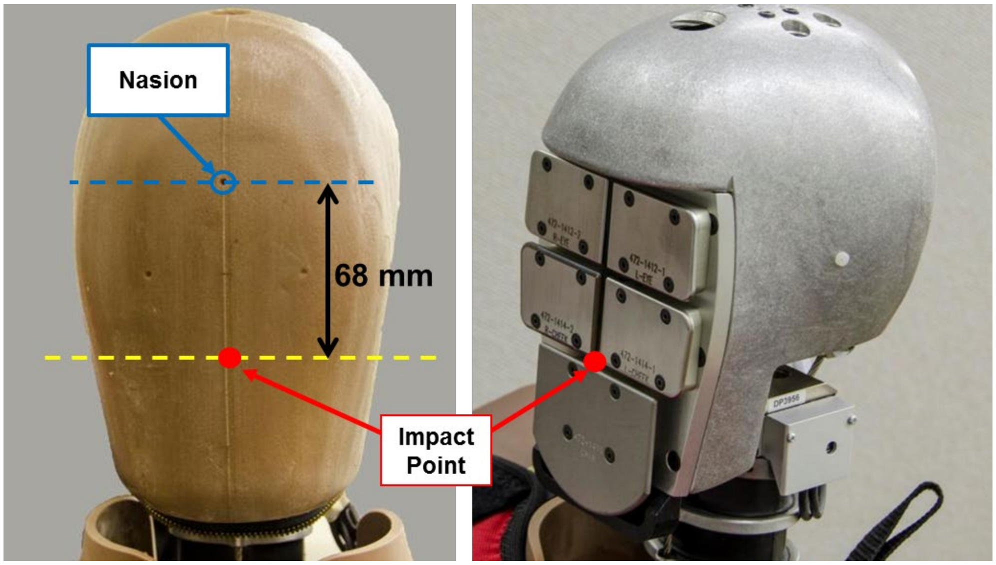


Figure 5-3. Face impact location relative to Nasion detent on head skin.

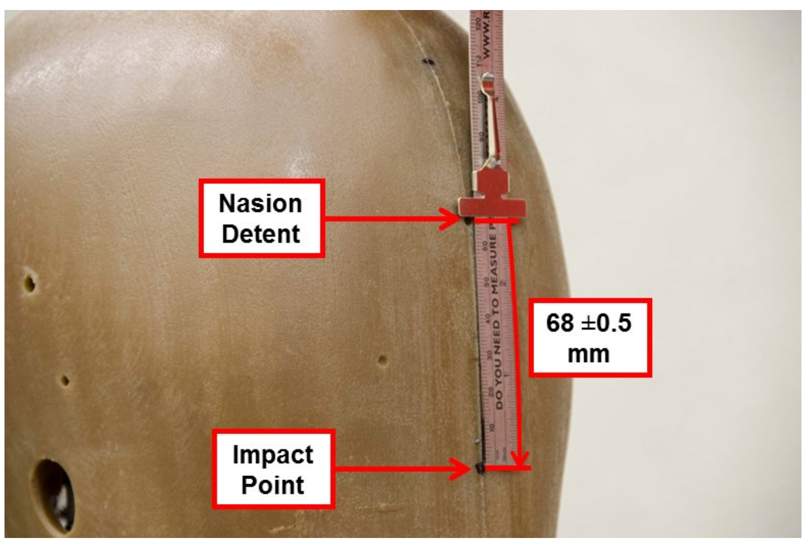


Figure 5-4. Measurement and marking of impact point on head skin.

5.5.5 With the jacket uninstalled, removed, or pulled away from the thorax (but with crotch strap in position so jacket installation does not affect positioning), remove the Upper and Lower Abdomen Velcro Cover (472-4763) from the anterior of the abdomen, insert the erect posture abdomen foam (472-0011), and replace the Velcro Cover such that the top edge attaches to the upper abdomen insert (Figure 5-5).

Figure 5-5. Erect posture foam (right) as inserted into the lower abdomen bag (left).

5.5.6 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward parallel to the midsagittal plane. The midsagittal plane shall be vertical within ±1 degree (Figure 5-6).

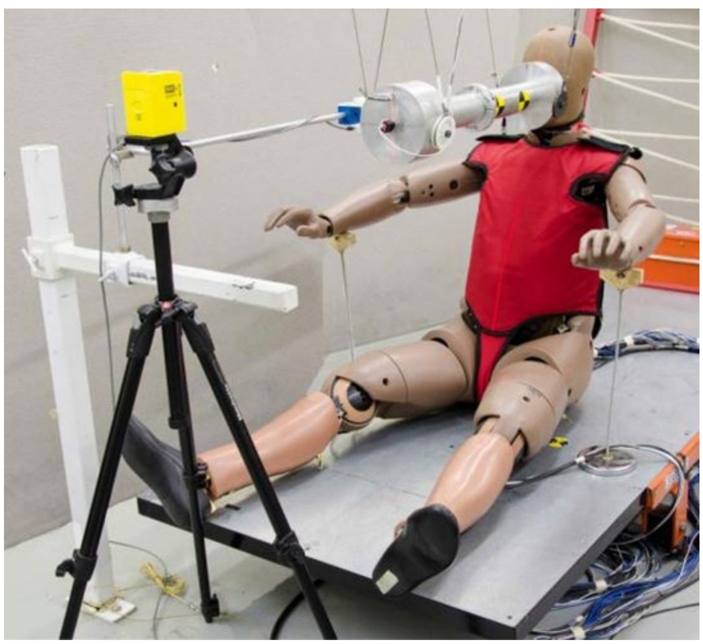


Figure 5-6. Initial setup for the face disk impact test.

5.5.7 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 5-6). If this cannot be achieved, or the torso cannot be stabilized in the following two steps, repeat the Arm and Shoulder Joint Torque Settings procedure in Section 3.3 before proceeding.

5.5.8 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5° in the X-axis and 13 ± 1° in the Y-axis.

5.5.9 Set the head so that the angle measured by the head CG tilt sensor is 0 ± 0.5° in the X-axis and 0 ± 1° in the Y-axis.

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

5.5.11 Adjust the table height or impactor height so that the center of the impact face is aligned with the point marked on the head skin in Step 5.5.4 (Figure 5-7). A removable pointer (threaded into the centerline of the pendulum with approximately 30mm protruding) will aid this process (Figure 5-7).

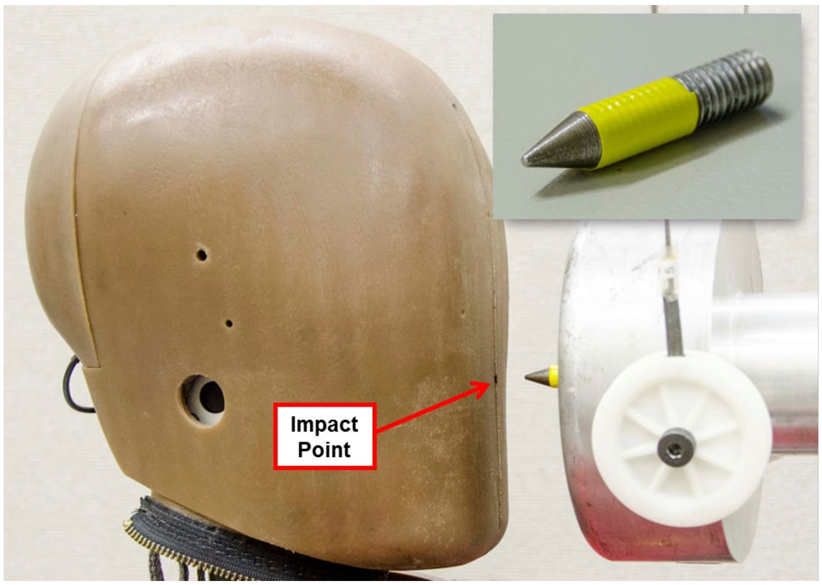


Figure 5-7. Use of a pointer at the center of the impact face to align impactor.

5.5.12 If used, remove the pointer by unthreading from the centerline of the impactor. The probe at rest should just be contacting the face. If it is not, carefully adjust the dummy position relative to the probe while maintaining setup angles for impact position.

5.5.13 If not already unzipped, unzip the top shoulder portion of the jacket to allow the shoulder alignment marks to be viewed (Figure 5-8). Manipulate the upper arm in the anterior-posterior orientation until the interface between the rear ROM buffer (472-3816) and shoulder support (472-3814) is aligned with the scribe mark on the spring housing cover. If this cannot be achieved, repeat the procedures in Section 3.3 before proceeding.

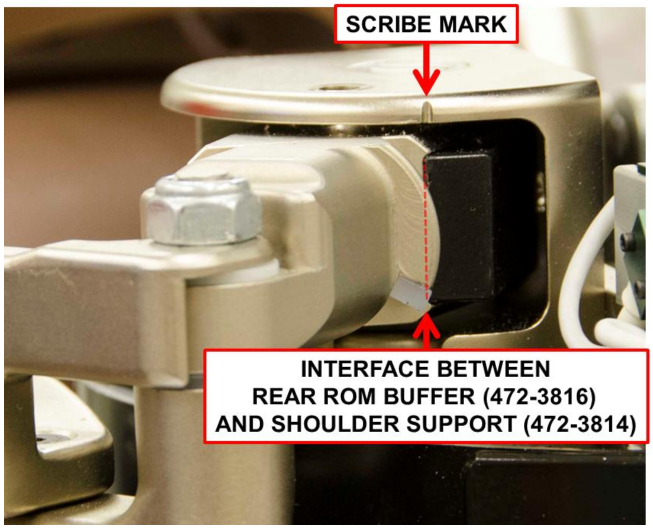


Figure 5-8. Align scribe mark to interface between rear ROM buffer and shoulder support.

5.5.14 Carefully reinstall the jacket by zipping the sides and shoulders of the jacket.

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

5.5.16 Record the “as measured (AM)” channels listed in Table 5-2 in accordance with SAE J211-1.

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

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

Parameter	Setting
Lower Thoracic Spine (LTS) Pitch Change Setting	Erect with Erect Posture Abdomen Foam
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 = 13 ± 1º
Wait Time Between Tests	At Least 24 Hours w/Head Skin Removed

5.5.18 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 measured (unfiltered) channels listed in the “Required Measurement Channels” (Table 5-2) by subtracting the average value of the data samples over the period between (.050 s) and (.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 2.5).

5.6.4 Calculate head CG resultant acceleration:

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

Where:

$$HDCG_R(t) = \text{time} - \text{history of head CG resultant acceleration}$$

$$HDCG_X = \text{time} - \text{history of head acceleration, X} - \text{axis}$$

$$HDCG_Y = \text{time} - \text{history of head acceleration, Y} - \text{axis}$$

$$HDCG_Z = \text{time} - \text{history of head acceleration, Z} - \text{axis}$$

Table 5-2. Required Measurement Channels for Face Qualification

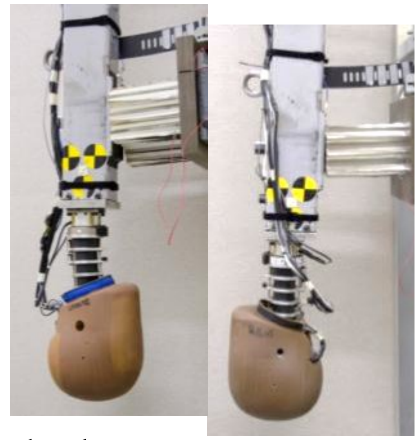
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Head CG Accelerometer, X-axis	1000	D0HEAD0000THACXA	XL	AM	HDCG	AC	G'S
Head CG Accelerometer, Y-axis	1000	D0HEAD0000THACYA	YL	AM	HDCG	AC	G'S
Head CG Accelerometer, Z-axis	1000	D0HEAD0000THACZA	ZL	AM	HDCG	AC	G'S
Head CG Resultant Acceleration	N/A	D0HEAD0000THACRA	RS	CM	HDCG	PP	G'S

5.7 Performance Specifications

Table 5-3. Face Rigid Disk Impact Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	6.68	6.78
Peak Probe Force	N	6378	7796
Peak Head CG Resultant Acceleration	g	124	152

6 NECK QUALIFICATION



6.1 Summary

There are six procedures used to qualify the THOR-50M 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 head-neck pendulum test defined in CFR Title 49, Part 572, Subpart E with 152.4 mm (6 in) 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 ES-2re head-neck lateral pendulum test defined in CFR Title 49, Part 572, Subpart U using 76.2 mm (3 in) aluminum honeycomb for pendulum deceleration. The lateral tests assess the neck performance in the left and right directions about the local X-axis. Logistically, it is recommended to run the neck 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 (torsion, frontal flexion, extension) or 3.40 m/s (lateral flexion) during contact with a Hexcel® aluminum honeycomb (or equivalent).

6.3 Materials

- ☐ THOR-50M ATD head and neck assembly (472-1000 and 472-2000), including all neck spring hardware
- ☐ Head-neck pendulum (as defined in CFR Title 49, §572.33(c)3). Modifications to the mounting plate referenced in §572.33(c)3, Figure 22 may be necessary to match the hole pattern of the THOR-50M lower neck load cell or structural replacement (SA572-S111 or 472-2600). A drawing for such is not included herein due to known differences in lab-specific pendulum configurations.
- ☐ 152.4 mm (6 in) deep aluminum honeycomb[6] used for decelerating the pendulum in flexion, extension, and torsion modes. Alternate deceleration methods may be used provided that the deceleration pulse requirements are met.

[6] Length and width of the honeycomb are specific to each lab's pendulum setup in order to obtain the specified pulse, so honeycomb sizes may vary between labs.

- ☐ 76.2 mm (3 in) deep aluminum honeycomb used for decelerating the pendulum in lateral mode. Alternate deceleration methods may be used provided that the deceleration pulse requirements are met.
- ☐ Neck torsion fixture (DL472-1000)

6.4 Instrumentation

- ☐ Upper neck 6-axis load cell
- ☐ 3 Angular Rate Sensors (ARS) in the head (X, Y, Z)
- ☐ Contact switch to determine Time Zero (T_0) (optional)
- ☐ Instrumentation to measure impact velocity, such as light trap or equivalent
- ☐ Rotational potentiometer on neck torsion fixture
- ☐ Pendulum accelerometer
- ☐ Pendulum Angular Rate Sensor (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 6-1).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.

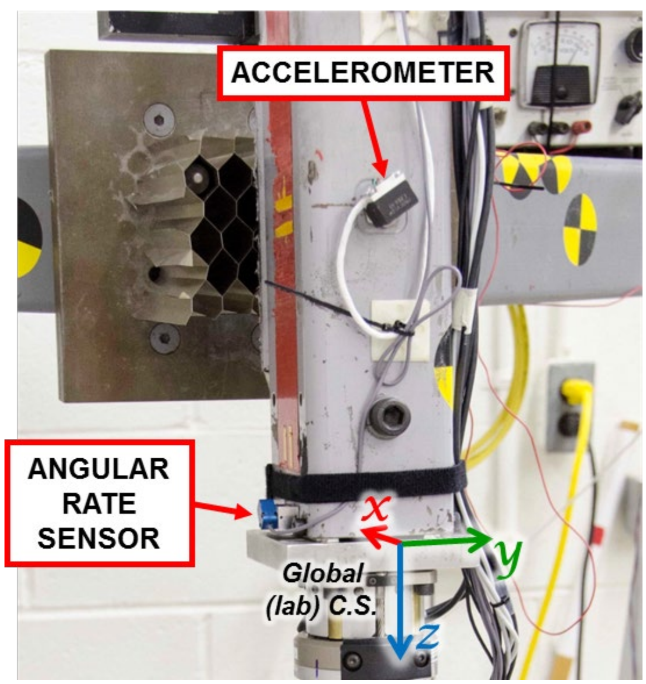


Figure 6-1. Installation of ARS on pendulum.

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 6-2). *Once the spring tower adjustment has been made and neck qualification tests have been performed, do not adjust the spring towers again or new neck qualification tests must be performed.*

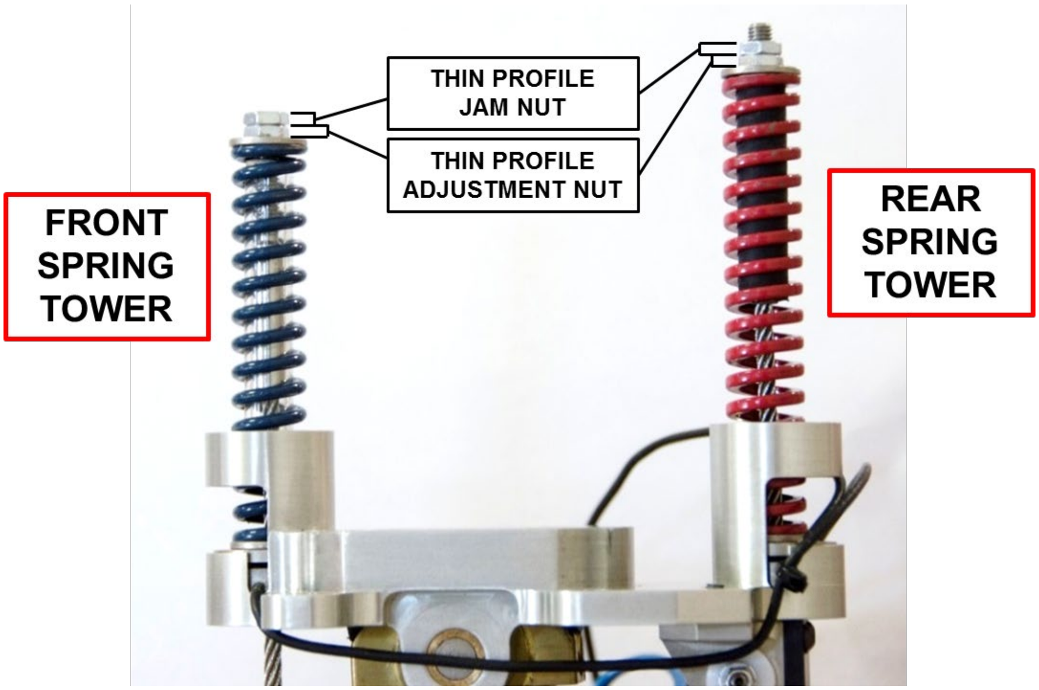


Figure 6-2. Neck spring tower jam nut configuration.

6.5.1 Remove the head from the neck by removing four M6 FHSCS from the bottom of the head/neck mounting platform (472-2210). Remove the front and rear spring tubes (472-2203) by unscrewing by hand from the head/neck mounting platform.

6.5.2 The spring tower cable setup is best performed with the base of the lower neck load cell clamped to a rigid, flat horizontal surface. Perform this procedure in both the anterior-posterior and lateral directions. Measure the angle of the surface; record this value (*Surface°*). Place an inclinometer on the top surface of the upper neck load cell socket connector cover (SA572-S110), as shown in Figure 6-3; measure and make note of the neck angle (*UpNeckLoadCell°)*. Calculate the bend in the neck (*MaxNeckBendAngle°*) using the equation below. If the maximum neck bend exceeds 2°, then manipulate the neck in flexion or extension as needed to straighten the neck below 2° of bend. Measure the upper neck load cell angle to ensure that the neck meets this criterion. If still unable to achieve the *MaxNeckBendAngle°*, the neck should be replaced before proceeding with this setup.

$$MaxNeckBendAngle° = |UpNeckLoadCell° - Surface°|$$

$$MaxNeckBend° \leq \pm 2°$$

6.5.3 Place the inclinometer on top of the neck mounting platform (472-2210) as shown in Figure 6-4 to measure (anterior-posterior) *NeckMountPlatform°*. Calculate the *PlateAngle°*.

$$PlateAngle° = \ |UpNeckLoadCell° - NeckMountPlatform°|$$

If the *PlateAngle°* is less than or equal to 1°, proceed directly to Section 6.5.5

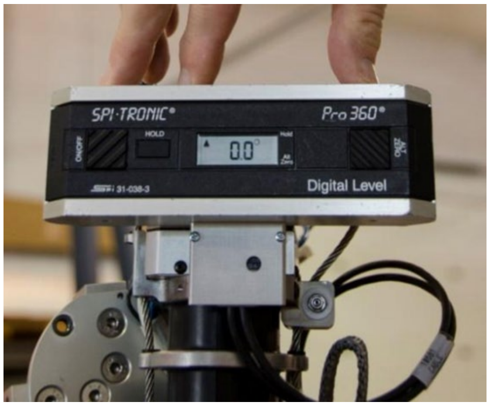


Figure 6-3. Inclinometer placement on top surface of upper neck load cell (*UpNeckLoadCell°*).

Figure 6-4. Inclinometer placement on top surface of neck mounting platform (*NeckMountPlatform°*).

6.5.4 If the *PlateAngle°* is greater than 1°, move the neck mounting platform until achieving a *PlateAngle°* of 1°. Do not force the *PlateAngle°* setting to a value ***much smaller*** than 1° as this puts undesired additional load on the neck cables. The goal is to achieve a *PlateAngle°* of 1° or less with *minimal* loads placed on front and rear neck cables. *While holding and maintaining the PlateAngle° to 1°,* proceed to Section 6.5.5.

6.5.5 Ensure that the springs are properly seated on the front and rear neck cables (Figure 6-5 and Figure 6-6). Install the M5 x 0.8 jam nuts on *both* the front and rear cables so that they just contact the springs (Figure 6-7). If the *PlateAngle°* required adjustment (if it was initially greater than 1° as in Section 6.5.4), check the *PlateAngle°* once again to ensure that it is 1° (Figure 6-3 and Figure 6-4); if it is not 1°, *slightly* adjust the front jam nut to achieve the 1° setting, keeping in mind that the goal is to achieve a *PlateAngle°* of 1° or less with *minimal* loads placed on front and rear neck cables.

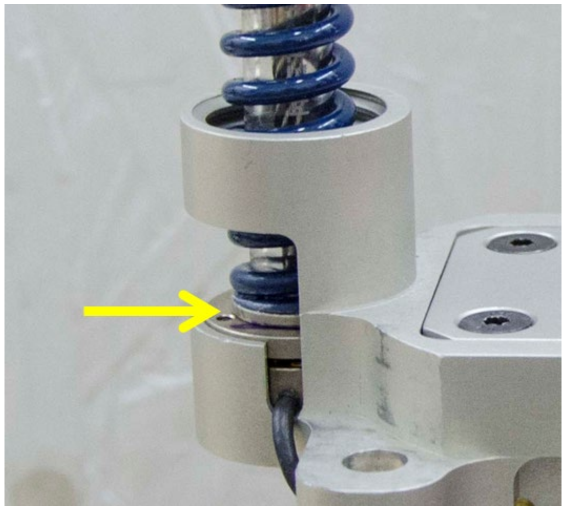


Figure 6-5. Front spring properly seated against spring load cell.

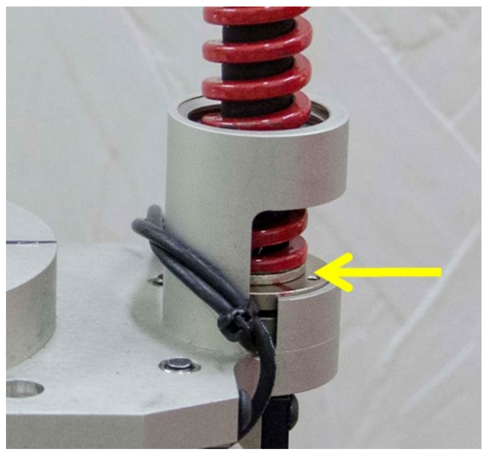


Figure 6-6. Rear spring properly seated against spring load cell.

Figure 6-7. Install jam nut on front and rear springs after achieving desired plate angle setting.

6.5.6 To ensure that the spring adjustment exercise has not added excessive bend to the neck, the angle of the top surface of the upper neck load cell (Figure 6-3) must be less than or equal to 2° relative to the mounting surface of the neck:

$$MaxNeckBendAngle° = |UpNeckLoadCell° - Surface°|$$

$$MaxNeckBend° \leq \pm 2°$$

6.5.7 If the maximum neck bends exceeds 2°, then the cable setup procedure should be repeated. If still unable to achieve the plate angle setting requirements and maximum neck bending requirements simultaneously, then try replacing the neck or the nodding block and repeating the procedures.

6.5.8 Once both plate angle and maximum neck bend angles are achieved, hold the wrench in place to maintain the front adjustment nut position and install an M5 x 0.8 jam nut on top of the front adjustment nut (Figure 6-8). Tighten the jam nut with a second wrench to a torque of at least 1.5 N-m. Repeat this procedure for the rear cable (Figure 6-9).

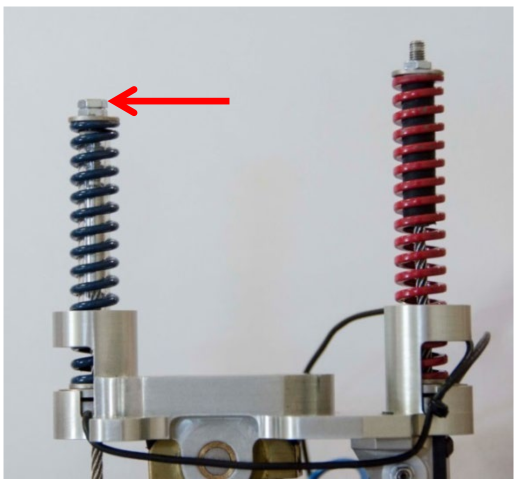


Figure 6-8. Jam nut installed on top of adjustment nut on front spring tower.

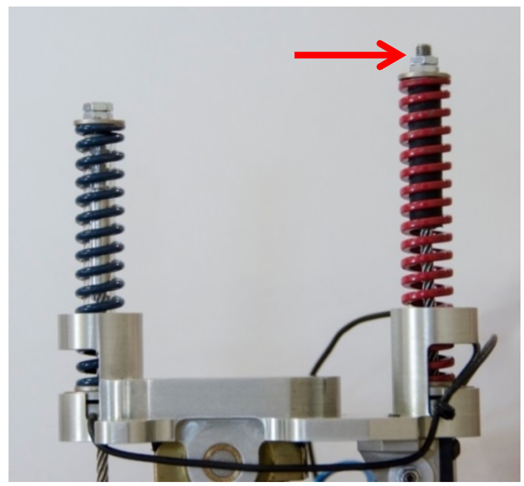


Figure 6-9. Jam nut installed on top of adjustment nut on rear spring tower.

6.5.9 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.

6.5.10 Screw on the Front and Rear Spring Tubes (472-2103) (Figure 6-10).

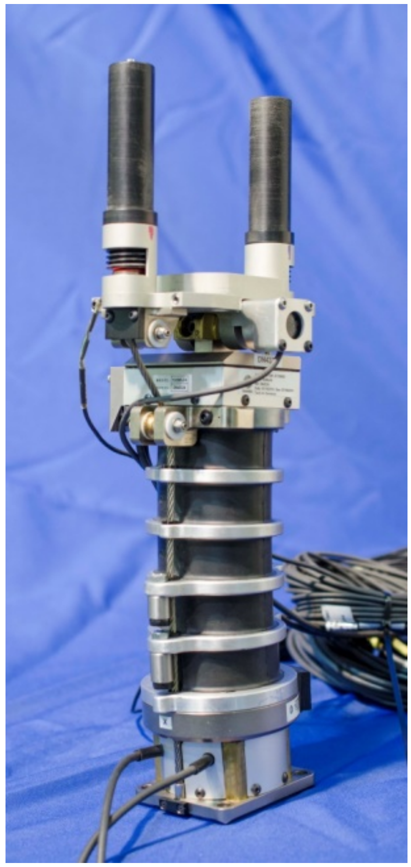


Figure 6-10. Screw on neck spring tubes.

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 Filter the pendulum acceleration at CFC1000 (if necessary).

6.6.2 Perform bias removal of the pendulum acceleration (CFC1000) by subtracting the average value of the data samples over the period between (.050 s) and (.010 s) prior to contacting the honeycomb.

6.6.3 Time zero (t_0) is defined as the time when the first data sample where the bias removed pendulum acceleration from Step 6.6.2 exceeds 5 g. If this results in a time shift from the original DAS-recorded time, apply this time shift to all measured channels listed in the "Required Measurement Channels" table for the respective neck test mode.

6.6.4 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 (.050 s) and (.010 s) prior to time zero (t_0).

6.6.5 Filter the data for all measured channels listed in the "Required Measurement Channels" table for the respective neck test mode.

6.6.6 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:

$$Pendulum\ Velocity(t) = \text{time} - \text{history of pendulum impact velocity}$$

$$Pend\ Accel(t) = \text{time} - \text{history of pendulum acceleration}$$

$$t_0 = \text{first time point for calculation (see 6.6.3 above)}$$

$$t_f = \text{final time point for collected data}$$

6.7 Neck Torsion Test

6.7.1 <u>Neck Torsion Test Procedure</u>

6.7.1.1 Inspect the neck assembly for wear, tears, or other damage and for any de-bonding between the rubber pucks and metal plates. Inspect the front and rear springs (including the inserted rubber tubes) within the head assembly for any wear or other damage. Inspect the front and rear OC stops at the bottom of the head also for wear and damage; if necessary take appropriate action to refurbish the parts (Section 2.4(d)2).

6.7.1.2 Soak the head and neck assembly 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.

6.7.1.3 Install the appropriate 152.4 mm (6") aluminum honeycomb (or equivalent) to meet the pendulum pulse specified in Table 6-12 for an impact velocity of 5.00 ± 0.05 m/s. Ensure that the contact area of the aluminum honeycomb engages the impactor plate on the pendulum upon impact.

6.7.1.4 If it has not yet been carried out on this ATD, conduct the Pre-Test Neck Setup Procedure (See Section 6.5).

6.7.1.5 If the Pre-Test Neck Setup Procedure was completed immediately prior to this test, re-install the neck spring tubes front and rear spring tubes (472-2203) by screwing in by hand to the head/neck mounting platform and skip to Step 6.7.1.13.

6.7.1.6 Remove the neck/head assembly (including the lower neck load cell) from the torso by removing the four M6 x 1 x 25 mm SHCS (two anterior and two posterior) that hold the base of the lower neck load cell to the torso (Figure 6-11 and Figure 6-12).

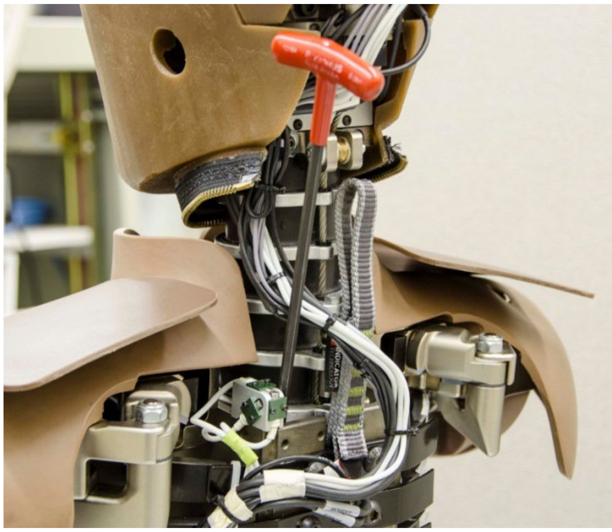


Figure 6-11. Removal of posterior bolts that attach the neck to the torso.

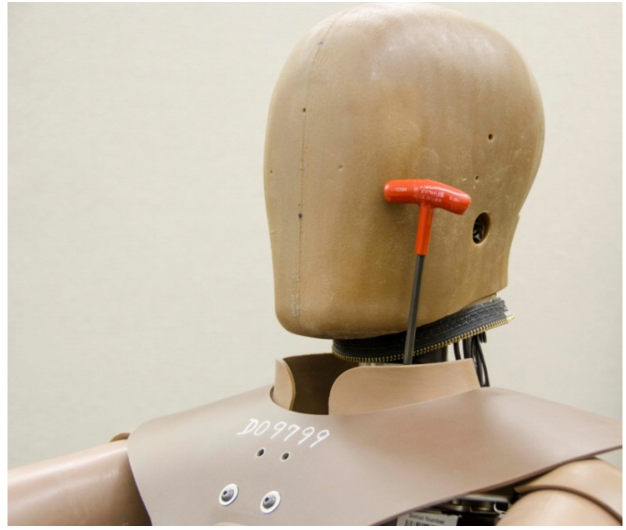


Figure 6-12. Removal of anterior bolts that attach the neck to the torso.

6.7.1.7 To separate the head/neck assembly from the remainder of the ATD, the first rib needs to be partially detached to allow the lower neck load cell wires to be removed. Remove the two M8 x 1.25 x 10 mm BHCS of rib #1 at the spine (Figure 6-13).

Figure 6-13. Two posterior bolts attaching rib #1 to the spine.

6.7.1.8 Remove only the right side M5 x 0.8 x 22 mm BHCS that holds the anterior right end of rib #1 to the bib (Figure 6-14).

Figure 6-14. Uninstall right bolt for rib #1 on the bib.

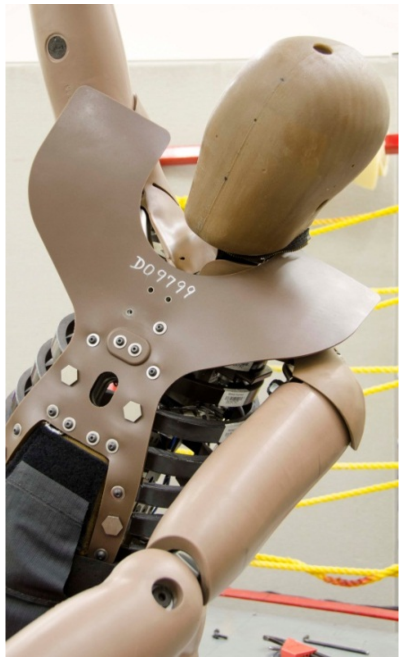


Figure 6-15. Raise right arm for easier access to remove load cell wiring.

Figure 6-16. Rib #1 can be moved to access wiring for neck removal.

6.7.1.9 Raise the right arm for easier access to the detached rib (Figure 6-15). The lower neck load cell wiring can then be routed under the anterior portion of rib #1 (Figure 6-16) and the head/neck assembly can be separated from the torso (Figure 6-17).

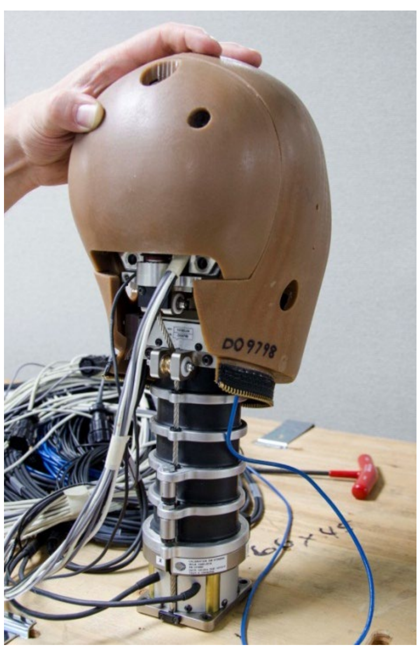


Figure 6-17. Isolated head and neck assembly.

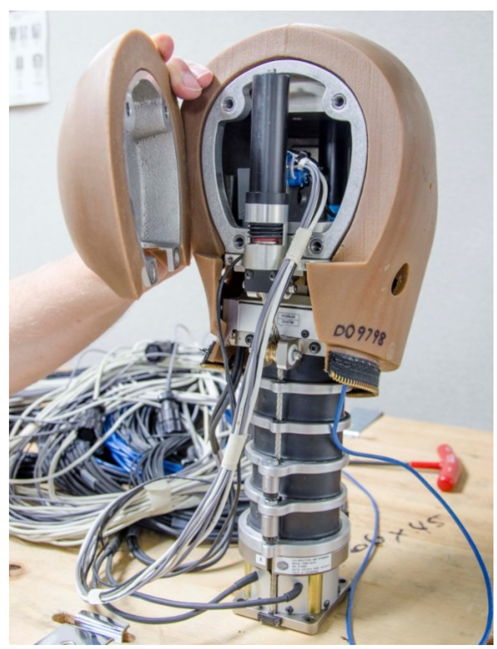


Figure 6-18. Removal of head cap.

6.7.1.10 Uninstall the head cap (472-1110) by removing the four M6 x 1 x 16 mm SHCS attaching it to the skull assembly (Figure 6-18).

6.7.1.11 Remove the head skin assembly (472-1320) by first spreading the posterior portion away from the groove at the rear of the skull assembly (Figure 6-19), then pulling the top of the head skin forward and down (Figure 6-20).

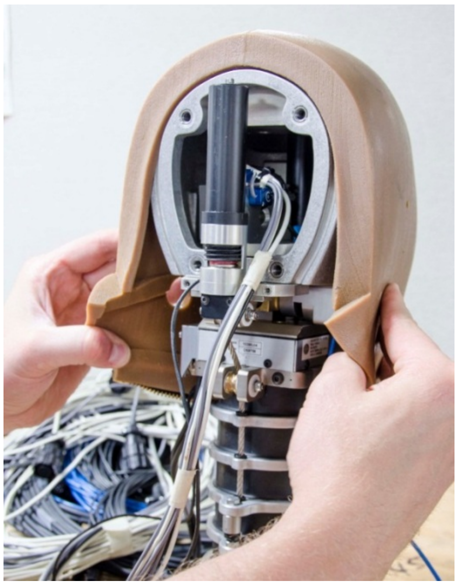


Figure 6-19. Separation of head skin from grooves at posterior of skull assembly.

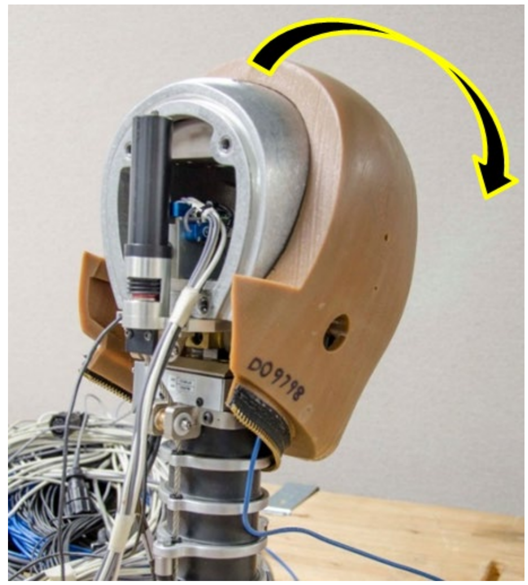


Figure 6-20. Removal of head skin from skull assembly.

6.7.1.12 Remove the four M6 x 1 x 25 mm FHCS at the bottom of the head/neck mounting platform to disconnect the head from the neck (Figure 6-21). 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 (Figure 6-22). If installed, remove the head instrumentation. The isolated neck assembly (472-2000) is shown in Figure 6-23.

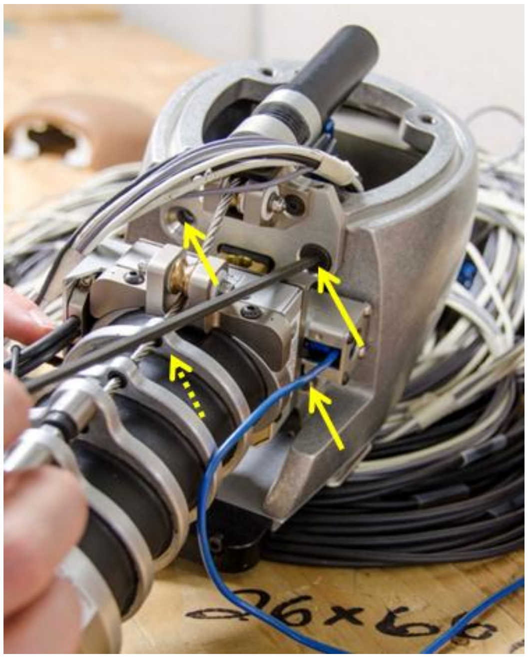


Figure 6-21. FHCS connecting head/neck mounting platform to skull assembly.

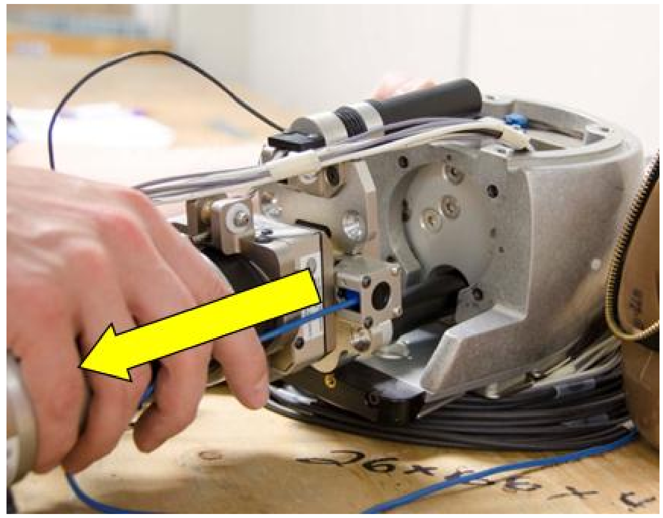


Figure 6-22. Motion necessary to separate the neck assembly from the skull assembly.

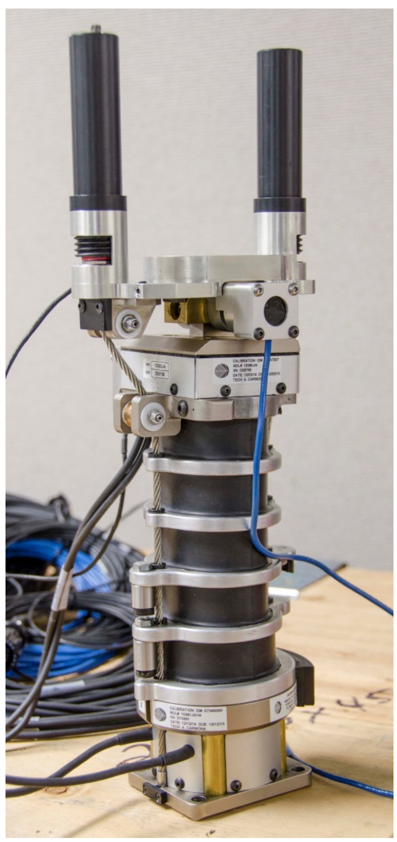


Figure 6-23. THOR-50M neck assembly.

6.7.1.13 Mount the angular rate sensor (ARS, SA572-S58) on top of the neck mounting adapter (DL472-1170) at the edge opposite the front spring tower recess, as shown in Figure 6-24.

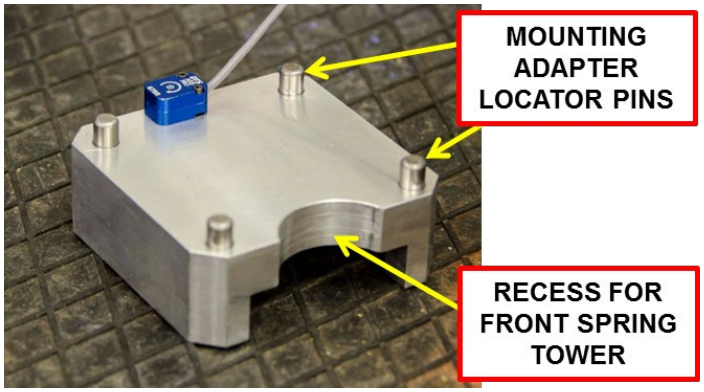


Figure 6-24. Angular rate sensor installation on neck mounting adapter.

6.7.1.14 Install the neck mounting adapter (DL472-1170) to the neck using four M6 x 1 x 25 mm FHCS (Figure 6-25). 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.

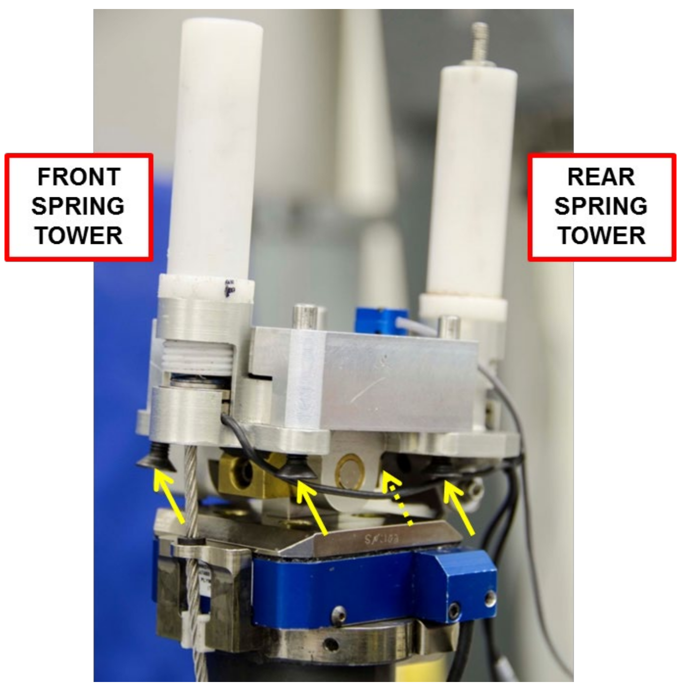


Figure 6-25. Neck mounting adapter installed on head/neck mounting assembly.

6.7.1.15 Attach the lower neck load cell to the end plate assembly (DL472-1130) using four M6 x 1 x 25 mm SHCS (Figure 6-26). Orient the neck so that the front spring tower is facing the locator pins (Figure 6-27).

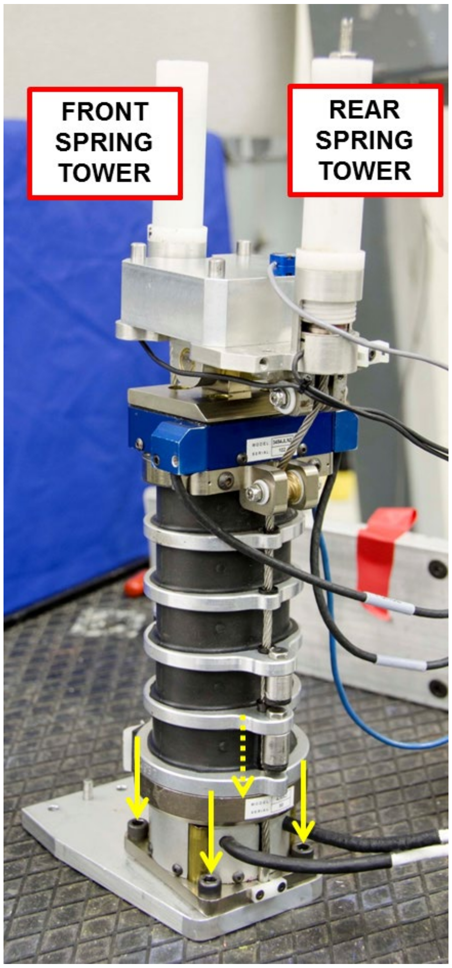


Figure 6-26. Attachment of lower neck load cell to neck end plate assembly.

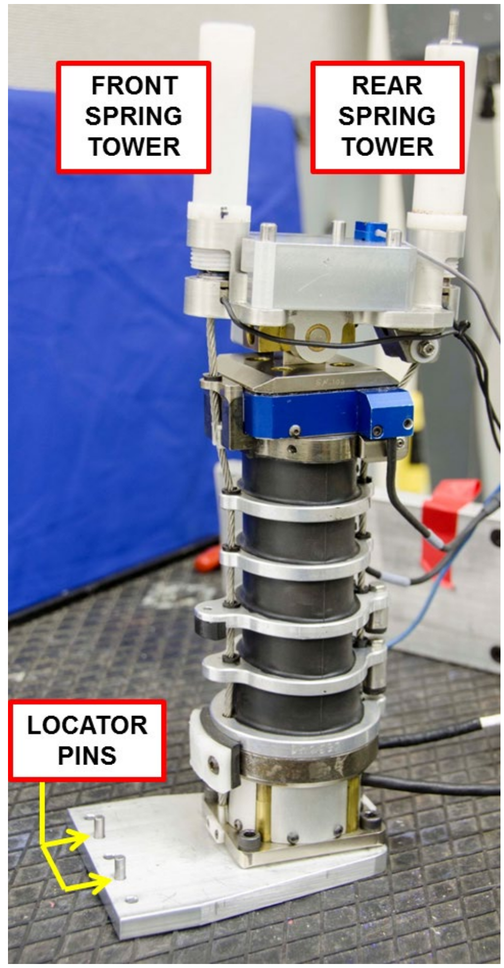


Figure 6-27. Orientation of neck relative to locator pins.

6.7.1.16 Mount the neck torsion fixture (DL472-1000) to the bottom of the neck pendulum using four ¼-20 x 5/8" SHCS (Figure 6-28). Orient the long axis of the torsion fixture top plate (DL472-1110) perpendicular to the direction of motion of the pendulum (Figure 6-29).

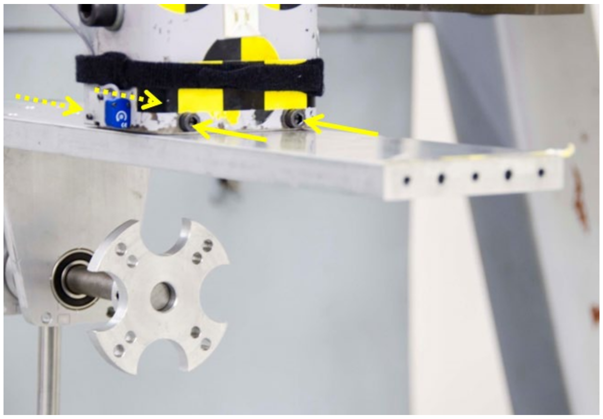


Figure 6-28. Attachment of torsion fixture to neck pendulum.

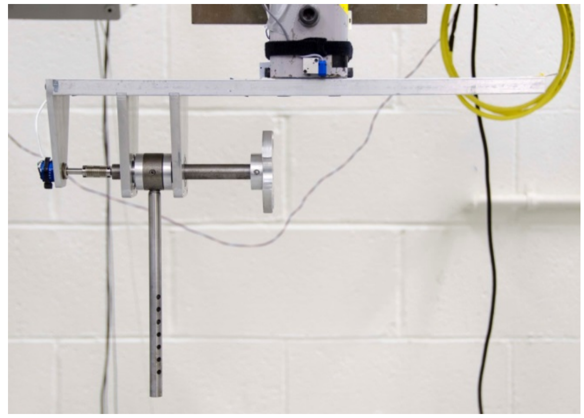


Figure 6-29. Long axis of torsion fixture top plate perpendicular to motion of neck pendulum.

6.7.1.17 Install the neck into the fixture by aligning the locator pins on the end plate assembly at the base of the neck into the end of the torsion fixture top plate (Figure 6-30). Orient the neck so that the rear spring tower faces the ground.

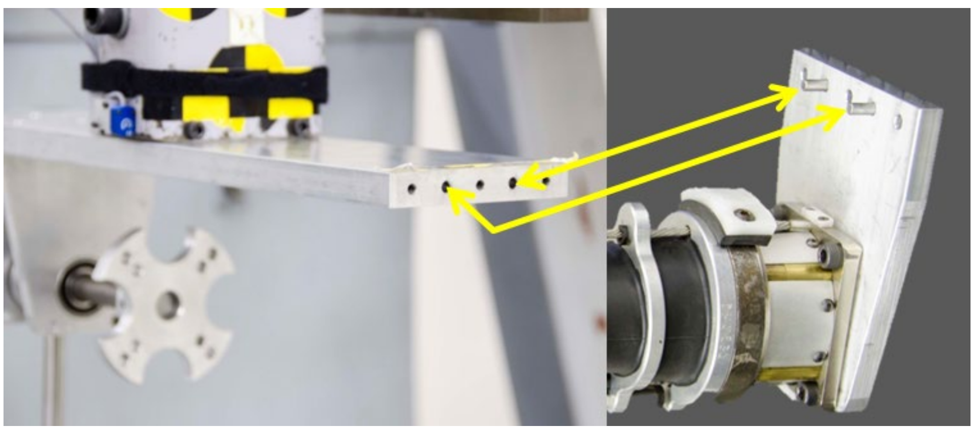


Figure 6-30. Alignment of locator pins with end plate of neck torsion fixture.

6.7.1.18 While positioning the end plate assembly in Step 6.7.1.17, simultaneously align the neck mounting adapter locator pins into the neck attachment plate (DL472-1151) (Figure 6-31 and Figure 6-32).

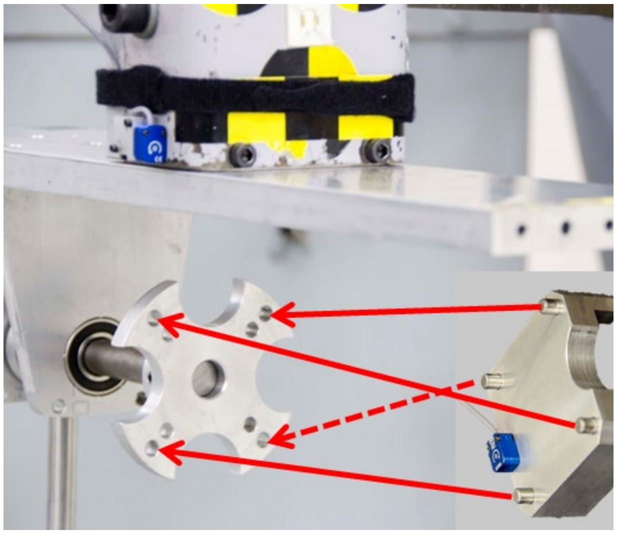


Figure 6-31. Alignment of neck mounting adapter locator pins with neck attachment plate locator holes.

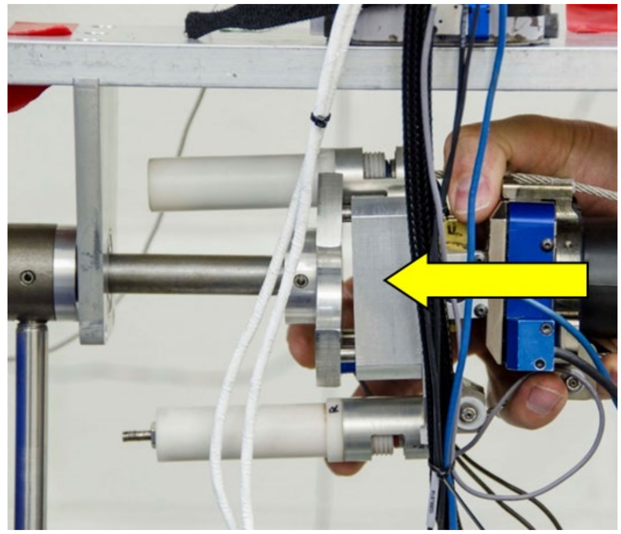


Figure 6-32. Installation of neck assembly into the torsion fixture.

6.7.1.19 Once the locator pins have been placed within the locator holes, install the three #10-24 x 1" SHCS through the end plate assembly into the top plate to secure the neck into the fixture (Figure 6-33).

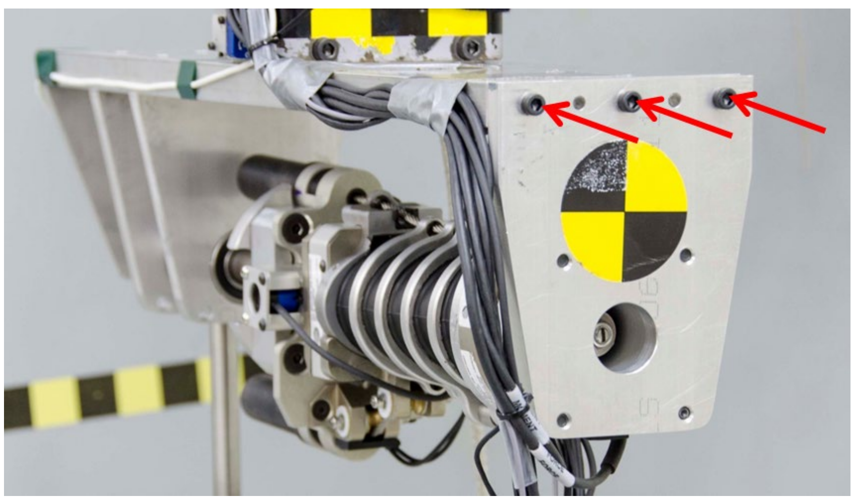


Figure 6-33. Attachment of end place to secure the neck into the torsion fixture.

6.7.1.20 Tape and route the cables so they do not interfere with the neck during the test. Leave at least 30 centimeters (12 inches) 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 6-34). 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.

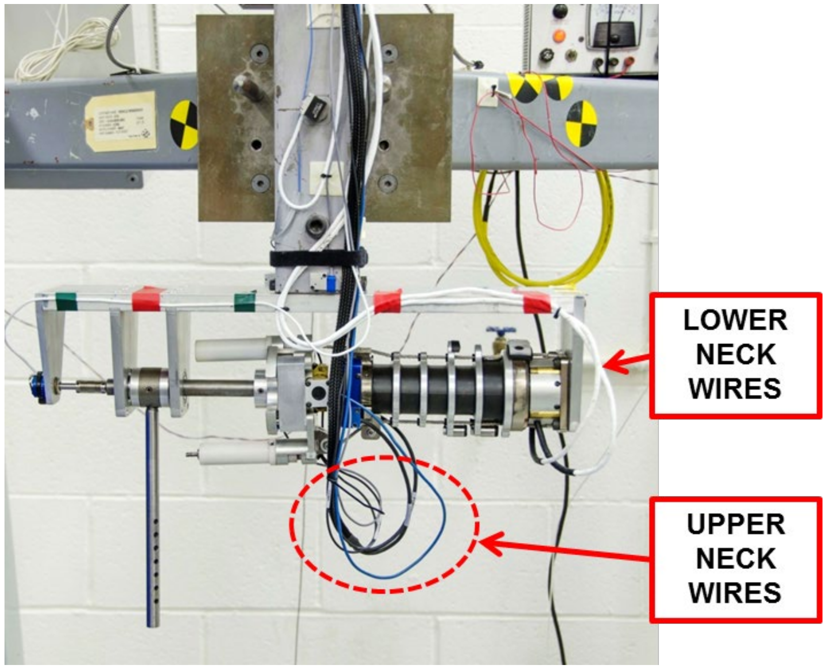


Figure 6-34. Tape wiring to minimize interference during test.

6.7.1.21 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 6-35).

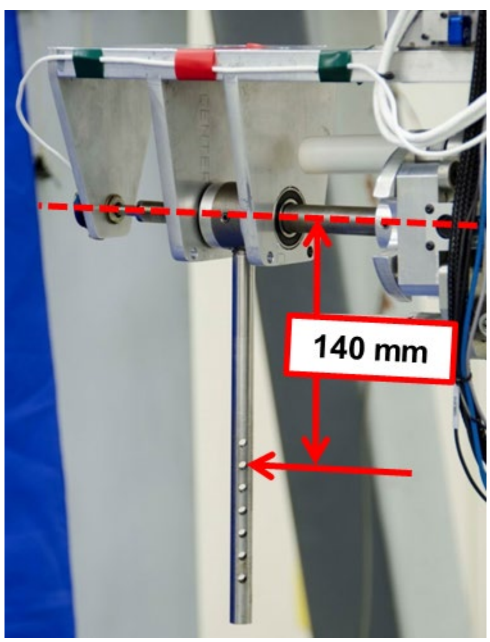


Figure 6-35. Pendulum rod hole position.

6.7.1.22 Record the "as measured (AM)" channels listed in Table 6-1 in accordance with SAE J211-1. Determine the time of first contact between the striker and the honeycomb (or equivalent deceleration device) using a contact switch or some other method such as change in pendulum acceleration; ensure that at least 50 milliseconds of data are recorded before contact.

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

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

6.7.1.25 The procedure and pictures above describe the right neck torsion test (Figure 6-36). To conduct the left neck torsion test (Figure 6-37), 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 6-28). Repeat Steps 6.7.1.22 and 6.7.1.23.

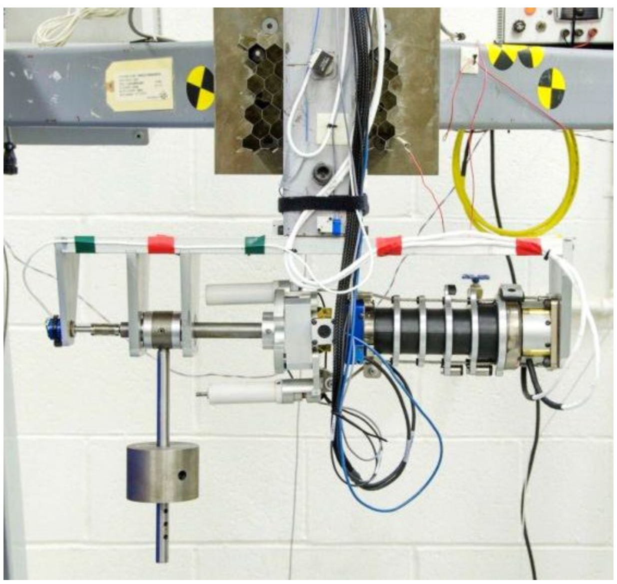


Figure 6-36. Torsion test for twist to the right .

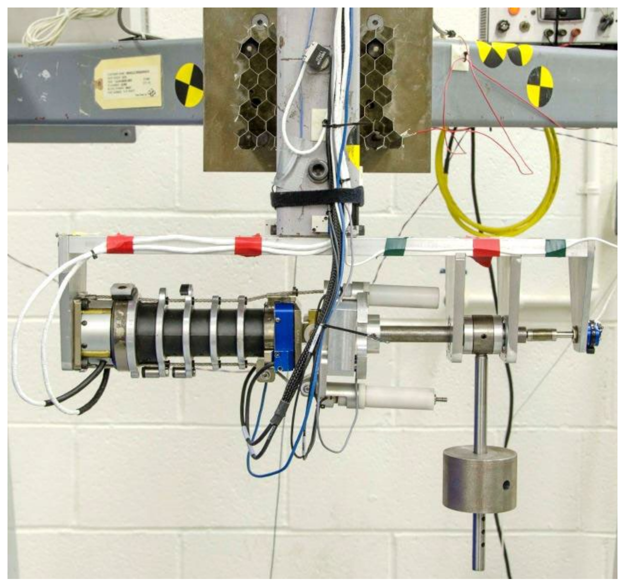


Figure 6-37. Torsion test for twist to the left.

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	D0NECKUP00THMOZB	ZL	AM	NEKU	LC	NWM
Upper Neck Angular Velocity, Z-axis (ARS)	60	D0NECKUP00THAVZD	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 10 ms after T0	m/s	1.71	2.09
Pendulum velocity at 15 ms after T0	m/s	2.57	3.14
Pendulum velocity at 20 ms after T0	m/s	3.46	4.23
Pendulum velocity at 25 ms after T0	m/s	4.27	5.22

Table 6-3. Neck Left Torsion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	4.95	5.05
Peak Upper Neck M_z	N-m	37.3	45.6
Peak Neck Fixture Rotation	deg	-52.7	-43.1
First Peak Upper Neck Angular Velocity ω_z (relative to earth)	deg/s	-1529	-1251

Table 6-4. Neck Right Torsion Response Requirements

Parameter	Units	Specification	
		Min.	**Max.**
Impact Velocity	m/s	4.95	5.05
Peak Upper Neck M_z	N-m	-45.6	-37.3
Peak Neck Fixture Rotation	deg	43.1	52.7
First Peak Upper Neck Angular Velocity ω_z (relative to earth)	deg/s	1251	1529

6.8 Neck Frontal Flexion Test

6.8.1 **Neck Frontal Test Procedure**

6.8.1.1 Inspect the neck assembly for wear, tears, or other damage and for any de-bonding between the rubber pucks and metal plates (Secion 2.4(d)2). Inspect the front and rear springs (including the inserted rubber tubes) within the head assembly for any wear or other damage. Inspect the front and rear OC stops at the bottom of the head also for wear and damage; if necessary take appropriate action to refurbish the parts[7].

6.8.1.2 Soak the head and neck assembly 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.

6.8.1.3 If the head and neck assembly are already attached, skip to the next step. Otherwise, attach the head to the neck assembly by aligning the front neck spring tower with the hole in the base of the skull and sliding the neck towards the head in a direction parallel to the neck column (Figure 6-38). Install four M6 x 1 x 25 mm FHCS at the bottom of the head/neck mounting platform (Figure 6-39) and torque to 12.0 N-m (8.9 ft-lbf).

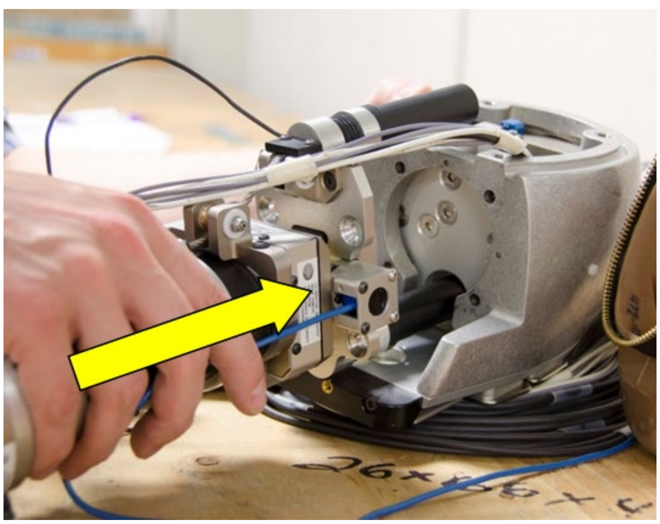


Figure 6-38. Alignment and installation of neck assembly to skull assembly.

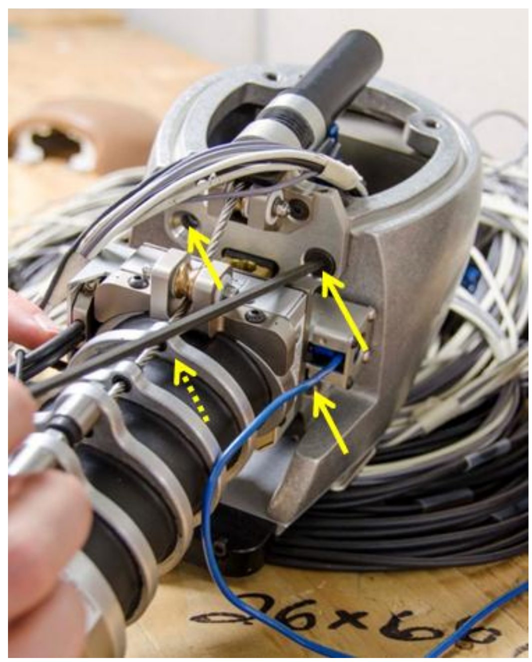


Figure 6-39. FHCS connecting head/neck mounting platform to skull assembly.

[7] See *Head Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

6.8.1.4 If the head skin is already installed, skip to the next step. Otherwise, ensure that the face foam (472-1401) is positioned in the head skin assembly (472-1320). 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 head cap (472-1110) using four M6 x 1 x 16 mm SHCS torqued to 20.3 N-m (15.0 ft-lbf).

6.8.1.5 Install the appropriate size 152.4 mm (6 in) aluminum honeycomb[8] (or equivalent) 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.

6.8.1.6 Mount the bottom of the neck assembly rigidly to the end plate of the head/neck pendulum using four M6 x 1 x 25 mm SHCS torqued to 20.3 N-m (15.0 ft-lbf). 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 longitudinal axis of the head coordinate system pointing in the direction of travel of the pendulum (Figure 6-40).

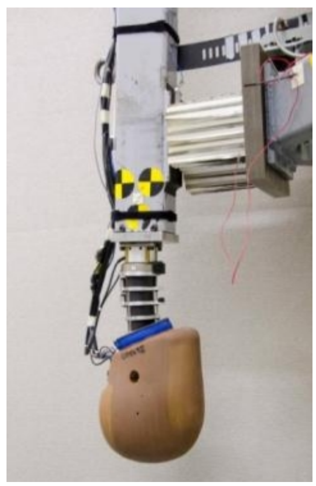


Figure 6-40. Head-neck assembly orientation for neck flexion tests.

6.8.1.7 Record the "as measured (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 (or equivalent deceleration device) using a contact switch or some other method such as change in pendulum acceleration; 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.

[8] As a starting point, use the same aluminum honeycomb configuration used in the Hybrid III 50th neck flexion test.

6.8.2 Neck Frontal Flexion Data Processing

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:

$$Head\ Rotation(t) = \text{time} - \text{history of head rotation (about Y} - \text{axis)}$$

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

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

$$t_0 = \text{first time point for calculation (see 6.6.3)}$$

$$t_f = \text{final time point for collected data}$$

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	D0NECKUP00THFOZA	ZL	AM	NEKU	LC	NWT
Upper Neck Moment, Y-axis	600	D0NECKUP00THMOYB	YL	AM	NEKU	LC	NWM
Head Angular Velocity, Y-axis (ARS)	60	D0HEAD0000THAVYD	YL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00THAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000THANYD	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	1.57	1.92
Pendulum velocity at 16 ms after T0	m/s	3.13	3.82
Pendulum velocity at 24 ms after T0	m/s	4.42	5.41

Table 6-7. Neck Flexion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.95	5.05
Peak Upper Neck M_y	N-m	27.9	34.1
Upper Neck F_z most positive value prior to 40 ms	N	774	946
Peak Head Angular Velocity ω_y (relative to earth)	deg/s	-2172	-1777
Peak Head Rotation (relative to pendulum)	deg	-71.0	-58.1

6.9 Neck Extension Test

6.9.1 <u>Neck Extension Test Procedure</u>

6.9.1.1 Inspect the neck assembly for wear, tears, or other damage and for any de-bonding between the rubber pucks and metal plates. Inspect the front and rear springs (including the inserted rubber tubes) within the head assembly for any wear or other damage. Inspect the front and rear OC stops at the bottom of the head also for wear and damage; if necessary take appropriate action to refurbish the parts[9].

6.9.1.2 Soak the head and neck assembly 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.

6.9.1.3 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 6.8.1.3 and 6.8.1.4 to assemble the head and neck.

6.9.1.4 Install the appropriate 152.4 mm (6 in) size aluminum honeycomb[10] 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.

6.9.1.5 Mount the bottom of the neck assembly rigidly to the end plate of the head/neck pendulum using four M6 x 1 x 25 mm SHCS torqued to 20.3 N-m (15.0 ft-lbf). 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 positive longitudinal axis of the head pointing opposite the direction of travel of the pendulum (Figure 6-41).

---

[9] See *Neck Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

[10] As a starting point, use the same aluminum honeycomb configuration used in the Hybrid III neck extension test.

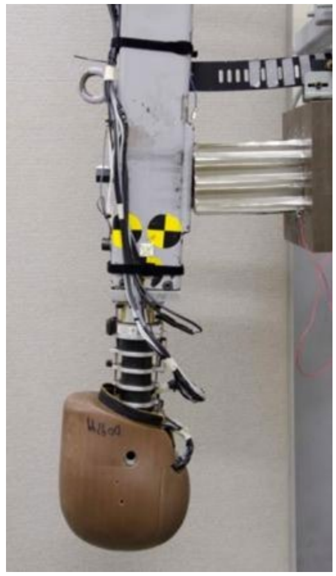


Figure 6-41. Mounting the head-neck assembly for neck extension tests.

6.9.1.6 Record the “as measured (AM)” channels listed in Table 6-8 in accordance with SAE J211. Determine the time of first contact between the striker and the honeycomb (or equivalent deceleration device) using a contact switch or some other method such as change in pendulum acceleration; ensure that at least 50 milliseconds of data are recorded before contact.

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

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

6.9.2 <u>Neck Extension Data Processing</u>

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:

$$Head\ Rotation(t) = \text{time} - \text{history of head rotation (about Y} - \text{axis)}$$

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

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

$$t_0 = \text{first time point for calculation (see 6.6.3)}$$

$$t_f = \text{final time point for collected data}$$

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	D0NECKUP00THFOZA	ZL	AM	NEKU	LC	NWT
Upper Neck Moment, Y-axis	600	D0NECKUP00THMOYB	YL	AM	NEKU	LC	NWM
Head Angular Velocity, Y-axis (ARS)	60	D0HEAD0000THAVYD	YL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00THAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000THANYD	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 10 ms after T0	m/s	1.74	2.12
Pendulum velocity at 20 ms after T0	m/s	3.30	4.04
Pendulum velocity at 30 ms after T0	m/s	4.53	5.54

Table 6-10. Neck Extension Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.95	5.05
Peak Upper Neck M_y	N-m	-25.3	-20.7
Peak Upper Neck F_z	N	-3210	-2626
Peak Head Angular Velocity ω_y (relative to earth)	deg/s	1855	2267
Peak Head Rotation (relative to pendulum)	deg	58.5	71.5

6.10 Neck Lateral Flexion Test

6.10.1 **Neck Lateral Flexion Test Procedure**

6.10.1.1 Inspect the neck assembly for wear, tears, or other damage and for any de-bonding between the rubber pucks and metal plates. Inspect the front and rear springs (including the inserted rubber tubes) within the head assembly for any wear or other damage. Inspect the front and rear OC stops at the bottom of the head also for wear and damage; if necessary take appropriate action to refurbish the parts[11].

6.10.1.2 Soak the head and neck assembly 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.

6.10.1.3 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 6.8.1.3 and 6.8.1.4 to assemble the head and neck.

6.10.1.4 Install the appropriate 76.2 mm (3 in) size aluminum honeycomb[12] 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.

6.10.1.5 Mount the bottom of the neck assembly rigidly to the end plate of the head/neck pendulum using four M6 x 1 x 25 mm SHCS torqued to 20.3 N-m (15.0 ft-lbf). For the lateral flexion test, the neck is placed such that the midsagittal plane of the head is vertical and anterior-posterior direction of the assembly is pointing 90 ± 0.5° from the direction of travel of the pendulum. The neck is tested in both left and right lateral modes (Figure 6-42 and Figure 6-43).

---

[11] See *Neck Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

[12] As a starting point, use the same aluminum honeycomb configuration used in the ES-2re lateral flexion neck test.

Neck Lateral Flexion, Left

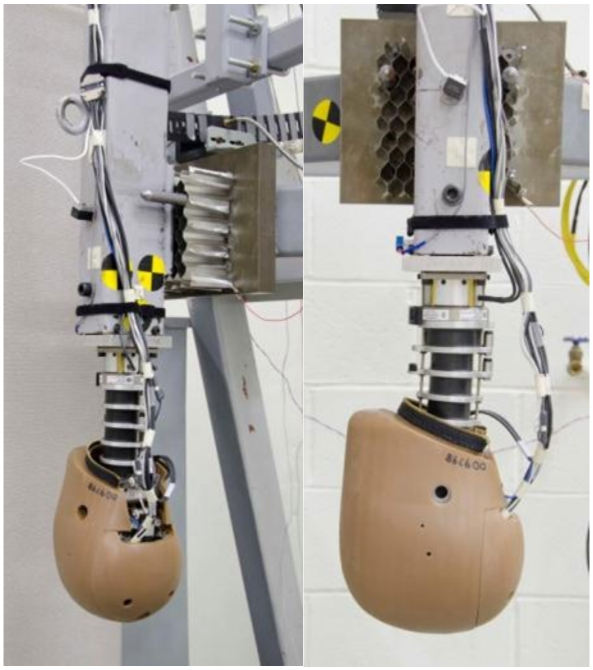


Figure 6-42. Left neck lateral flexion setup.

Neck Lateral Flexion, Right

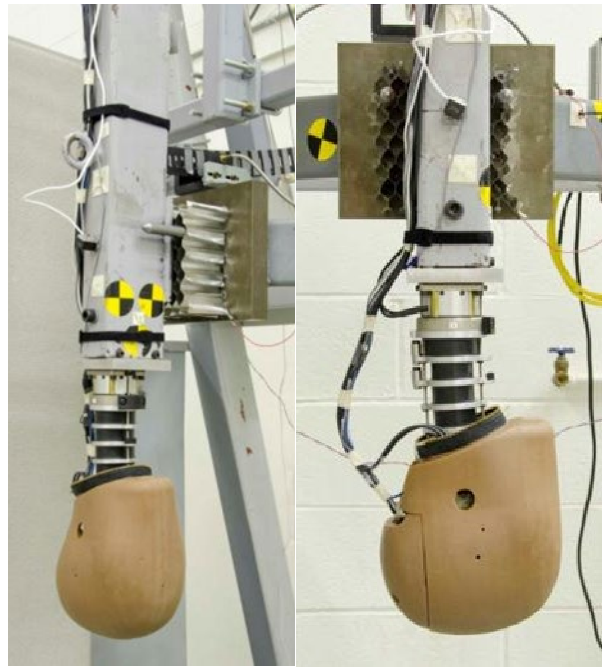


Figure 6-43. Right neck lateral flexion setup.

6.10.1.6 Record the "as measured (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 (or equivalent deceleration device) using a contact switch or some other method such as change in pendulum acceleration; 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:

$$Head\ Rotation\ (t) = \text{time} - \text{history of Head Rotation (about Y} - \text{axis)}$$

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

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

$$t_0 = \text{first time point for calculation (see 6.6.3)}$$

$$t_f = \text{final time point for collected data}$$

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	D0NECKUP00THMOXB	XL	AM	NEKU	LC	NWM
Head Angular Velocity, X-axis (ARS)	60	D0HEAD0000THAVXD	XL	AM	HDCG	AV	DPS
Pendulum Angular Velocity (ARS)	60	T0SENSMI00THAVYD	YG	AM	PEND	AV	DPS
Head Rotation (relative to pendulum)	N/A	D0HEAD0000THANXD	XL	CM	HDCG	PP	DEG

6.10.3 Neck Lateral Flexion Test Performance Specification

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 4 ms after T0	m/s	1.06	1.30
Pendulum velocity at 8 ms after T0	m/s	2.09	2.55
Pendulum velocity at 12 ms after T0	m/s	3.16	3.86

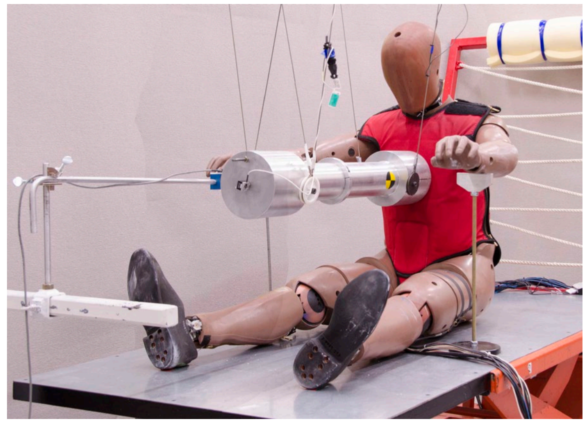
Table 6-13. Neck Left Lateral Flexion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Upper Neck M_x first peak after 40.0 ms	N-m	44.8	54.7
First Peak Head Angular Velocity ω_x (relative to earth)	deg/s	-1498	-1226
Peak Head Rotation (relative to pendulum)	deg	-45.9	-37.6

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 first peak after 40.0 ms	N-m	-54.7	-44.8
First Peak Head Angular Velocity ω_x (relative to earth)	deg/s	1226	1498
Peak Head Rotation (relative to pendulum)	deg	37.6	45.9

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 23.36 kg rigid impactor at 4.30 m/s.

7.2 Materials

- ☐ Fully-assembled THOR-50M ATD
- ☐ Impactor 23.36 ± 0.02 kg (51.50 ± 0.05 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables, as specified in Part 572[13]. The test probe is a 152.40 ± 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 (0.5 ± 0.01 in).

7.3 Instrumentation

- ☐ Instrumentation to measure impact force (accelerometer on impactor or load cell / accelerometer combination if using a linear impactor)
- ☐ Instrumentation to measure the impact velocity
- ☐ A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T6) 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
- ☐ 3-D IR-TRACC assemblies in the upper left (472-3550) and upper right (472-3560) thorax, installed as shown in 472-3000.

[13] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.36(a).

7.4 Pre-Test Procedures

7.4.1 Remove the jacket, if installed, and inspect the ribcage, bib, and jacket for wear, tears, or other damage. Prior to assembly, the profiles of the ribs should be examined to determine if they have been permanently deformed; if necessary take appropriate action to refurbish the part[14].

7.4.2 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.

7.4.3 Set the lower thoracic spine (LTS) pitch change joint to the **slouched** position (see Section 3.1).

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

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

7.5 Test Procedure

7.5.1 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward parallel to the midsagittal plane. The midsagittal plane shall be vertical within ±1 degree (Figure 7-1).

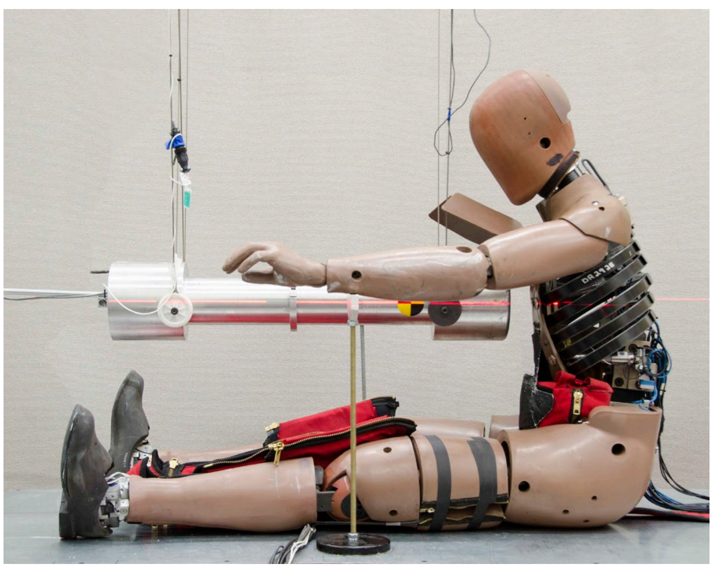


Figure 7-1. Initial setup for the upper thorax qualification test.

[14] See *Thorax Assembly- Inspection and Repairs* and *Jacket and Clothing Assembly- Inspection and Repairs* Sections of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

7.5.2 If the jacket is installed, unzip the left and right shoulder and left and right torso zippers to expose the rib cage. If the jacket is not installed, position the crotch strap in place under the pelvis so that later jacket installation does not change torso position.

7.5.3 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 7-1). If this cannot be achieved, or the torso cannot be stabilized in the following two steps, repeat the Arm and Shoulder Joint Torque Settings procedure in Section 3.3 before proceeding.

7.5.4 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5° in the X-axis and 15 ± 1° in the Y-axis.

7.5.5 Position the thorax so that the T6 tilt sensor (SA572-S44) reads -4 ± 1° (forward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

7.5.6 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 attachment bolts of the left and right upper thorax IR-TRACC assemblies (Figure 7-2).

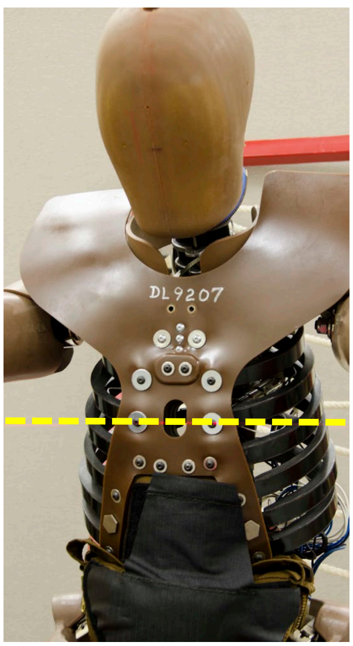


Figure 7-2. Vertical alignment of impact location.

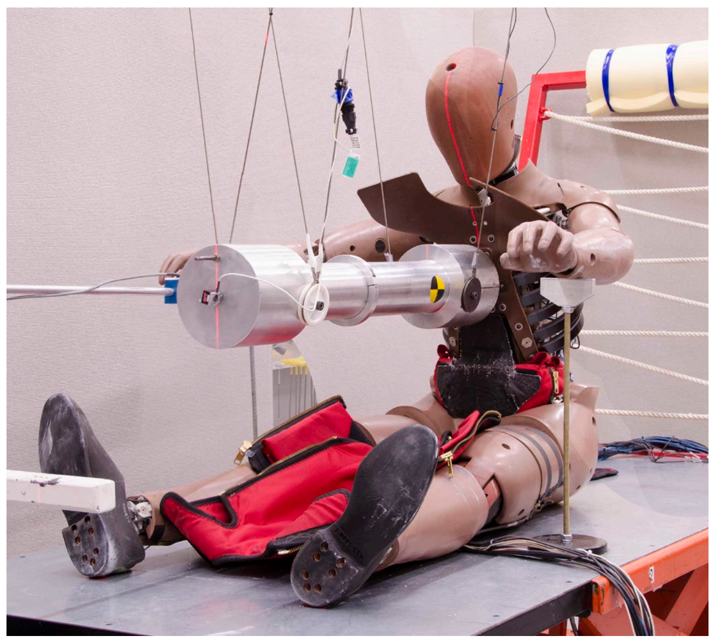


Figure 7-3. Lateral alignment of impact location.

7.5.7 Align the vertical centerline of the probe with the midsagittal plane of the dummy (Figure 7-3). The midsagittal plane can be visualized using the Nasion detent on the head skin, the front neck cable, the midpoint between the sternum-to-bib attachment bolts, and the pelvis flesh at the pubic symphysis.

7.5.8 Unzip the top shoulder portion of the jacket to allow the shoulder alignment marks to be viewed (Figure 7-4). Manipulate the upper arm in the anterior-posterior orientation until the interface between the rear ROM buffer (472-3816) and shoulder support (472-3814) is aligned with the scribe mark on the spring housing cover. If this cannot be achieved, repeat the procedures in Section 3.3 before proceeding.

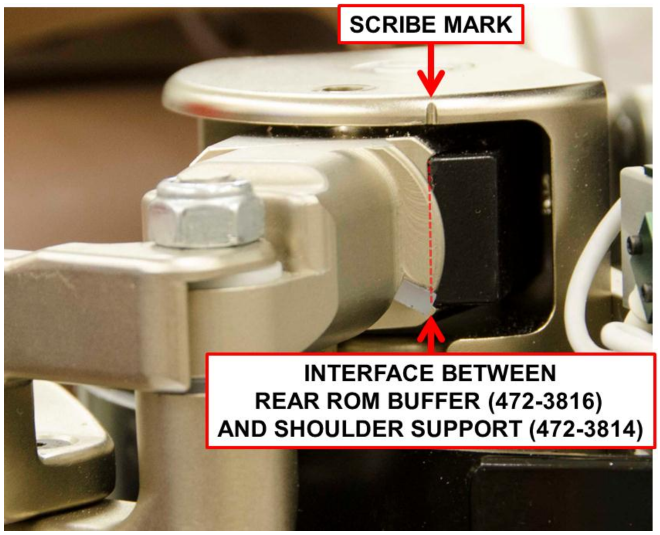


Figure 7-4. Align scribe mark to interface between rear ROM buffer and shoulder support.

7.5.9 Carefully reinstall the dummy's jacket by zipping the sides and shoulders of the jacket.

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

7.5.11 Record the "as measured (AM)" channels listed in Table 7-2 in accordance with SAE J211-1.

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

Table 7-1. Upper Thorax Qualification Setup Parameters

Parameter	Setting
Lower Thoracic Spine (LTS) Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T6	X = 0 ± 0.5º; Y = -4 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 15 ± 1º
Wait Time Between Tests	At Least 30 Minutes

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

7.5.14 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 IR-TRACCs and associated potentiometer channels, perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 7-2) by subtracting the average value of the data samples over the period between (.050 s) and (.010 s) prior to contact.

7.6.2 Filter channels based on the CFC filter classes listed in Table 7-2. Do not filter the raw IR-TRACC voltage, as this will be filtered at CFC 180 after it is linearized and scaled during Step 7.6.4.

7.6.3 Calculate time-history of impact force at the contact interface (see Section 2.5).

7.6.4 Calculate the upper thorax X-axis, Y-axis, and Z-axis deflections in the *local spine coordinate system* (upper thoracic spine (UTS)) (see the *THOR-50M IR-TRACC Processing* Section in the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)").

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

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

Where:

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

$$D_X = \text{time} - \text{history of upper thorax deflection (L or R), X} - \text{axis}$$

$$D_Y = \text{time} - \text{history of upper thorax deflection (L or R), Y} - \text{axis}$$

$$D_Z = \text{time} - \text{history of upper thorax deflection (L or R), Z} - \text{axis}$$

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

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

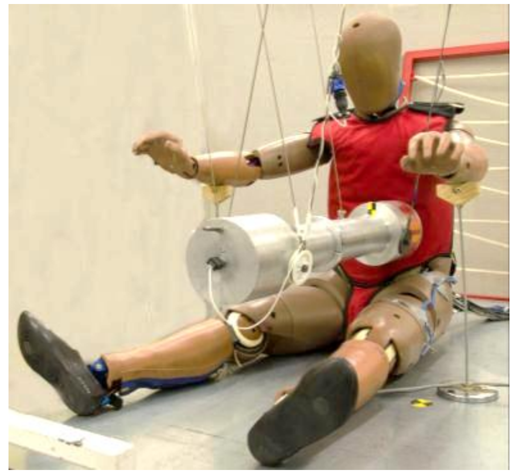
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Upper left IR-TRACC tube	N/A	D0CHSTLEUPTHVO0C	NA	AM	CHLU	DS	VOL
Upper left X-axis rotational potentiometer	180	D0CHSTLEUPTHANXC	XL	AM	CHLU	AD	DEG
Upper left Y-axis rotational potentiometer	180	D0CHSTLEUPTHANYC	YL	AM	CHLU	AD	DEG
Upper left Z-axis rotational potentiometer	180	D0CHSTLEUPTHANZC	ZL	AM	CHLU	AD	DEG
Upper right IR-TRACC tube	N/A	D0CHSTRIUPTHVO0C	NA	AM	CHRU	DS	VOL
Upper right X-axis rotational potentiometer	180	D0CHSTRIUPTHANXC	XL	AM	CHRU	AD	DEG
Upper right Y-axis rotational potentiometer	180	D0CHSTRIUPTHANYC	YL	AM	CHRU	AD	DEG
Upper right Z-axis rotational potentiometer	180	D0CHSTRIUPTHANZC	ZL	AM	CHRU	AD	DEG
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Upper left X-axis deflection WRT UTS	N/A	D0CHSTLEUPTHDSXC	XL	CM	CHLU	PP	MM
Upper left Y-axis deflection WRT UTS	N/A	D0CHSTLEUPTHDSYC	XL	CM	CHLU	PP	MM
Upper left Z-axis deflection WRT UTS	N/A	D0CHSTLEUPTHDSZC	XL	CM	CHLU	PP	MM
Upper right X-axis deflection WRT UTS	N/A	D0CHSTRIUPTHDSXC	XL	CM	CHRU	PP	MM
Upper right Y-axis deflection WRT UTS	N/A	D0CHSTRIUPTHDSYC	XL	CM	CHRU	PP	MM
Upper right Z-axis deflection WRT UTS	N/A	D0CHSTRIUPTHDSZC	XL	CM	CHRU	PP	MM
Upper left resultant deflection WRT UTS	N/A	D0CHSTLEUPTHDSRC	NA	CM	CHLU	PP	MM
Upper right resultant deflection WRT UTS	N/A	D0CHSTRIUPTHDSRC	NA	CM	CHRU	PP	MM

7.7 Performance Specifications

Table 7-3. Upper Thorax Qualification Response Requirements

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Units</th><th colspan="2">Specification</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>Impact Velocity</td><td>m/s</td><td>4.25</td><td>4.35</td></tr>
<tr><td>Peak Probe Force</td><td>N</td><td></td><td>3039</td></tr>
<tr><td>Peak Upper Left Resultant Deflection</td><td>mm</td><td rowspan="2">48.3</td><td rowspan="2">59.0</td></tr>
<tr><td>Peak Upper Right Resultant Deflection</td><td>mm</td></tr>
<tr><td>Difference Between Peak Left & Right Resultant Deflections</td><td>mm</td><td></td><td>< 5.0</td></tr>
<tr><td>Force at Left Peak Resultant Deflection</td><td rowspan="2">N</td><td rowspan="2">2409</td><td rowspan="2">2944</td></tr>
<tr><td>Force at Right Peak Resultant Deflection</td></tr>
</table>

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 23.36 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-50M ATD
- ☐ Impactor 23.36 ± 0.02 kg (51.5 ± 0.05 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables, as specified in Part 572[15]. The test probe is a 152.4 ± 0.25 mm (6.0 ± 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 (0.5 ± 0.01 in).

8.3 Instrumentation

- ☐ Instrumentation to measure impact force (accelerometer on impactor or load cell / accelerometer combination if using a linear impactor)
- ☐ Instrumentation to measure the impact velocity
- ☐ A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T6) 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
- ☐ 3-D IR-TRACC assemblies in the lower left (472-3580) and lower right (472-3570) thorax, installed as shown in 472-3000.

---

[15] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.36(a).

8.4 Pre-Test Procedures

8.4.1 Remove the jacket, if installed, and inspect the ribcage, bib, and jacket for wear, tears, or other damage. Prior to assembly, the profiles of the ribs should be examined to determine if they have been permanently deformed and if necessary take appropriate action to replace or refurbish the part[16].

8.4.2 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.

8.4.3 Set the lower thoracic spine (LTS) pitch change joint to the **slouched** position (see Section 3.1).

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

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

8.5 Test Procedure

8.5.1 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward parallel to the midsagittal plane. The midsagittal plane shall be vertical within ± 1 degree (Figure 8-1).

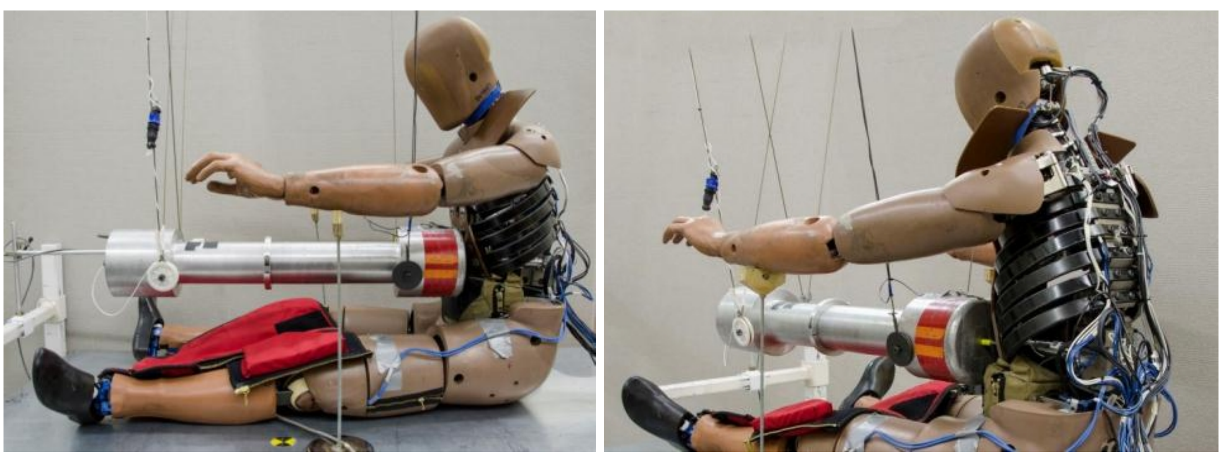


Figure 8-1. Initial setup for the lower thorax qualification test.

8.5.2 If the jacket is installed, unzip the left and right shoulder and left and right torso zippers to expose the rib cage. If the jacket is not installed, position the crotch strap in place under the pelvis so that later jacket installation does not affect positioning.

---

[16] See *Thorax Assembly- Inspection and Repairs* and *Jacket and Clothing Assembly- Inspection and Repairs* Sections of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

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). If this cannot be achieved, or the torso cannot be stabilized in the following two steps, repeat the Arm and Shoulder Joint Torque Settings procedure in Section 3.3 before proceeding.

8.5.4 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5° in the X-axis and 15 ± 1° in the Y-axis.

8.5.5 Position the thorax so that the T6 tilt sensor (SA572-S44) reads -4 ± 1° (forward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

8.5.6 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 IR-TRACC assembly (Figure 8-2).

8.5.7 Align the impactor face with the center of the left or right lower thorax IR-TRACC bolt. A removable pointer (threaded into the centerline of the pendulum with approximately 30mm protruding) will aid this process (Figure 8-2). Remove the pointer tool when this step has been completed.

Figure 8-2. Alignment of impact location using pointer tool (shown in inset).

8.5.8 Unzip the top shoulder portion of the jacket to allow the shoulder alignment marks to be viewed (Figure 8-3). Manipulate the upper arm in the anterior-posterior orientation until the interface between the rear ROM buffer (472-3816) and shoulder support (472-3814) is aligned with the scribe mark on the spring housing cover. If this cannot be achieved, repeat the procedures in Section 3.3 before proceeding.

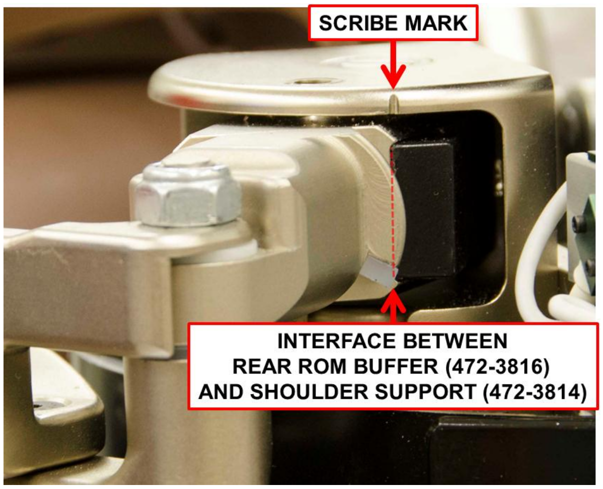


Figure 8-3. Align scribe mark to interface between rear ROM buffer and shoulder support.

8.5.9 Carefully reinstall the dummy's jacket by zipping the sides and shoulders of the jacket.

8.5.10 Align the frontal (coronal) plane of the dummy perpendicular to the impact direction. A right-angled guide placed behind the dummy's pelvis and aligned perpendicular to the line of impact may facilitate the process (Figure 8-4).

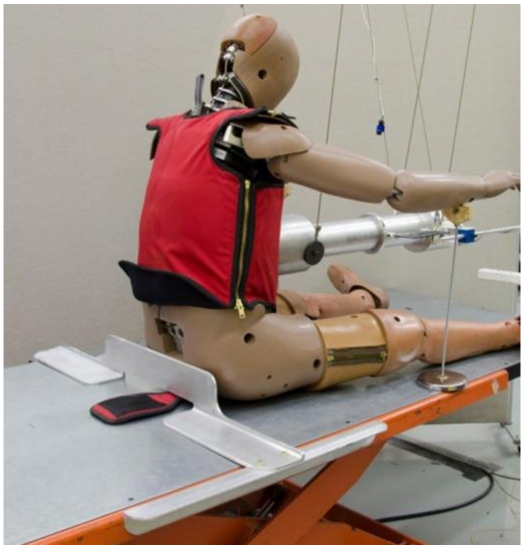


Figure 8-4. Alignment of the frontal plane perpendicular to the impact direction using a right-angled guide.

8.5.11 Remove the right-angled guide, if used.

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

8.5.13 Record the "as measured (AM)" channels listed in Table 8-2 (for left impacts) or

8.5.14 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
Lower Thoracic Spine (LTS) Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T6	X = 0 ± 0.5º; Y = -4 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 15 ± 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 IR-TRACCs and associated potentiometer channels, perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 8-2) by subtracting the average value of the data samples over the period between (.050 s) and (.010 s) prior to contact.

8.6.2 Filter channels based on the CFC filter classes listed in Table 8-2 (for left impacts) or Table 8-3 (for right impacts). Do not filter the raw IR-TRACC voltage, as this will be filtered at CFC 180 after it is linearized and scaled during Step 8.6.4

8.6.3 Calculate time-history of impact force at the contact interface (see Section 2.5).

8.6.4 Calculate the lower left and lower right X-axis, Y-axis, and Z-axis thoracic deflections in the *local spine coordinate system* (lower thoracic spine (LTS)) (see the *THOR-50M IR-TRACC Processing* Section in the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)").

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

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

Where:

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

$$D_X = \text{time} - \text{history of lower thorax deflection (L or R), X} - \text{axis}$$

$$D_Y = \text{time} - \text{history of lower thorax deflection (L or R), Y} - \text{axis}$$

$$D_Z = \text{time} - \text{history of lower thorax deflection (L or R), Z} - \text{axis}$$

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	D0CHSTLELOTHVO0C	NA	AM	CHLL	DS	VOL
Lower left X-axis rotational potentiometer	180	D0CHSTLELOTHANXC	XL	AM	CHLL	AD	DEG
Lower left Y-axis rotational potentiometer	180	D0CHSTLELOTHANYC	YL	AM	CHLL	AD	DEG
Lower left Z-axis rotational potentiometer	180	D0CHSTLELOTHANZC	ZL	AM	CHLL	AD	DEG
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Lower left X-axis deflection WRT LTS	N/A	D0CHSTLELOTHDSXC	XL	CM	CHLL	PP	MM
Lower left Y-axis deflection WRT LTS	N/A	D0CHSTLELOTHDSYC	YL	CM	CHLL	PP	MM
Lower left Z-axis deflection WRT LTS	N/A	D0CHSTLELOTHDSZC	ZL	CM	CHLL	PP	MM
Lower left resultant deflection WRT LTS	N/A	D0CHSTLELOTHDSRC	NA	CM	CHLL	PP	MM

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

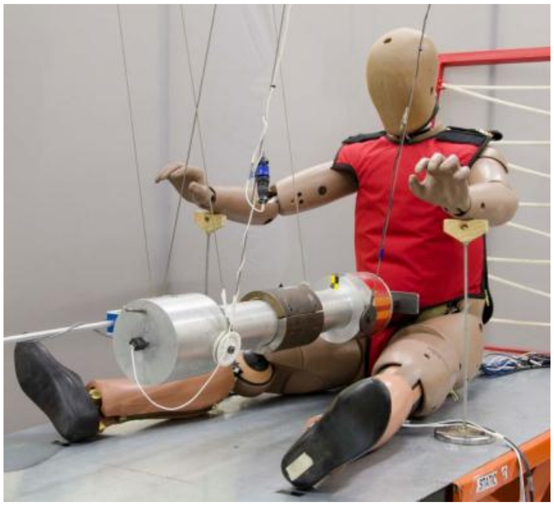
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Lower right IR-TRACC tube	N/A	D0CHSTRILOTHVO0C	NA	AM	CHRL	DS	VOL
Lower right X-axis rotational potentiometer	180	D0CHSTRILOTHANXC	XL	AM	CHRL	AD	DEG
Lower right Y-axis rotational potentiometer	180	D0CHSTRILOTHANYC	YL	AM	CHRL	AD	DEG
Lower right Z-axis rotational potentiometer	180	D0CHSTRILOTHANZC	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	D0CHSTRILOTHDSXC	XL	CM	CHRL	PP	MM
Lower right Y-axis deflection WRT LTS	N/A	D0CHSTRILOTHDSYC	YL	CM	CHRL	PP	MM
Lower right Z-axis deflection WRT LTS	N/A	D0CHSTRILOTHDSZC	ZL	CM	CHRL	PP	MM
Lower right resultant deflection WRT LTS	N/A	D0CHSTRILOTHDSRC	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	3136	3832
Left or Right Resultant Deflection at Peak Force	mm	45.8	56.0

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 32.00 kg rigid impactor (utilizing a horizontally-oriented rigid bar impactor face) at 3.30 m/s.

9.2 Materials

- ☐ Fully assembled THOR-50M ATD
- ☐ Impactor 32.00 ± 0.02 kg (70.50 ± 0.05 lb) in mass, including rectangular impact face, instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables. The standard 23.36 kg, 152.4 ± 0.25 mm (6.0 ± 0.01 in) diameter, rigid cylinder test probe[17] can be used, with the 177.8 x 50.8 mm rectangular impact face attached (Figure 9-1); additional mass must be added to achieve the 32.00 kg mass requirement. The rectangular impact surface attached to the test probe (DL472-3000) has a flat, right angle face with an edge radius of 6.0 ± 0.3 mm (0.24 ± 0.01 in).

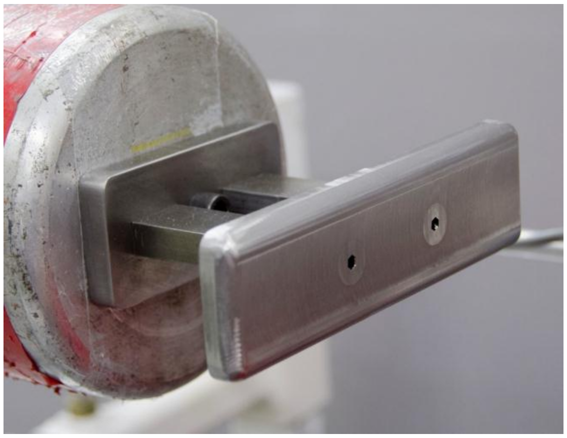


Figure 9-1. Rectangular impact face used in lower abdomen tests.

9.3 Instrumentation

- ☐ Instrumentation to measure impact force (accelerometer on impactor or load cell / accelerometer combination if using a linear impactor)
- ☐ Instrumentation to measure the impact velocity

---

[17] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.36(a).

- ☐ A dual-axis tilt sensor (SA572-S44) on the thoracic spine (T6) 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
- ☐ 3-D IR-TRACC assemblies in the lower left (472-4730-1) and lower right (472-4730-2) abdomen, installed as shown in 472-4700.

9.4 Pre-Test Procedures

9.4.1 If the jacket is installed, unzip the left and right shoulder and left and right torso zippers to expose the rib cage and abdomen inserts. Inspect the lower abdomen bag (472-4763) for wear, tears, or other damage. Unzip the lower abdomen bag and inspect the abdomen foam inserts (472-4764 and 472-4765) for damage. Prior to assembly, the abdomen should also be inspected for any permanent set and if necessary take appropriate action to replace or refurbish the part[18].

9.4.2 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.

9.4.3 Set the lower thoracic spine (LTS) pitch change joint to the **slouched** position (see Section 3.1).

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

9.5 Test Procedure

9.5.1 Seat the dummy on a horizontal surface (±0.5°) with no back support, with all limbs extended horizontally and forward parallel to the midsagittal plane. The midsagittal plane shall be vertical within ±1 degree (Figure 9-2).

---

[18] See *Lower Absdmen Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

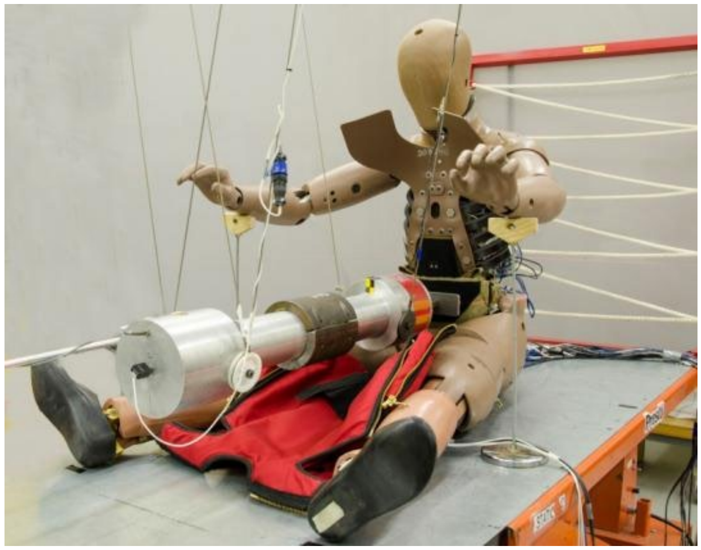


Figure 9-2. Initial setup for lower abdomen impact test.

9.5.2 Place the crotch strap portion of the jacket under the pelvis so that later jacket installation does not affect positioning

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). If this cannot be achieved, or the torso cannot be stabilized in the following two steps, repeat the Arm and Shoulder Joint Torque Settings procedure in Section 3.3 before proceeding.

9.5.4 Position the pelvis so that the pelvis tilt sensor (SA572-S44) reads 10 ± 1° (rearward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

9.5.5 Position the thorax so that the T6 tilt sensor (SA572-S44) reads -4 ± 1° (forward tilt about the Y-axis) and 0 ± 0.5° laterally (about the X-axis).

9.5.6 Align the vertical centerline of the probe with the midsagittal plane of the ATD (Figure 9-3). The midsagittal plane can be visualized using the Nasion detent on the head skin, the front neck cable, the midpoint between the sternum-to-bib attachment bolts, and the pelvis flesh at the pubic symphysis.

Figure 9-3. Lateral alignment of impact location.

9.5.7 Using a straight edge with an inclinometer or using a laser level, ensure that the centers of the anterior attachment nuts of the abdomen IR-TRACC measurement assemblies are in the horizontal (±1°) plane (Figure 9-4). If not, gently manipulate the abdomen bag and re-measure until a horizontal (±1°) measurement is achieved. Confirm that the tilt sensor measurements from step 9.5.4 and 9.5.5 are retained.

Figure 9-4. Horizontal alignment of IR-TRACC attachment nuts.

Figure 9-5. Vertical alignment of impact location.

9.5.8 Adjust the table height or impactor height so that the vertical center of the impact face is aligned with the anterior attachment nuts of the abdomen IR-TRACC measurement assemblies (Figure 9-5).

9.5.9 Position the impact face adjacent to the abdomen. Measure the distance from the center of the anterior attachment nut of the left abdomen IR-TRACC measurement assembly to the nearest point on the impactor face (Figure 9-6). Repeat this measurement on the right side. The difference between these two distances must be less than 5 mm. If the difference is greater than 5 mm, ensure that the midsagittal plane of the dummy is aligned with the pendulum, and if necessary gently manipulate the abdomen bag and re-measure until the measurement difference is less than 5 mm.

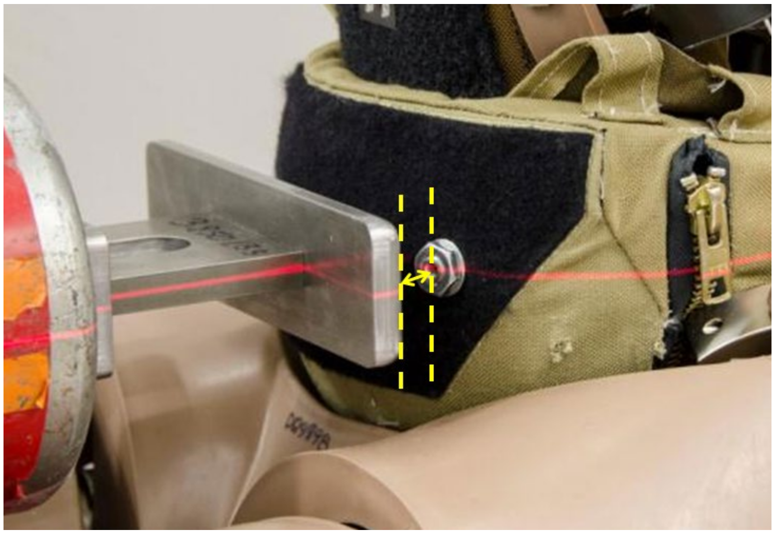


Figure 9-6. Measurement of distance from IR-TRACC attachment nuts to impactor.

9.5.10 Manipulate the upper arm in the anterior-posterior orientation until the interface between the rear ROM buffer (472-3816) and shoulder support (472-3814) is aligned with the scribe mark on the spring housing cover (Figure 9-7). If this cannot be achieved, repeat the procedures in Section 3.3 before proceeding.

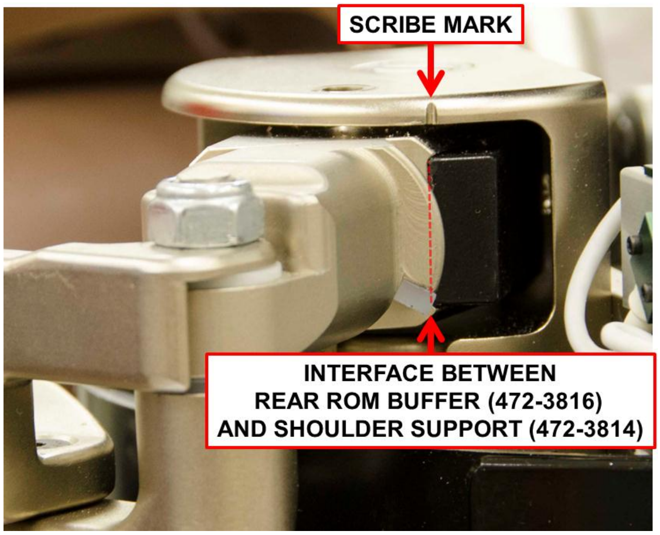


Figure 9-7. Align scribe mark to interface between rear ROM buffer and shoulder support.

9.5.11 Replace the Upper And Lower Abdomen Velcro Cover (472-4763-8) on the front of the abdomen and carefully reinstall the dummy's jacket by zipping the sides and shoulders of the jacket.

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

9.5.13 Record the "as measured (AM)" channels listed in Table 9-2 in accordance with SAE J211-1.

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

Table 9-1. Lower Abdomen Impact Test Setup Parameters

Parameter	Setting
Lower Thoracic Spine (LTS) Pitch Change Setting	Slouched
Neck Pitch Change Setting	Neutral
Tilt Sensor Reading: T6	X = 0 ± 0.5º; Y = -4 ± 1º
Tilt Sensor Reading: Pelvis	X = 0 ± 0.5º; Y = 10 ± 1º
Wait Time Between Tests	At Least 30 Minutes

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

9.5.16 Conduct the test at an impact velocity of 3.30 ± 0.05 m/s.

9.6 Data Processing

9.6.1 With the exception of IR-TRACCs and associated potentiometer channels, perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 9-2) by subtracting the average value of the data samples over the period between (.050 s) and (.010 s) prior to contact.

9.6.2 Filter channels based on the CFC filter classes listed in Table 9-2. Do not filter the raw IR-TRACC voltage, as this will be filtered at CFC 180 after it is linearized and scaled during Step 9.6.4.

9.6.3 Calculate time-history of impact force at the contact interface (see Section 2.5).

9.6.4 Calculate the lower left and lower right X-axis abdomen deflections in the *local spine coordinate system* (lumbar spine (LS)) (see the *THOR-50M IR-TRACC Processing* Section in the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)").

9.6.5 Calculate the absolute value of the difference between the peak left and right X-axis deflections in the *local coordinate system* (lumbar spine (LS)).

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

Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Lower left abdomen IR-TRACC tube	N/A	D0ABDOLE00THVO0C	NA	AM	ABDL	DS	VOL
Lower left abdomen Y-axis rotational potentiometer	180	D0ABDOLE00THANYC	YL	AM	ABDL	AD	DEG
Lower left abdomen Z-axis rotational potentiometer	180	D0ABDOLE00THANZC	ZL	AM	ABDL	AD	DEG
Lower right abdomen IR-TRACC tube	N/A	D0ABDORI00THVO0C	NA	AM	ABDR	DS	VOL
Lower right abdomen Y-axis rotational potentiometer	180	D0ABDORI00THANYC	YL	AM	ABDR	AD	DEG
Lower right abdomen Z-axis rotational potentiometer	180	D0ABDORI00THANZC	ZL	AM	ABDR	AD	DEG
Pendulum Accelerometer	180	T0SENSMI0000ACXC	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXC	XG	CM	PEND	PP	NWT
Lower left abdomen X-axis deflection WRT LS	N/A	D0ABDOLE00THDSXC	XL	CM	ABDL	PP	MM
Lower right abdomen X-axis deflection WRT LS	N/A	D0ABDORI00THDSXC	XL	CM	ABDR	PP	MM

9.7 Performance Specifications

Table 9-3. Abdomen Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.25	3.35
Peak Probe Force	N	2626	3210
Lower Left Abdomen X-axis Deflection at Time of Peak Force	mm	-91.3	-74.7
Lower Right Abdomen X-axis Deflection at Time of Peak Force			
Difference Between Peak Left & Right X-axis Deflections	mm		< 8.0

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 5.00 kg rigid impactor 2.60 m/s.

10.2 Materials

☐ Fully-assembled THOR-50M ATD

☐ Impactor 5.00 ± 0.02 kg (11.00 ± 0.05 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables, as defined in Part 572[19]. The test probe is a 76.2 ± 0.2 mm (3.00 ± 0.01 in) diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 0.5 ± 0.2 mm (0.02 ± 0.01 in).

10.3 Instrumentation

☐ Instrumentation to measure impact force (accelerometer on impactor or load cell / accelerometer combination if using a linear impactor)

☐ Acetabulum load cell

☐ Femur (Fz) load cell

☐ Instrumentation to measure the impact velocity

10.4 Pre-Test Procedures

10.4.1 Inspect the knee skin, knee insert and femur compression element[20] for wear, tears, or other damage. Prior to assembly, the femur compression element should also be inspected for any significant permanent set. A small radial bulge is usual after the femur compression element has been in service for some time; if necessary take appropriate action to refurbish the part[21].

[19] Code of Federal Regulations, Anthropomorphic Test Devices, Title 49, §572.36(b)

[20] Part no. 472-5206

[21] See *Upper Leg Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

10.4.2 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.

10.4.3 Set the lower thoracic spine (LTS) pitch change joint to the **slouched** position (see Section 3.1).

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

10.4.5 Position the lower leg as shown in Figure 10-1**.** Adjust the torque of the modified M10 shoulder bolt (472-5302) at the knee joint such that the lower leg remains in this position under its own mass but falls once any additional mass or force is added.

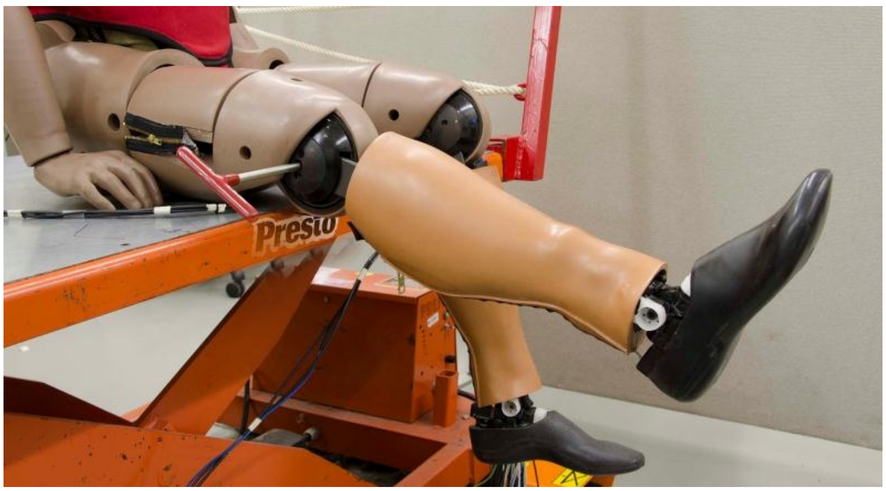


Figure 10-1. Knee orientation for setting joint torque to 1G.

10.5 Test Procedure

10.5.1 Seat the dummy on a horizontal surface (±0.5°) with no back support (Figure 10-2), with femurs extended horizontally and forward parallel to the midsagittal plane and lower legs extended vertically and downward parallel to the vertical plane (Figure 10-3). The midsagittal plane shall be vertical within ±1 degree.

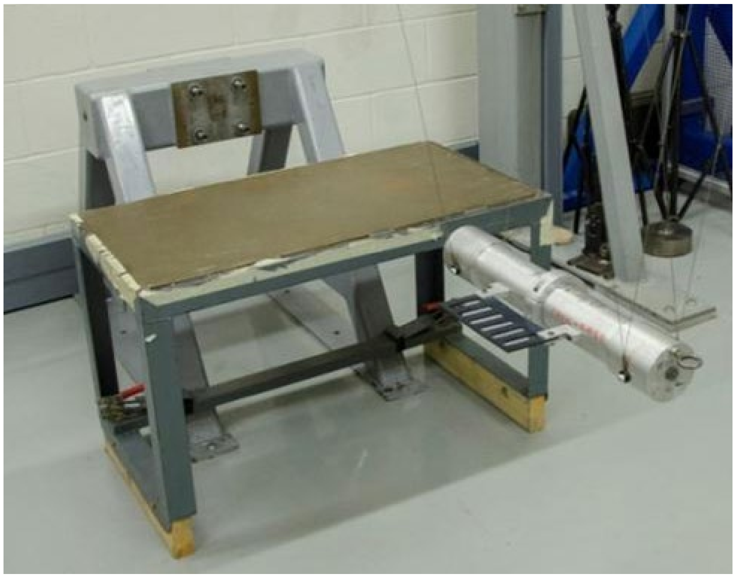


Figure 10-2. Seat setup for upper leg qualification test.

Figure 10-3. Initial setup for the upper leg qualification test.

10.5.2 Position the arms along the side of the body (Figure 10-3).

10.5.3 Set the pelvis so that the angle measured by the pelvis tilt sensor is 0 ± 0.5° in the X-axis and 15 ±1° in the Y-axis.

10.5.4 Unzip the thigh flesh (472-5503-1 or 472-5503-2).

10.5.5 With the lower legs positioned over the front edge of the seating surface, measure the angle of the line between the center of the knee joint and the centerline of the femur shaft, which is visible through the gap between the thigh and pelvis flesh (Figure 10-4 and Figure 10-5), using a straight edge with an inclinometer or using a laser level. Place support shims under the thigh in order to level the centerline of the femur shaft in the horizontal plane (±0.5°).

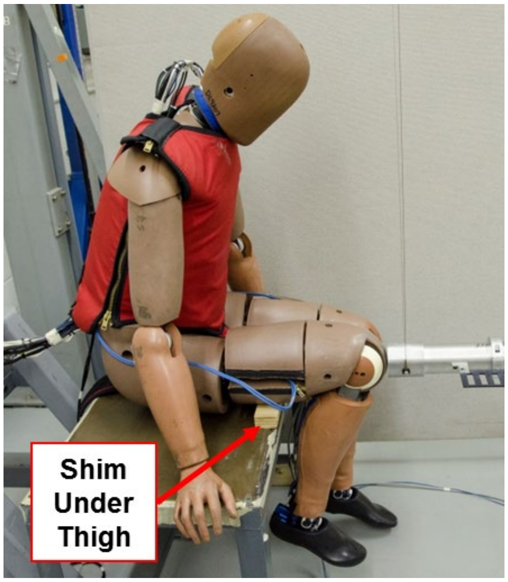


Figure 10-4. Location of shim used to level upper leg in horizontal plane.

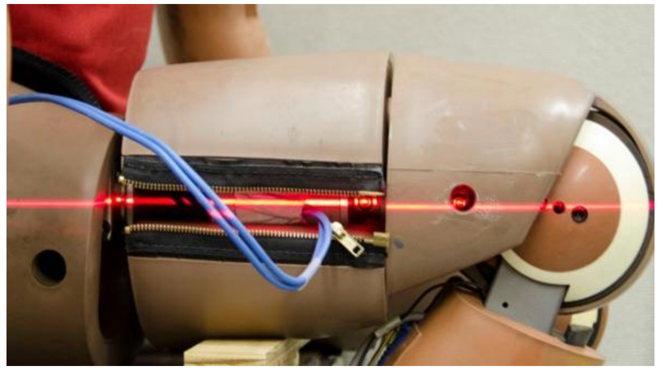


Figure 10-5. Horizontal alignment of knee and femur bone using laser level.

10.5.6 Position the tibia at an angle of 20 ± 1° (in flexion, such that the ankle is behind the knee), as measured at the anterior aspect of the knee clevis (472-7200; Figure 10-6). The distance between the posterior surface of the tibia and the leading edge of the test seat shall be no less than 25 mm.

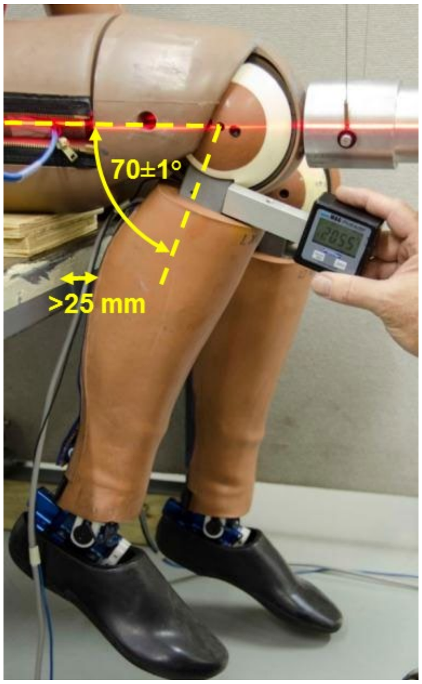


Figure 10-6. Lower leg angle measurement.

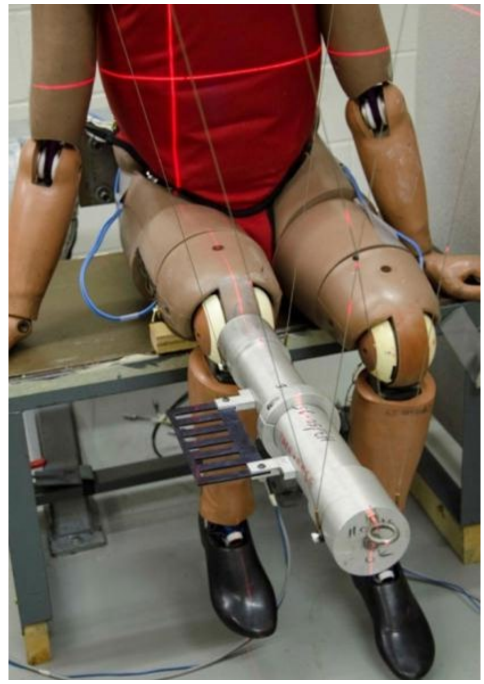


Figure 10-7. Lateral alignment of impact location.

10.5.7 Align the impact probe so that at the point of contact, the center of the probe face is centered on the surface of the knee and the longitudinal centerline of the probe is collinear within 0.5° of the longitudinal centerline of the femur load cell (Figure 10-7).

10.5.8 Taking care not to change the position of the leg, carefully re-zip the thigh flesh (472-5503-1 or 472-5503-2).

10.5.9 Position the foot and lower leg such that the center the ankle X-axis potentiometer is in the same vertical plane as the femur centerline. This can be accomplished by aligning the centerline of the probe with the centerline of the lower leg through the ankle (Figure 10-8). An alternate method uses an inclinometer on the outer side of the knee clevis to measure the angle relative to vertical (Figure 10-9).

Figure 10-8. Orient lower leg along centerline.

Figure 10-9. Alternate method to orient lower leg.

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

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

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

10.5.13 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 = 15 ± 1º
Wait Time Between Tests	At Least 30 Minutes

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

10.5.15 Conduct the test at a velocity of 2.60 ± 0.05 m/s.

10.5.16 Repeat Section 10.5 for the opposite upper leg.

10.6 Data Processing

10.6.1 Perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (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 (.050 s) and (.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 2.5).

10.6.4 Calculate resultant acetabulum force:

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

Where:

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

$$PVA_{FX} = \text{time} - \text{history of acetabulum force (L or R), X} - \text{axis}$$

$$PVA_{FY} = \text{time} - \text{history of acetabulum force (L or R), Y} - \text{axis}$$

$$PVA_{FZ} = \text{time} - \text{history of acetabulum force (L or R), Z} - \text{axis}$$

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	DOFEMRLE00THFOZB	ZL	AM	FMRL	LC	NWT
Left Acetabulum Force, X-axis	600	D0ACTBLE00THFOXB	XL	AM	PVAL	LC	NWT
Left Acetabulum Force, Y-axis	600	D0ACTBLE00THFOYB	YL	AM	PVAL	LC	NWT
Left Acetabulum Force, Z-axis	600	D0ACTBLE00THFOZB	ZL	AM	PVAL	LC	NWT
Left Acetabulum Force, Resultant	N/A	D0ACTBLE00THFORB	RS	CM	PVAL	PP	NWT

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

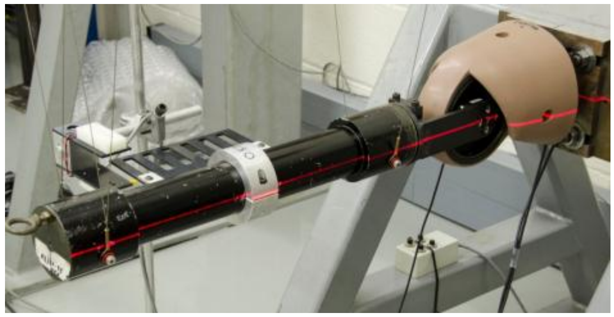
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Pendulum Accelerometer	600	T0SENSMI0000ACXB	XG	AM	PEND	AC	G'S
Pendulum Force	N/A	T0SENSMI0000FOXB	XG	CM	PEND	PP	NWT
Right Femur Force, Z-axis	600	DOFEMRRI00THFOZB	ZL	AM	FMRR	LC	NWT
Right Acetabulum Force, X-axis	600	D0ACTBRI00THFOXB	XL	AM	PVAR	LC	NWT
Right Acetabulum Force, Y-axis	600	D0ACTBRI00THFOYB	YL	AM	PVAR	LC	NWT
Right Acetabulum Force, Z-axis	600	D0ACTBRI00THFOZB	ZL	AM	PVAR	LC	NWT
Right Acetabulum Force, Resultant	N/A	D0ACTBRI00THFORB	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	2.55	2.65
Peak Probe Force	N	4221	5158
Peak Femur Force, F_z	N	-3314	-2712
Peak Resultant Acetabulum Force	N	1478	1806

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 12.00 kg rigid impactor at 2.20 m/s.

11.2 Materials

- ☐ THOR ATD knee assembly (472-5100-1 or 472-5100-2)
- ☐ Impactor 12.00 ± 0.02 kg (26.46 ± 0.04 lb) in mass, including instrumentation, rigid attachments and the mass of the lower 1/3 of the suspension cables (Section 2.4(a)4)). The test probe is a 76.2 ± 0.2 mm (3.00 ± 0.01 in) diameter rigid cylinder. The impacting surface has a flat, right angle face with an edge radius of 0.5 ± 0.2 mm (0.02 ± 0.01 in).
- ☐ Knee slider load distribution bracket assembly (DL472-5000) (Note that unlike the Hybrid III 50th knee slider test, *no foam pad* is used on the impact surface for this test.)

11.3 Instrumentation

- ☐ THOR femur load cell (SA572-S120)
- ☐ Instrumentation to measure the impact velocity
- ☐ THOR knee slider string potentiometer (SA572-S90)

11.4 Pre-Test Procedures

11.4.1 Inspect the knee assembly for damage. Pay particular attention to the left and right side slider assemblies to ensure the tracks are clean and free from damage, and if necessary take appropriate action to refurbish the part[22]. Ensure that the potentiometer is installed correctly by manipulating the knee joint and verifying that the potentiometer string is free from obstruction.

11.4.2 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.

---

[22] See *Upper Leg Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

11.5 Test Procedure

11.5.1 Mount the THOR femur load cell (Figure 11-1) to a rigid surface using four modified M6 BHSS and torque to 10.0 N-m (7.4 ft-lbf).

11.5.2 Orient the inboard/outboard knee slider assembly (472-5310) such that motion along the knee slider track is horizontal, parallel to the long axis of the femur load cell. Install the knee slider load distribution bracket to the inboard and outboard slider assemblies in the orientation shown in Figure 11-1 using two M6x1 FHCS on each side and torque to 12.0 N-m (8.9 ft-lbf). Note that the knee slider distribution bracket is installed perpendicular to the orientation of the knee clevis in the fully-assembled, seated dummy.

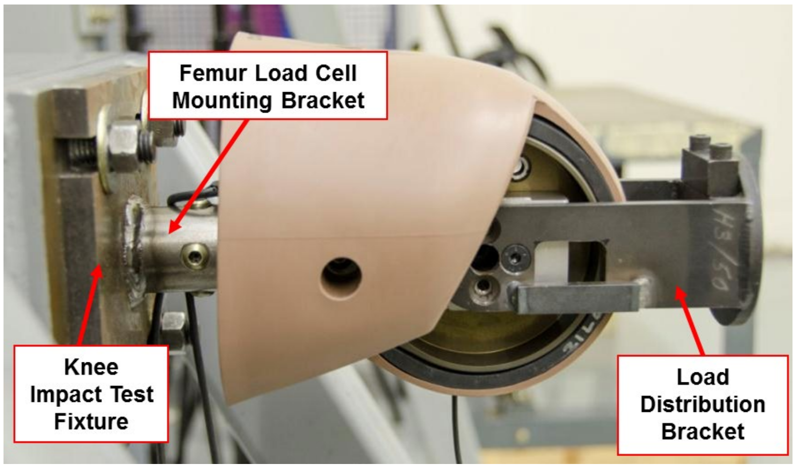


Figure 11-1. Knee slider impact test fixture.

11.5.3 Once the knee slider load distribution bracket is installed, set the torque on the modified M10 shoulder bolt (472-5302) to 5 N-m (Figure 11-2).

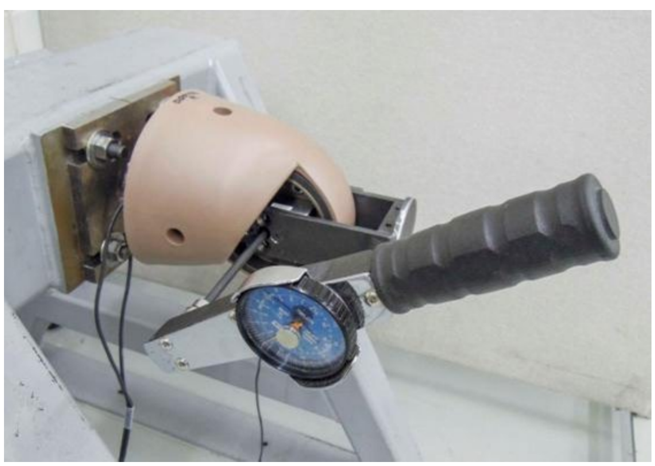


Figure 11-2. Knee joint bolt torque setting.

11.5.4 Adjust the position of the impact probe such that its longitudinal centerline is collinear within 2 degrees with the centerline of the femur load cell. A laser level positioned between the centerline of the knee and the centerline of the probe both laterally (Figure 11-3) and on the top surface of the probe/knee (Figure 11-4) will aid in this process.

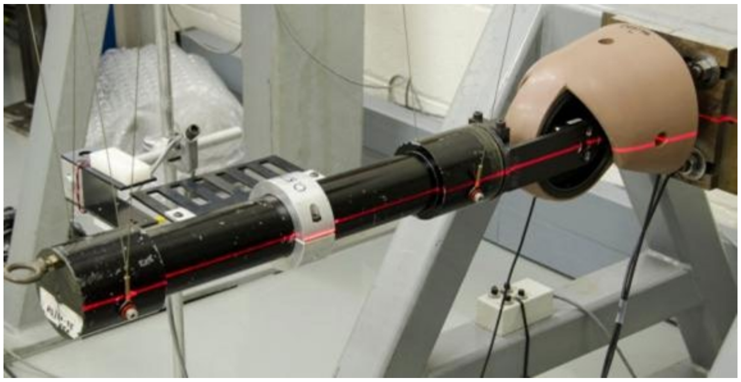


Figure 11-3. Vertical alignment of impact location.

Figure 11-4. Lateral alignment of impact location.

11.5.5 After alignment, confirm that the impact surfaces of the probe and the knee slider load distribution bracket are approximately flush (Figure 11-5).

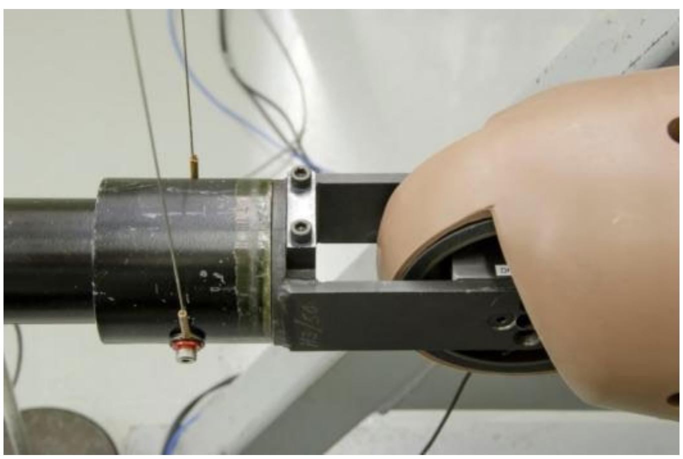


Figure 11-5. Alignment probe and knee slider load distribution bracket impact surfaces.

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

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

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

11.5.9 Conduct the test at a velocity of 2.20 ± 0.05 m/s.

11.5.10 Repeat Section 11.5 for the opposite knee.

11.6 Data Processing

11.6.1 Perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (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 (.050 s) and (.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	D0FEMRLE00THFOZC	ZL	AM	FMRL	LC	NWT
Left Knee Slider Deflection	180	D0KNSLLE00THDSXC	XL	AM	KNEL	DS	MM

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

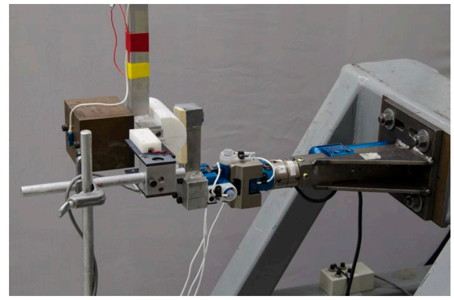
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Femur Force, Z-axis	180	D0FEMRRI00THFOZC	ZL	AM	FMRR	LC	NWT
Right Knee Slider Deflection	180	D0KNSLRI00THDSXC	XL	AM	KNER	DS	MM

11.7 Performance Specifications

Table 11-3. Knee Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	2.15	2.25
Peak Femur Z-axis Force	N	-7156	-5855
Knee Deflection at Peak Femur Force	mm	-22.2	-18.2

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 5.00 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 Ensolite® padding to reduce noise transmission through the bracket into the ankle and load cell.

12.2 Materials

- ☐ THOR ATD lower leg (472-7000-1 or 472-7000-2)
- ☐ NHTSA Dynamic Impactor (TLX-9000-013) 5.00 ± 0.02 kg (11.02 ± 0.04 lb) in *effective* mass, which includes the mass of instrumentation, ballast (TLX-9000-001), 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 (TLX-9000-016M)
- ☐ Dynamic inversion/eversion bracket (TLX-9000-015)
- ☐ Lower leg mounting bracket assembly (DL472-4100) attached to a rigid surface

12.3 Instrumentation

- ☐ THOR lower tibia load cell (SA572-S33)
- ☐ THOR X-axis ankle potentiometer (SA572-114)
- ☐ Instrumentation to measure the impact velocity

12.4 Pre-Test Procedures

12.4.1 Inspect the lower leg assembly for damage. Inspect the ankle soft stops (472-7532, 472-7536, 472-7537 x 2) for tears, permanent deformations, or separation from the soft stop brackets. If necessary, take appropriate action to refurbish the part[23].

12.4.2 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.

12.4.3 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.4.

12.5 Test Procedure

12.5.1 Remove the tibia skin (472-7370) and the two M6 x 1 x 16 BHCS which attach the tibia guard (472-5420) to the lower leg assembly (Figure 12-1).

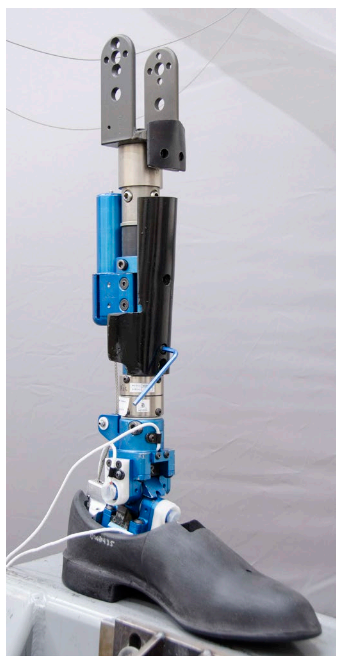


Figure 12-1. Remove tibia guard.

12.5.2 Separate the ankle assembly from the leg by removing the four modified M6 BHSS (W50-61042) attaching the lower tibia tube assembly (472-7310) to the lower tibia load cell (Figure 12-2). Set the rest of the lower leg mechanical assembly (472-7300) aside.

---

[23] See *Lower Extremity Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

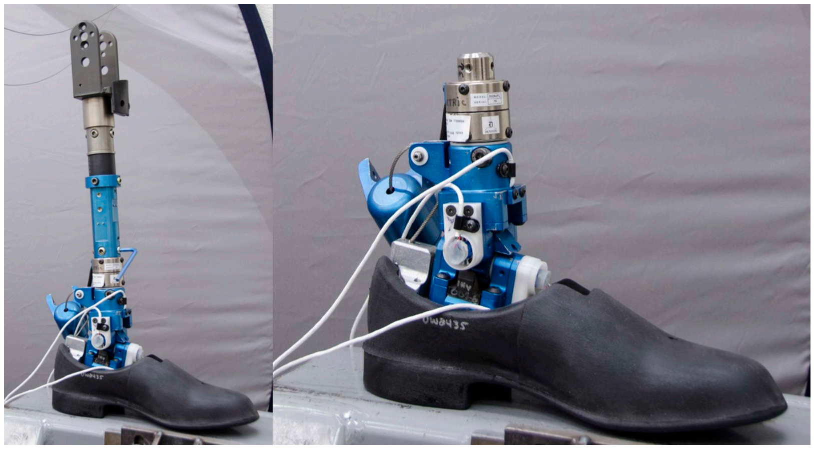


Figure 12-2. Separate the ankle assembly from the lower tibia load cell.

12.5.3 Mount the Lower Leg Mounting Bracket Assembly (472-4100) to a rigid surface (Figure 12-3, Figure 12-4). The remainder of the procedural instructions in this Section are written for the left leg inversion test. The setup for eversion tests follows the same procedures as inversion, except that the orientation is rotated 180° about its longitudinal axis (Figure 12-4).

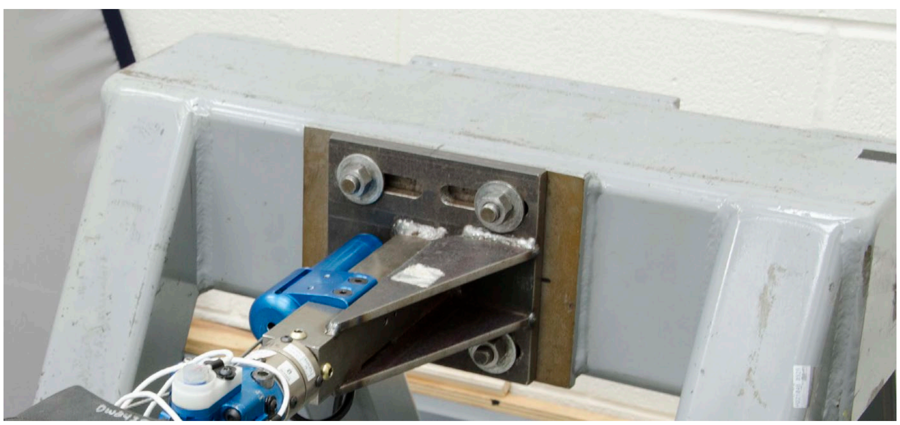


Figure 12-3. Orientation of lower leg mounting bracket for inversion tests.

Figure 12-4. Orientation of lower leg mounting bracket for eversion tests.

12.5.4 Mount the ankle assembly to the leg mounting bracket using four modified M6 BHSS (W50-61042) with torque set to 10.0 ± 2.5 N-m (7.4 ± 1.8 ft-lbf) such that the X-Z plane of the foot and lower leg are horizontal (Figure 12-5).

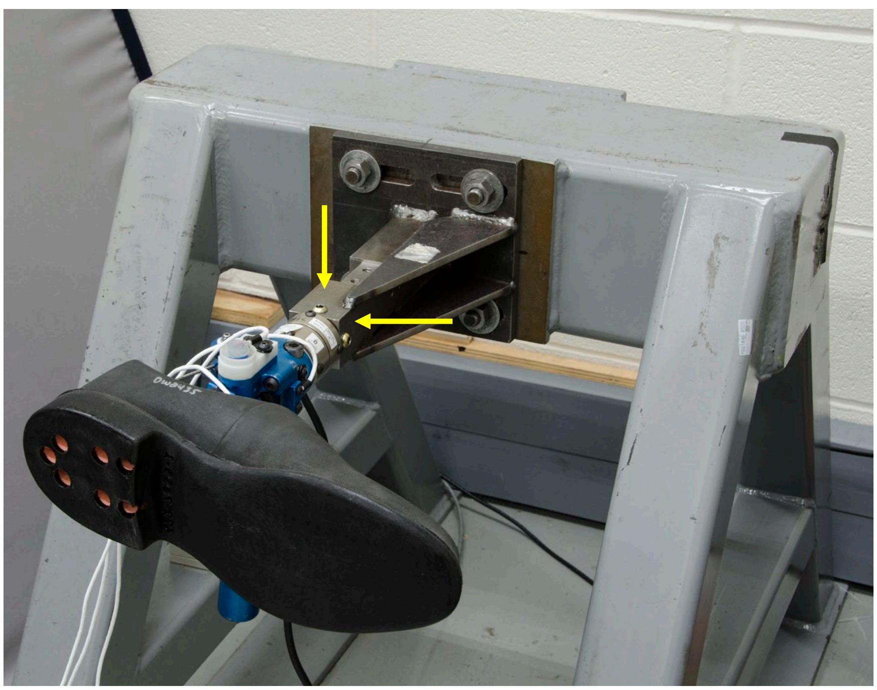


Figure 12-5. Lower (left) leg mounted to bracket for inversion test.

12.5.5 Secure the Achilles spring tube assembly to the leg mounting bracket using four M6 x 12mm FHCS (Figure 12-6).

Figure 12-6. Install Achilles tube assembly to mounting bracket.

12.5.6 Remove the four FHCS from the bottom of the heel of the molded shoe (Figure 12-7).

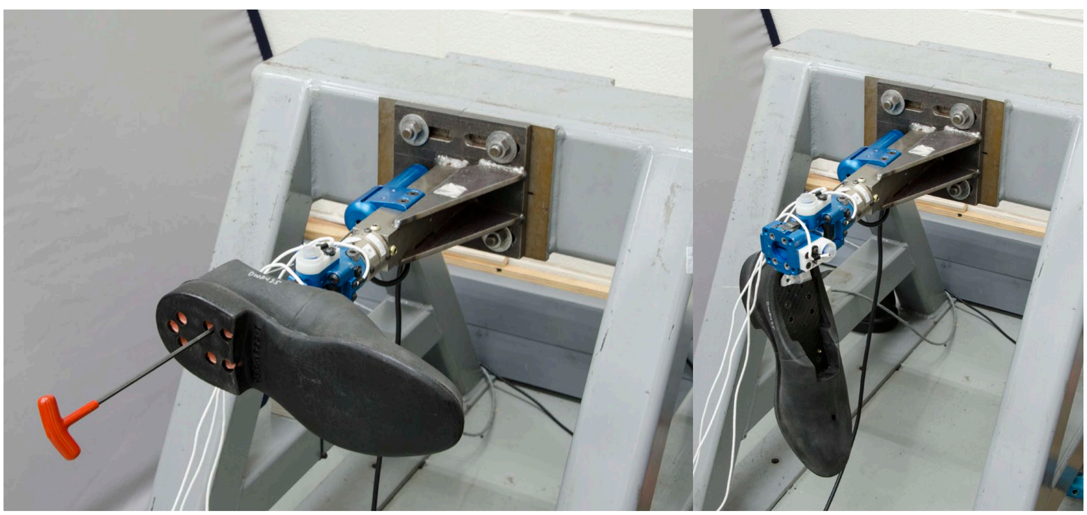


Figure 12-7. Remove molded shoe from ankle.

12.5.7 Orient the foot at 0° ± 0.5° dorsiflexion/plantarflexion and inversion/eversion. Use the external positioning bracket (TLX-9000-016M; Figure 12-8) to hold the ankle in the proper orientation (Figure 12-9).

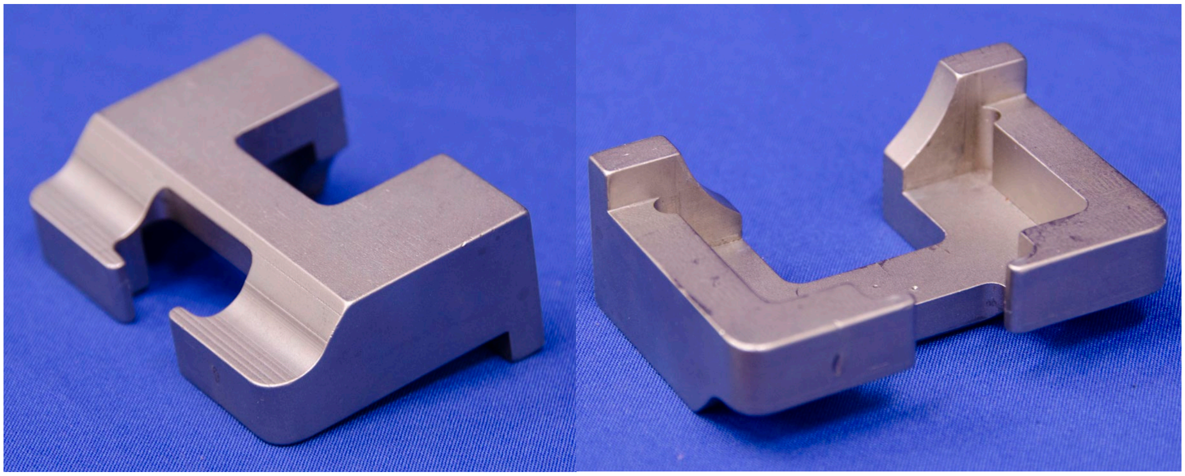


Figure 12-8. External positioning bracket for holding ankle orientation.

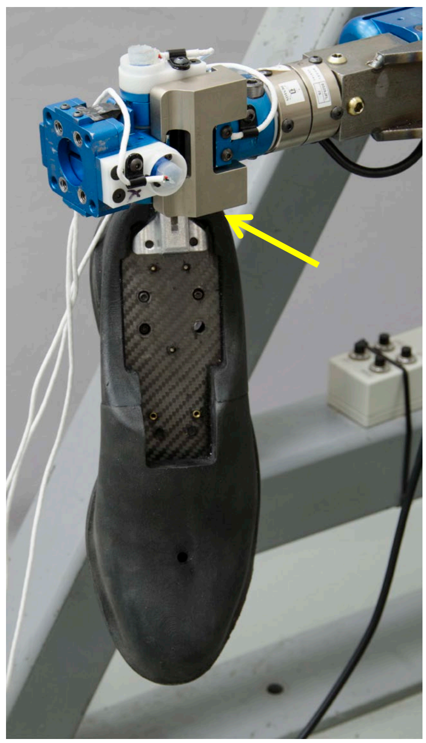


Figure 12-9. External positioning bracket installed on ankle.

12.5.8 Attach the dynamic inversion/eversion bracket (TLX-9000-015; Figure 12-10) in place of the molded shoe to the bottom (inferior) side of the ankle using four M6 x 1 x 35 mm SHCS torqued to 20.3 ± 2.5 N-m (15.0 ± 1.8 ft-lbf) (Figure 12-11). *Note: Do not use bolts longer than 47.6 mm, as these may damage the inversion/eversion soft stop brackets.*

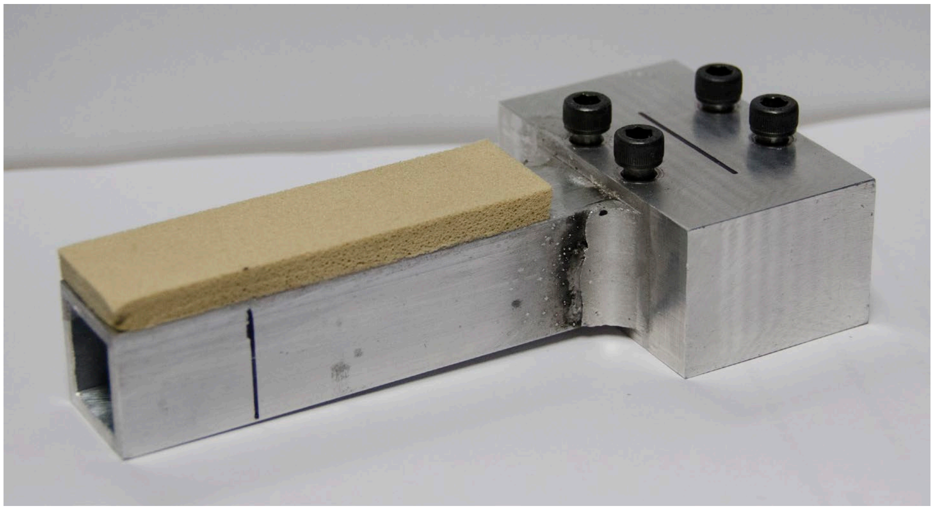


Figure 12-10. Dynamic inversion/eversion bracket.

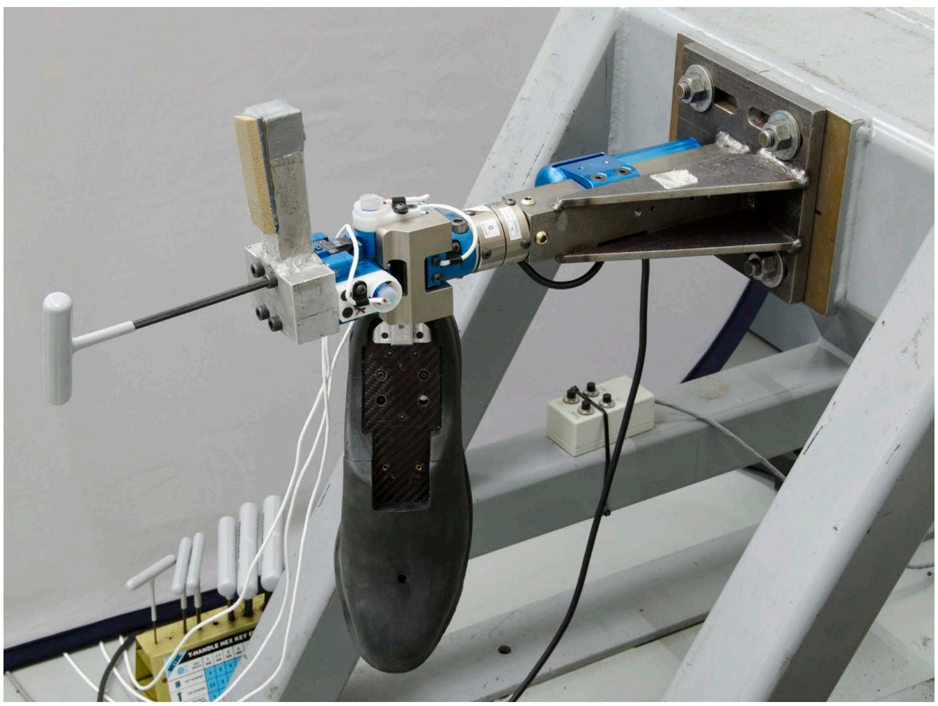


Figure 12-11. Install dynamic inversion/eversion bracket.

12.5.9 In order to aid in setup, remove the foot from the Achilles cable so that the weight of the foot does not interfere with ankle positioning (Figure 12-12). Using the zero offset values collected in Section 3.4, position the ankle Y axis and Z axis rotations to 0° ± 0.5°.

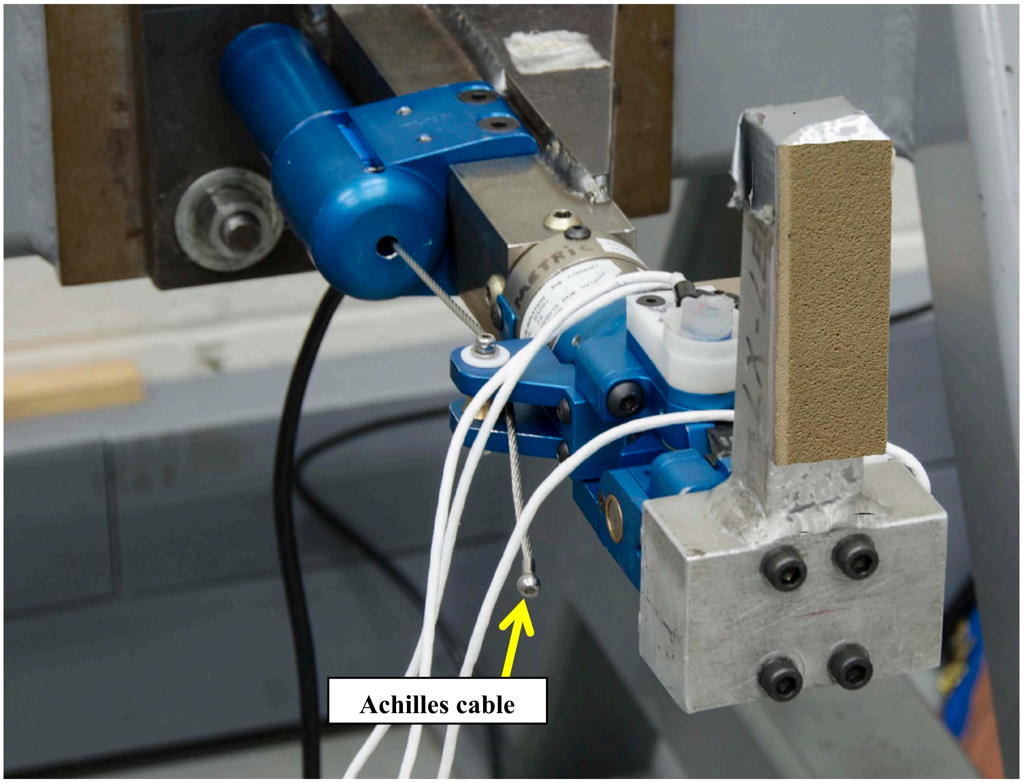


Figure 12-12. Remove foot from Achilles cable.

12.5.10 Remove the four M6 x 1 x 12 FHCS (two per side) which attach the Achilles spring tube assembly to the rear of the lower tibia tube (Figure 12-13).

Figure 12-13. Remove Achilles spring tube assembly.

12.5.11 Ensure that the impactor arm is vertical.

12.5.12 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, within ±0.5° and the point of impact is 102.6 ± 2.5 mm (4.04 ± 0.1 in) above the ankle X-axis pivot point (Figure 12-14).

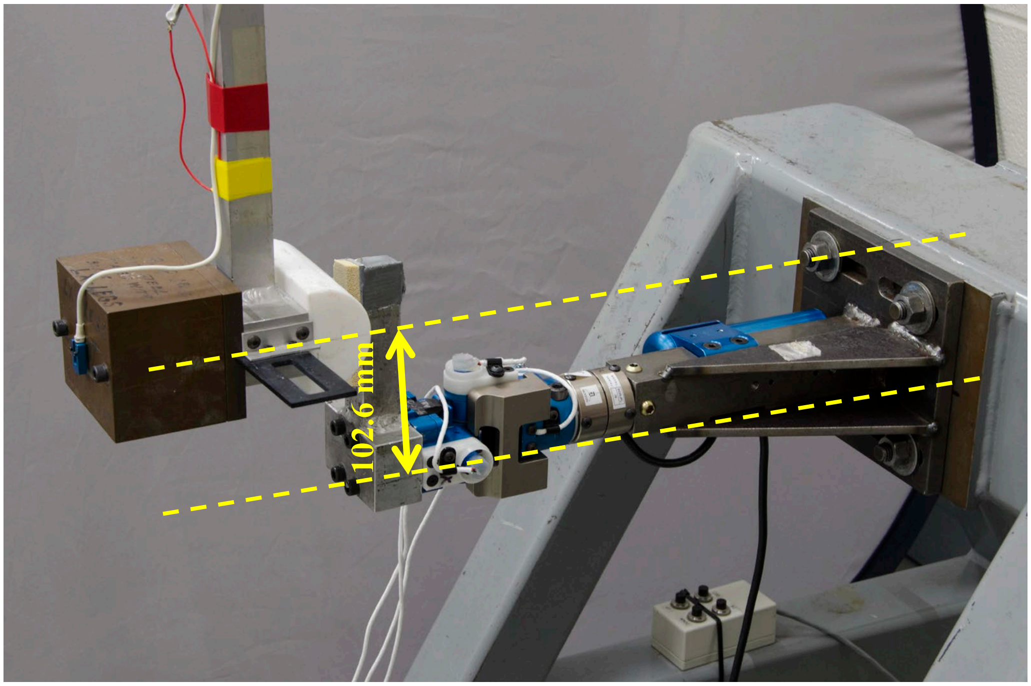


Figure 12-14. Set impact location for inversion (or eversion) test.

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

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

12.5.15 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 2.00 ± 0.05 m/s (6.60 ± 0.15 ft/s).

12.5.16 For eversion tests, rotate the mounting bracket 180° about its longitudinal axis as shown in Figure 12-4. Remove the dynamic inversion/eversion bracket from the ankle assembly by uninstalling the four M6 x 1 x 35 mm SHCS. Rotate the bracket 180 degrees about the longitudinal axis of the tibia and reinstall using four M6 x 1 x 35 mm SHCS torqued to 20.3 ± 2.5 N-m (15.0 ± 1.8 ft-lbf) (Figure 12-15). Follow the same procedures as described in Section 12.5 for inversion.

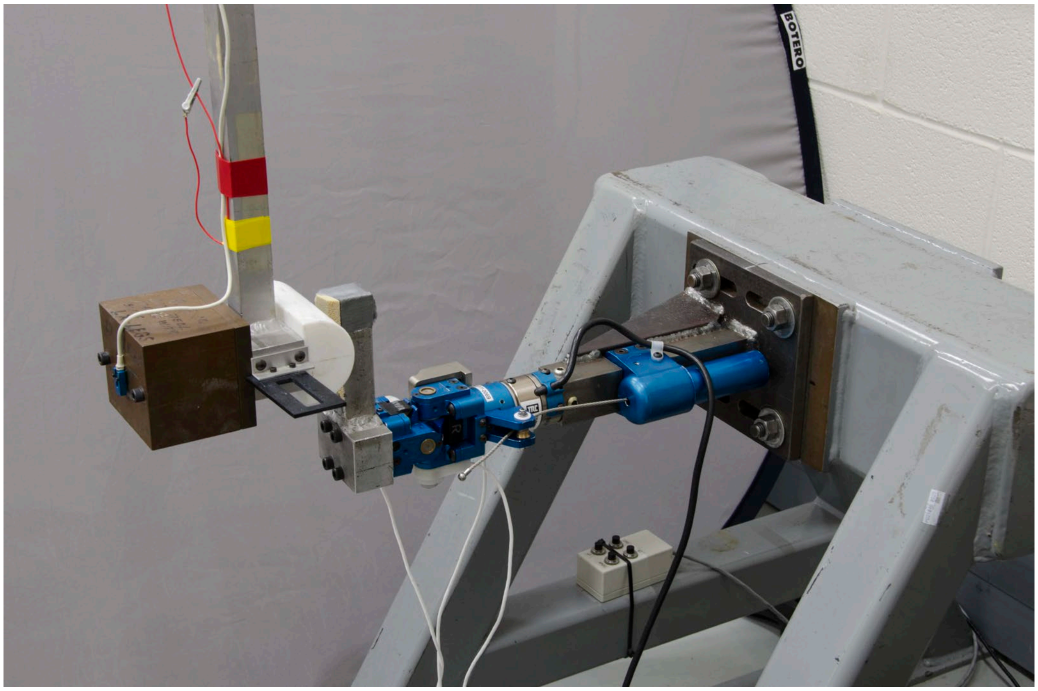


Figure 12-15. Eversion test setup.

12.6 Data Processing

12.6.1 With the exception of the ankle rotational potentiometer channel, perform bias removal of the measured (unfiltered) channels listed in the "Required Measurement Channels" (Table 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 (.050 s) and (.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: $$M_{ANKL}(t) = M_{x_{TBLL}} + \left[0.1054m \times F_{y_{TBLL}}\right]$$

Right: $$M_{ANKR}(t) = M_{x_{TBLR}} + \left[0.1054m \times F_{y_{TBLR}}\right]$$

Where:

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

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

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

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	D0TIBILELOTHFOYB	YL	AM	TBLL	LC	NWT
Left Lower Tibia Axial Force, Z-axis	600	D0TIBILELOTHFOZB	ZL	AM	TBLL	LC	NWT
Left Lower Tibia Moment, X-axis	600	D0TIBILELOTHMOXB	XL	AM	TBLL	LC	NWM
Left Ankle Rotation, X-axis	180	D0ANKLLE00THANXC	XL	AM	ANKL	AD	DEG
Left Ankle Resistive Moment	N/A	D0ANKLLE00THMOXB	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	D0TIBIRILOTHFOYB	YL	AM	TBRL	LC	NWT
Right Lower Tibia Axial Force, Z-axis	600	D0TIBIRILOTHFOZB	ZL	AM	TBRL	LC	NWT
Right Lower Tibia Moment, X-axis	600	D0TIBIRILOTHMOXB	XL	AM	TBRL	LC	NWM
Right Ankle Rotation, X-axis	180	D0ANKLRI00THANXC	XL	AM	ANKR	AD	DEG
Right Ankle Resistive Moment	N/A	D0ANKLRI00THMOXB	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
Peak Lower Tibia F_z	N	-555	-454
Peak Ankle Resistive Moment	Nm	-43.0	-35.2
Peak Ankle X-axis Rotation	deg	-37.9	-31.0

Table 12-4. Right Ankle Inversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Peak Lower Tibia F_z	N	-555	-454
Peak Ankle Resistive Moment	Nm	35.2	43.0
Peak Ankle X-axis Rotation	deg	31.0	37.9

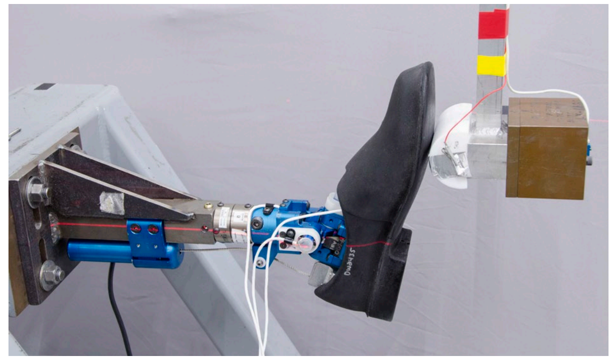
Table 12-5. Left Ankle Eversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Peak Lower Tibia F_z	N	-629	-514
Peak Ankle Resistive Moment	Nm	38.7	47.3
Peak Ankle X-axis Rotation	deg	26.6	32.5

Table 12-6. Right Ankle Eversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Peak Lower Tibia F_z	N	-629	-514
Peak Ankle Resistive Moment	Nm	-47.3	-38.7
Peak Ankle X-axis Rotation	deg	-32.5	-26.6

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 5.00 kg rigid impactor at 5.00 m/s to elicit dorsiflexion.

13.2 Materials

- ☐ THOR ATD lower leg (472-7000-1 or 472-7000-2)
- ☐ NHTSA Dynamic Impactor (TLX-9000-013) 5.00 ± 0.02 kg (11.02 ± 0.04 lb) in *effective* mass, which includes the mass of instrumentation, ballast (TLX-9000-001), 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.
- ☐ Lower leg mounting bracket assembly (DL472-4100) attached to a rigid surface

13.3 Instrumentation

- ☐ THOR lower tibia load cell (SA572-S33)
- ☐ THOR Y-axis ankle potentiometer (SA572-114)
- ☐ Instrumentation to measure the impact velocity

13.4 Pre-Test Procedures

13.4.1 Inspect the lower leg assembly for damage. Inspect the ankle soft stops (472-7532, 472-7536, 472-7537 x 2) for tears, permanent deformations, or separation from the soft stop brackets. Inspect the foot skin for wear and tears. If necessary, take appropriate action to refurbish the part[24].

---

[24] See *Lower Extremity Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

13.4.2 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.

13.4.3 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.4.

13.4.4 If not yet carried out on the lower leg being used for this test, conduct the Achilles Cable Adjustment Procedure described in Section 3.5.

13.5 Test Procedure

13.5.1 Follow the steps in Sections 3.4.1 through 3.4.6 to install the lower leg to the lower leg mounting bracket assembly (Figure 13-1).

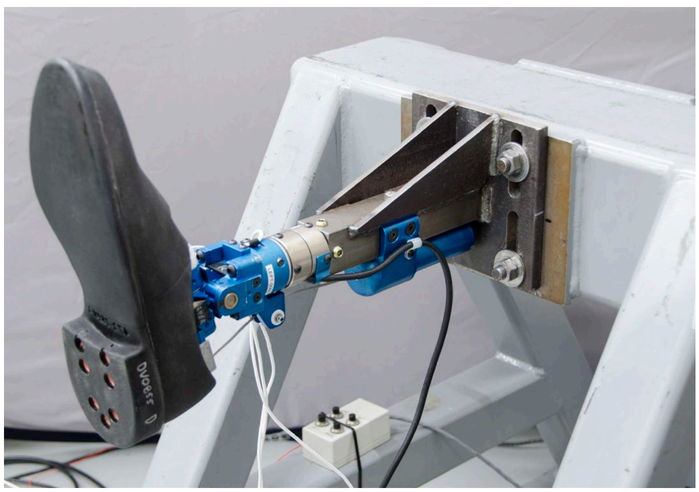


Figure 13-1. Install lower leg to mounting bracket assembly.

13.5.2 Initialize the ankle Y axis potentiometer and apply any necessary corrections developed in Section 3.4, Ankle Rotary Potentiometer Zeroing Procedure.

13.5.3 Verify using the Y-axis potentiometer reading that the foot is at 20 ± 0.5° plantarflexion (toe further away from tibia than heel) (Figure 13-2). Be certain to apply any necessary corrections to the angle (Section 13.5.2). If the foot does not achieve this position, rotate the foot over the range of motion in plantarflexion and dorsiflexion a few times. Confirm that the Y axis potentiometer reading is 20 ± 0.5° plantarflexion before proceeding. If necessary, a light piece of masking tape may be used between the toe and the fixture to hold the position.

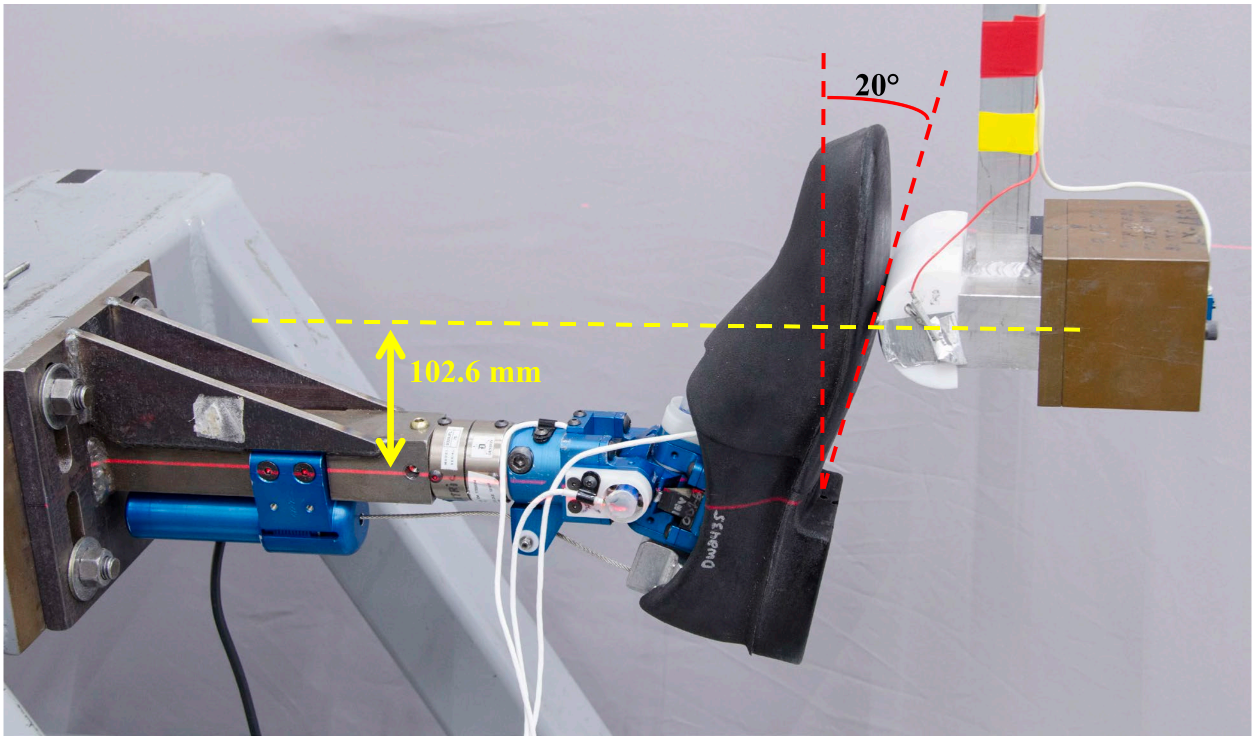


Figure 13-2. Ball of foot setup.

13.5.4 Adjust the position of the impactor so that the longitudinal centerline of the pendulum arm is vertical at impact, within ± 0.5°, and the point of impact is 102.6 ± 2.5 mm (4.04 ± 0.1 in) above the ankle Y-axis pivot point (Figure 13-2).

13.5.5 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.

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

13.5.7 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 5.00 ± 0.05 m/s (16.40 ± 0.15 ft/s).

13.5.8 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 (.050 s) and (.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: $M_{ANKL} = M_{y_{TBLL}} - [0.0907m \times F_{x_{TBLL}}]$

Right: $M_{ANKR} = M_{y_{TBLR}} - [0.0907m \times F_{x_{TBLR}}]$

Where:

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

$M_{y_{TBL[LR]}} =$ measured Y axis moment time − history measured at the lower [left or right] tibia load cell

$F_{x_{TBL[LR]}} =$ measured X axis force time − history measured at the lower [left or right] 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	D0TIBILELOTHFOXB	XL	AM	TBLL	LC	NWT
Left Lower Tibia Axial Force, Z-axis	600	D0TIBILELOTHFOZB	ZL	AM	TBLL	LC	NWT
Left Lower Tibia Moment, Y-axis	600	D0TIBILELOTHMOYB	YL	AM	TBLL	LC	NWM
Left Ankle Rotation, Y-axis	180	D0ANKLLE00THANYC	YL	AM	ANKL	AD	DEG
Left Ankle Resistive Moment	N/A	D0ANKLLE00THMOYB	YL	CM	ANKL	PP	NWM

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

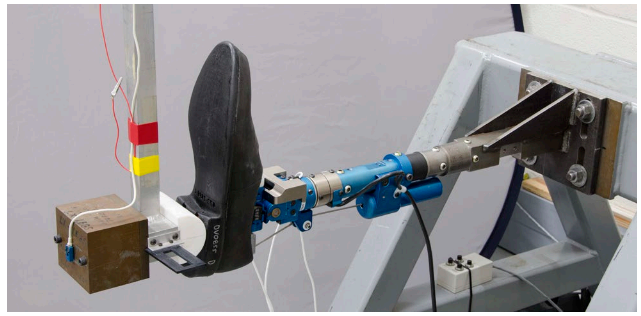
Channel Description	CFC	ISO-MME Code	AXIS	DASTAT	SENATT	SENTYP	YUNITS
Right Lower Tibia Shear Force, X-axis	600	D0TIBIRILOTHFOXB	XL	AM	TBRL	LC	NWT
Right Lower Tibia Axial Force, Z-axis	600	D0TIBIRILOTHFOZB	ZL	AM	TBRL	LC	NWT
Right Lower Tibia Moment, Y-axis	600	D0TIBIRILOTHMOYB	YL	AM	TBRL	LC	NWM
Right Ankle Rotation, Y-axis	180	D0ANKLRI00THANYC	YL	AM	ANKR	AD	DEG
Right Ankle Resistive Moment	N/A	D0ANKLRI00THMOYB	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	4.95	5.05
Peak Lower Tibia F_z	N	-3487	-2853
Peak Ankle Resistive Moment	Nm	49.8	60.8
Peak Ankle Y-axis Rotation (in dorsiflexion)	deg	30.4	37.2

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 5.00 kg rigid impactor at 4.00 m/s.

14.2 Materials

- ☐ THOR ATD lower leg (472-7000-1 or 472-7000-2)
- ☐ NHTSA Dynamic Impactor (TLX-9000-013) 5.00 ± 0.02 kg (11.02 ± 0.04 lb) in *effective* mass, which includes the mass of instrumentation, ballast (TLX-9000-001), 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 (TLX-9000-016M)

14.3 Instrumentation

- ☐ THOR lower tibia load cell (SA572-S33)
- ☐ Instrumentation to measure the impact velocity

14.4 Pre-Test Procedures

14.4.1 Inspect the tibia compliant bushing assembly (472-7315) for fatigue and deformation. Check plunger retaining bolts (472-7335) for wear and proper torque of 20.3 ± 2.5 N-m (15.0 ± 1.8 ft-lbf). Inspect the molded shoe for wear and tear. Replace components that have experienced excessive wear [25].

14.4.2 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.

14.4.3 If not yet carried out on the lower leg being used for this test, conduct the Ankle Rotary Potentiometer Zeroing Procedure described in Section 3.4.

---

[25] See *Lower Extremity Assembly- Inspection and Repairs* Section of the "THOR 50th Percentile Male (THOR-50M) Procedures for Assembly, Disassembly, and Inspection (PADI)".

14.4.4 If not yet carried out on the lower leg being used for this test, conduct the Achilles Cable Adjustment Procedure described in Section 3.5.

14.5 Test Procedure

14.5.1 Remove the tibia skin (472-7370) and the two M6 x 1 x 16 BHCS which attach the tibia guard (472-5420) to the lower leg assembly (Figure 14-1).

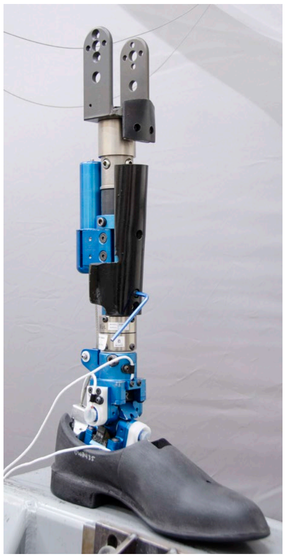


Figure 14-1. Remove tibia guard.

14.5.2 Remove the four M6 x 1 x 12 FHCS (two per side) which attach the Achilles spring tube assembly to the rear of the lower tibia tube (Figure 14-2).

Figure 14-2. Remove Achilles spring tube assembly.

14.5.3 Remove the four modified M6 BHSS which attach the upper tibia load cell (SA572-S32) to the tibia compliant bushing (472-7315) (Figure 14-3).

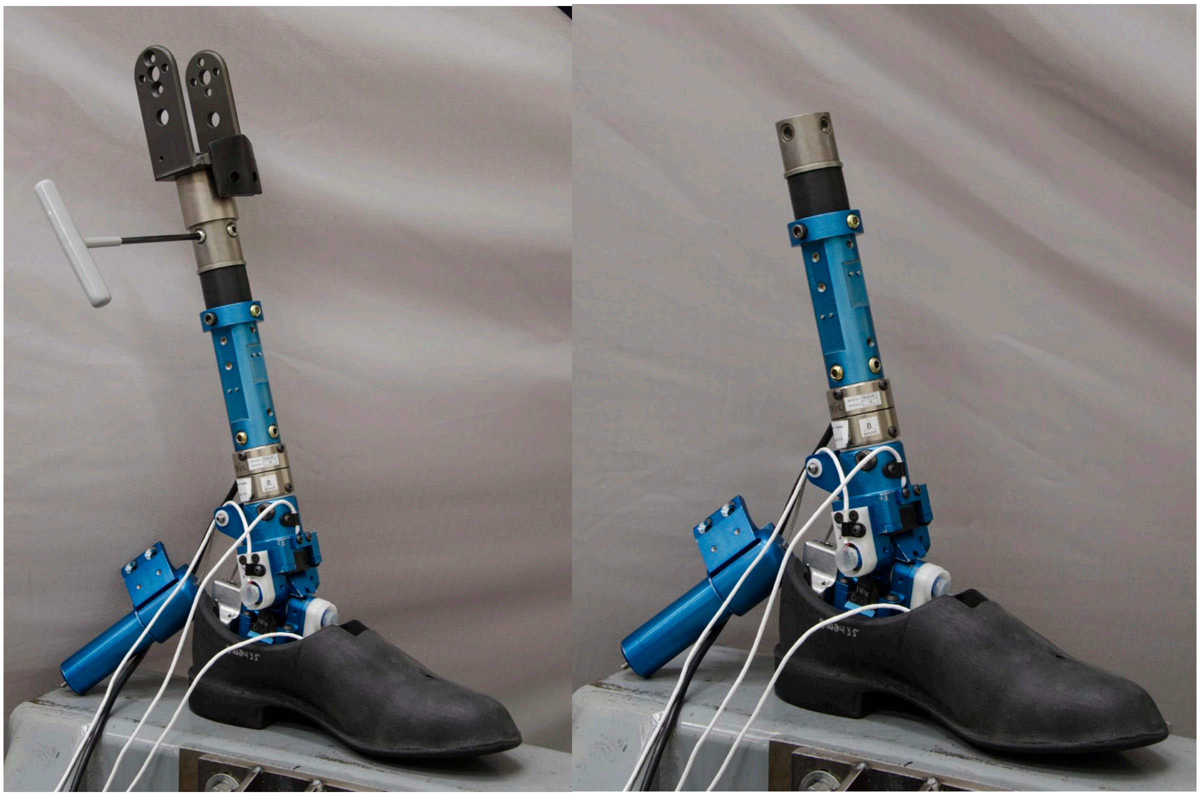


Figure 14-3. Remove knee clevis.

14.5.4 Install the upper tibia adapter (DL472-4300) to the leg using four modified M6 BHSS and torque to 10.0 ± 2.5 N-m (7.4 ± 1.8 ft-lbf) (Figure 14-4).

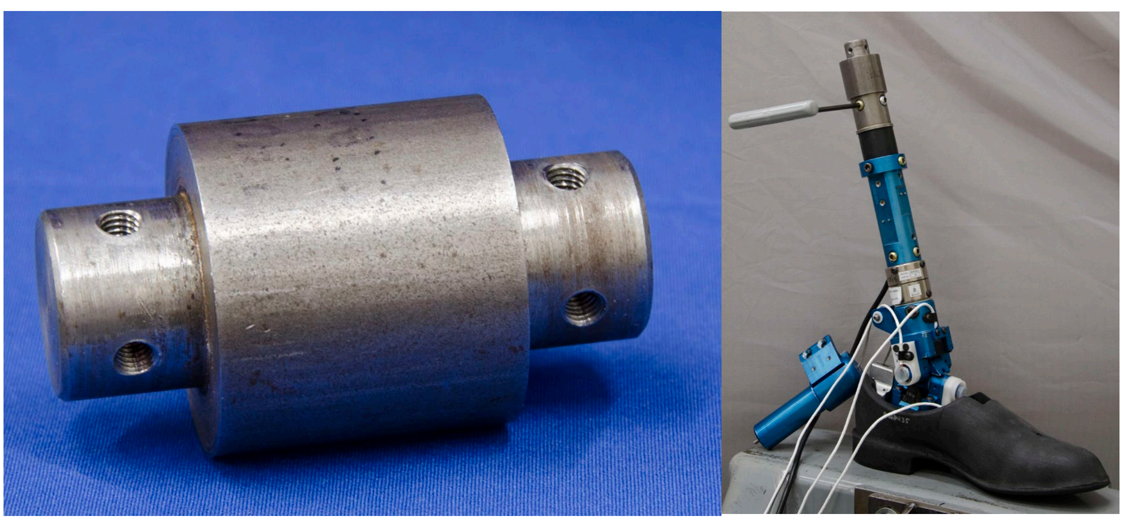


Figure 14-4. Install upper tibia adapter.

14.5.5 Secure the four M6 x 1 x 12 FHCS (two per side) which attach the Achilles spring tube assembly to the rear of the lower tibia tube.

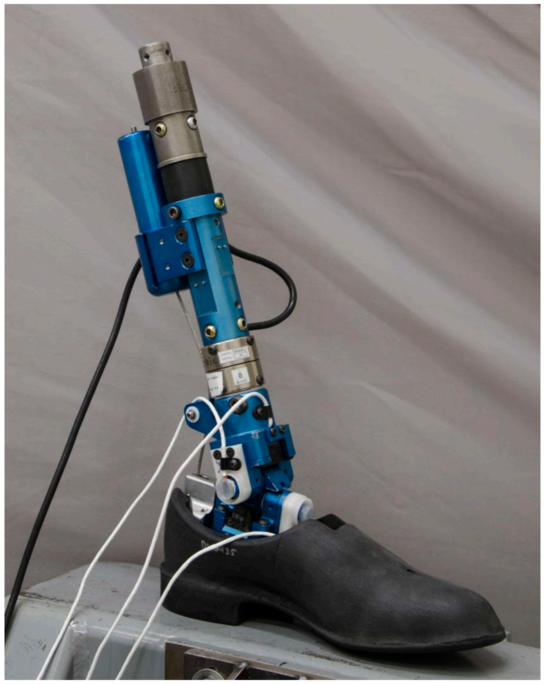


Figure 14-5. Attach Achilles.

14.5.6 Mount the Lower Leg Mounting Bracket Assembly (472-4100) to a rigid surface (Figure 14-6).

Figure 14-6. Install the lower leg mounting bracket.

14.5.7 Mount the leg with the toe pointing upward (Figure 14-7) by attaching the upper tibia adapter to the lower leg mounting bracket using four modified M6 BHSS and torque to 10.0 ± 2.5 N-m (7.4 ± 1.8 ft-lbf).

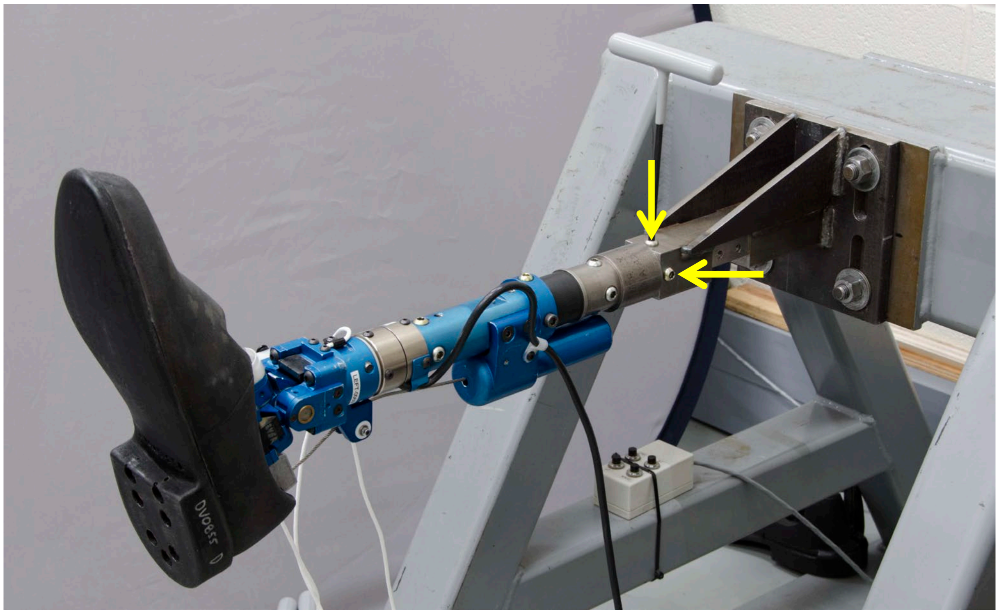


Figure 14-7. Install lower leg to mounting bracket for heel impact test.

14.5.8 Orient the foot at 0° ± 0.5° dorsiflexion/plantarflexion and inversion/eversion. Use the external positioning bracket (TLX-9000-016M; Figure 12-8) to hold the ankle in the proper orientation (Figure 14-8 and Figure 14-9).

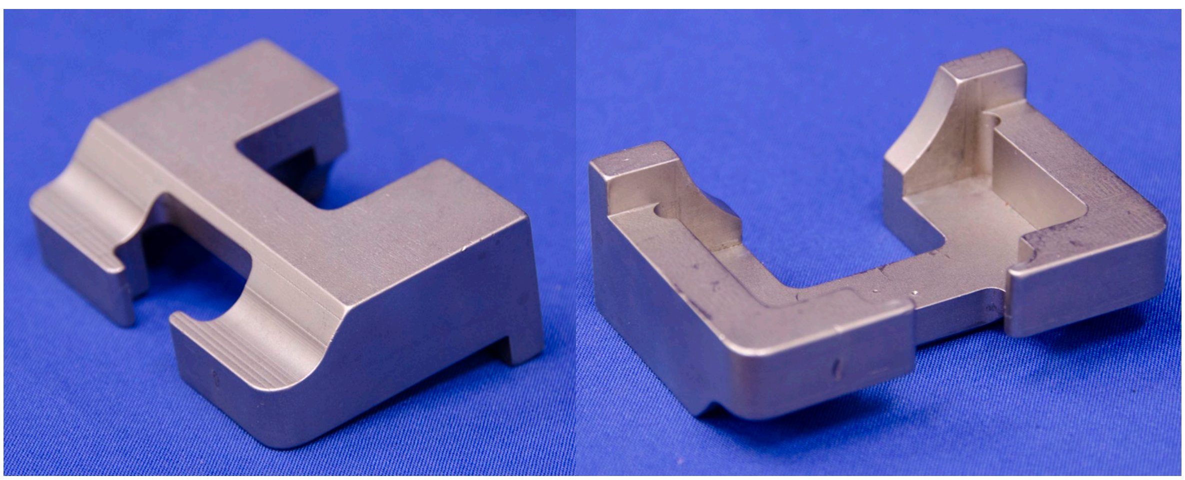


Figure 14-8. External positioning bracket for holding ankle orientation.

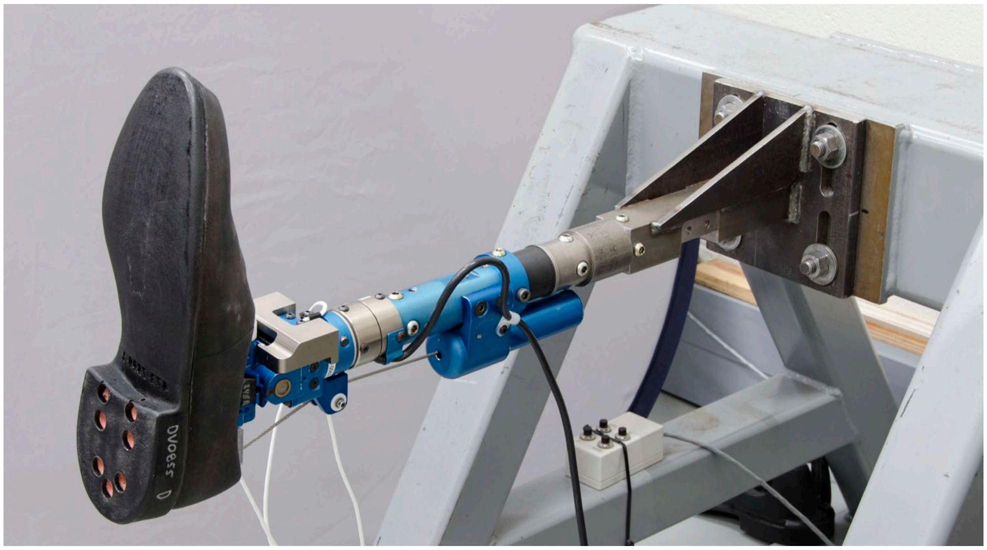


Figure 14-9. Install external positioning bracket for heel impact test.

14.5.9 Using the zero offset values collected in Section 3.4, position the ankle X axis and Z axis rotations to 0° ± 0.5°.

14.5.10 Ensure that the impactor arm is vertical.

14.5.11 Adjust the position of the impactor so that the longitudinal centerline of the pendulum arm is vertical at impact, within ±0.5°, and the point of impact is aligned with the longitudinal axis of the tibia within ±2.5 mm (±0.1 in) (Figure 14-10). 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 (472-7335), and the modified BHSC (W50-61042) attaching the tibia compliant bushing assembly to the upper tibia mounting fixture.

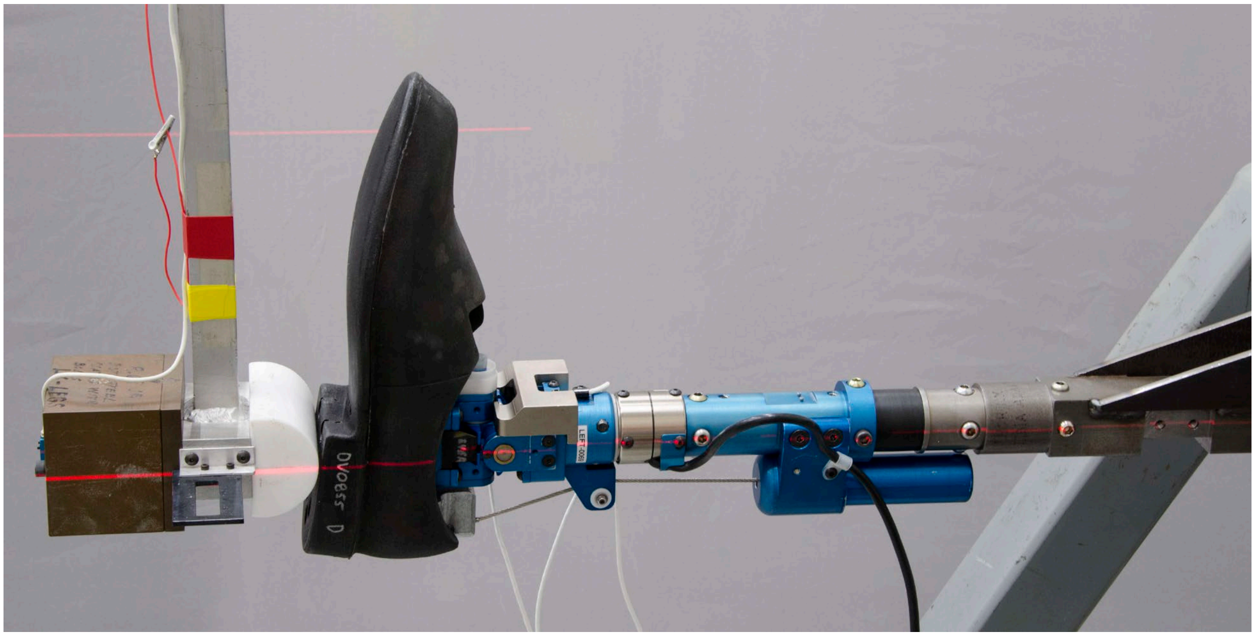


Figure 14-10. Alignment of the impactor for heel impact test.

14.5.12 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.

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

14.5.14 Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 4.00 ± 0.05 m/s (13.10 ± 0.15 ft/s).

14.5.15 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 (.050 s) and (.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).

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	D0TIBILELOTHFOZB	ZL	AM	TBLL	LC	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	D0TIBIRILOTHFOZB	ZL	AM	TBRL	LC	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
Peak Lower Tibia F_z	N	-3478	-2846

APPENDIX A. TEST FIXTURES

A- 1. Summary of Test Fixtures for THOR-50M Qualification Tests

Test Fixture Description [± 0.02 kg, ± 0.25 mm]	**Reference**	**Section(s)**	**Title**
Rigid disk impactor 23.36 kg, 152.4 mm diameter disk	CFR Title 49, §572.36(a); DL500-325	4, 7, 8	Head Qualification, Upper Thorax Qualification, Lower Thorax Qualification
Rigid disk impactor 13.0 kg, 152.4 mm diameter disk	Section 5.2 herein	5	Face Qualification
Neck pendulum	Figure A-2; CFR Title 49, §572.33(c)3	6.6, 6.7, 6.8, 6.9	Neck Torsion Test, Neck Frontal Flexion Test, Neck Extension Test, Neck Lateral Flexion Test
THOR neck twist fixture	DL472-1000	6.6	Neck Torsion Test
Lower abdomen probe face assembly	DL472-3000	9	Abdomen Qualification
Rigid disk impactor 5.0 kg, 76.2 mm diameter disk	Section 10.2 herein	10	Upper Leg Qualification
Rigid disk impactor 12.0 kg, 76.2 mm diameter disk	Section 11.2 herein	11	Knee Qualification
Dynamic impactor	TLX-9000-013	12, 13, 14	Ankle Inversion and Eversion Qualification, Ball of Foot Qualification, Heel Qualification
External positioning bracket	TLX-9000-016M	12, 14	Ankle Inversion and Eversion Qualification, Heel Qualification
Dynamic inversion/eversion bracket	TLX-9000-015	12	Ankle Inversion and Eversion Qualification
Lower leg mounting bracket assembly	DL472-4100	12, 13	Ankle Inversion and Eversion Qualification, Ball of Foot Qualification
Lower leg zero bracket	DL472-3500	3.4	Ankle Rotary Potentiometer Zeroing Procedure
Achilles fixture complete assembly	DL472-4000	3.5	Achilles Cable Adjustment Procedure
Load cell mounting assembly	DL472-4200	3.5	Achilles Cable Adjustment Procedure
Knee slider load distribution bracket assembly	DL472-5000	11	Knee Qualification
Tibia adaptor	DL472-4300	14	Heel Qualifcation

APPENDIX B. CHANGE LOG

Date	Description
2015-08-31	Pre-release for initial review
2015-09-10	Updated neck torsion measurement channels and data processing to use rotational potentiometer installed on fixture for rotation and rotation delay requirements, adjusted wording on Achilles and ankle procedures to allow more flexibility in test procedure, fixed some ISO-MME codes and Entrée fields in instrumentation requirements, applied minor adjustments to draft specifications upon further review of data, fixed minor grammatical errors
2015-09-18	Fixed several ISO-MME codes (neck cables, CHRI → CHST, lower abdomen) to align with 2015-04-15 codes; clarified upper thorax and abdomen procedures to define difference between left and right as the difference between the peaks, not the peak of the difference between the time-histories.
2015-10-16	Changed abdomen qualification test velocity to 3.3 m/s and adjusted specs accordingly (this change was made to reduce the risk of damaging IR-TRACCs or abdomen components during qualification testing); added note instructing users not to filter IR-TRACC voltage until after it is linearized and scaled; clarified head skin treatment in Step 5.5.1; removed images of fixture drawings that are now included in the THOR-50M Drawing Package (see http://www.nhtsa.gov/Research/Biomechanics+&+Trauma/THOR+50th+Male+ATD)
2015-12-01	Updated calculation of head angle wrt pendulum in neck pendulum qualification tests
August 2016 version - Docket # NHTSA-2015-0119	Changed abdomen impactor edge radius from 12.7mm to 6.0mm; fixed several typos in ankle qualification test procedure; updated 3.4Ankle Rotary Potentiometer Zeroing Procedure; added drawings for leg zero bracket, Achilles tension bracket, leg mounting bracket to Appendix; updated Achilles tension procedure; ball of foot procedures updated; inversion/eversion procedures updated; heel Impact procedures updated; updated neck spring cable setup.
September 2018 version	Section 14.5.3 corrected bolt description to modified M6 BHSS and corrected the components to which these BHSS attach
	Clarified deadband check procedure for pot zero on ankle zero procedure. Previously said see PADI.
	Changed SAE J211 references for polarity to SAE J1733 since THOR specific polarities are in J1733. Also, changed filter references from J211 to J211-1 and referenced J211-1.
	Referenced specific Section of PADI for inspections
	Updated Upper Thorax Z deflection specs which had been incorrectly calculated
	Changed 0°±0.5° to zero position reference in Section 3.5.9
	Changed 0°±0.5° to "closest to the zero position" in Section 3.5.10
	Deleted upper tibia load cell instrumentation in heel test
	Deleted Achilles tension from inversion/eversion pre-test setups
	Added wording to check that damping tubes inside springs are biased downwards.
	Changed contact strip to "contact switch" in neck tests.
	Delete "light trap, instrumentation level trigger, or equivalent" as forms of contact assessment on neck tests. Only a switch should be used or time zero could be set incorrectly. Consistency of time zero is important in neck tests.
	Corrected Section reference to 5.5.4 in Section 5.5.11
	Corrected caption from upper to lower thorax Figure 8-1
	Added "relative to earth" to Head Angular Velocity and Pendulum Angular Velocity Channels in Table 6-4, Neck Flexion Test
	Added "relative to earth" to Head Angular Velocity and Pendulum Angular Velocity Channels in Table 6-7, Neck Extension Test
	Added "relative to earth" to Neck Angular Velocity Channel in Table for Neck Torsion Test
	Added "relative to earth" to Head Angular Velocity and Pendulum Angular Velocity Channels in Table for Neck Lateral Flexion Test
	Changed angular "rate" to angular "velocity" Table 6-6, Table 6-9, Table 6-12

	Added “relative to earth” to angular velocity entry in Table 6-6, Table 6-9, Table 6-12
	Added T0 to integral on Equation 6.8.2.5; also added “begin integration at time zero” for clarity
	Added filter class CFC 180 to clarify filter for linearized, scaled IR-TRACC data
	Added a page break before Section 4 to correct diagram overlapping ankle adjustment image Deleted a sentence in the Achilles Cable Adjustment Procedure that was misleading.
	Added front and rear skull spring load cells to neck instrumentation in Section 6.4
	Changed pelvis setup angle from 18° to 13° on face and head tests to account for orientation differences with the straight neck and longer spring cable.
	Change all lower leg velocity tolerances to 0.05 m/s
	Removed references to netutral ankle position in “Achilles Cable Adjustment Procedure” and in “Ball Of Foot Qualification” sections.
	Added lower leg pendulum drawings
	Corrected torque settings for M6 button head and flat head screws
	Add sentence to perform neck angle measurements in both anterior-posterior and lateral directions in Section 6.5.2. Add clarification that *PlateAngle*° is measured for the anterior-posterior direction.
	Added Section 2.5 to further explain Measured Channels
	Added 15° pelvis angle to upper leg tests
	Clarified orientation method for the lower leg in upper leg tests
	Changed recovery time for face foam to 24 hours
	Added footnote statement to note that some photos contain the molded foot but this has since been replaced with the molded shoe
	For neck torsion, removed “decay time to 0° from peak rotation” specification requirement from neck torsion qualification test; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	For neck flexion, removed “peak upper neck F_x”, “posterior neck cable F_z before 60.0 ms”, and “decay time to 0° from peak rotation” specification requirements from neck flexion qualification test; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	For neck extension, removed “peak upper neck F_x”, “anterior neck cable F_z”, and “decay time to 0° from peak rotation” specification requirements from neck flexion qualification test; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	For neck lateral flexion, removed “decay time to 0° from peak rotation” specification requirement from neck lateral flexion qualification test; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	For upper thorax, removed X-axis and Z-axis deflection requirements and replaced them with resultant deflection specifications, added specification for force at peak resultant deflection, added “peak force” requirements; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	For lower thorax, removed “peak X-axis deflection” and “probe force at time of peak X-axis deflection”, added “peak force” and “resultant deflection at peak force” requirements; updated "Required Measurement Channels” Tables and “Response Requirements” Tables accordingly
	Updated all corridors to reflect (mean ± 10%)
	Added left and right side results for neck torsion and lateral flexion, ankle inversion/eversion
	Added explanation of variables for resultant calculations for upper and lower thorax
	Added “Normative Documents” Section
	Added “Neck Test Data Zero Setting and Offset Calculation” Section and updated Data Processing sections for each neck test mode accordingly
	Updated Data Processing sections for each test mode to clarify debias procedures
	Clarified specification for neck frontal flexion Fz as most positive value after 40 ms
	Deleted fixture drawings from Appendix since these can be found in drawing package