CERTIFICATION PROCEDURE
FOR THE
THOR-LX/HYBRID III RETROFIT VERSION 3.2

October 2001

National Highway Traffic Safety Administration
Vehicle Research and Test Center

Certification Procedure for the
Thor-Lx/HIII Retrofit Version 3.2

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I. BACKGROUND

This manual describes the procedures for certifying the correct performance of the advanced dummy lower leg, Thor-Lx/Hybrid III retrofit version 3.2 (Thor-Lx/HIIIr). The Thor-Lx/HIIIr is part of the National Highway Traffic Safety Administration (NHTSA) advanced dummy effort, Thor, and exhibits improved biofidelic response and greater instrumentation capabilities. The Thor-Lx/HIIIr is designed to fit either the Thor or Hybrid III 50^{th} percentile dummies.

Thor-Lx/HIIIr is shown in Figure 1. The appropriate flesh elements for the tibia are not shown. Figure 2 is a schematic of the leg defining the key elements and sub-assemblies. Detailed drawings of individual components and assemblies can be found in the Thor-Lx/HIIIr drawing package. In addition, thorough instructions of the product assembly and disassembly are located in the Thor-Lx/HIIIr User's Manual.

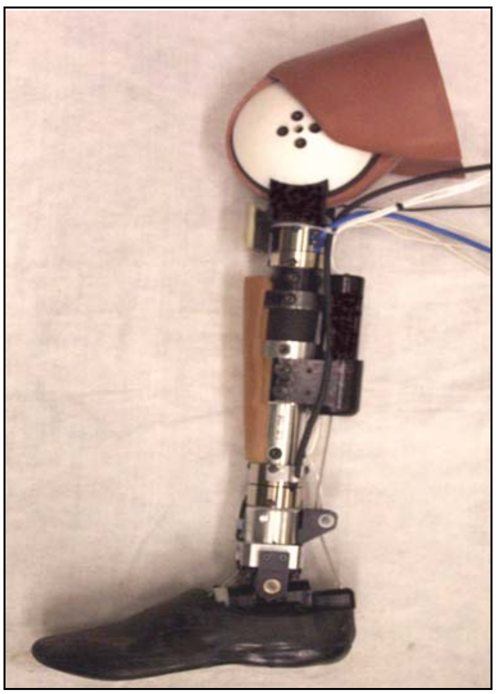

Figure 1. Thor-Lx/HIIIr (Tibia Flesh Removed)

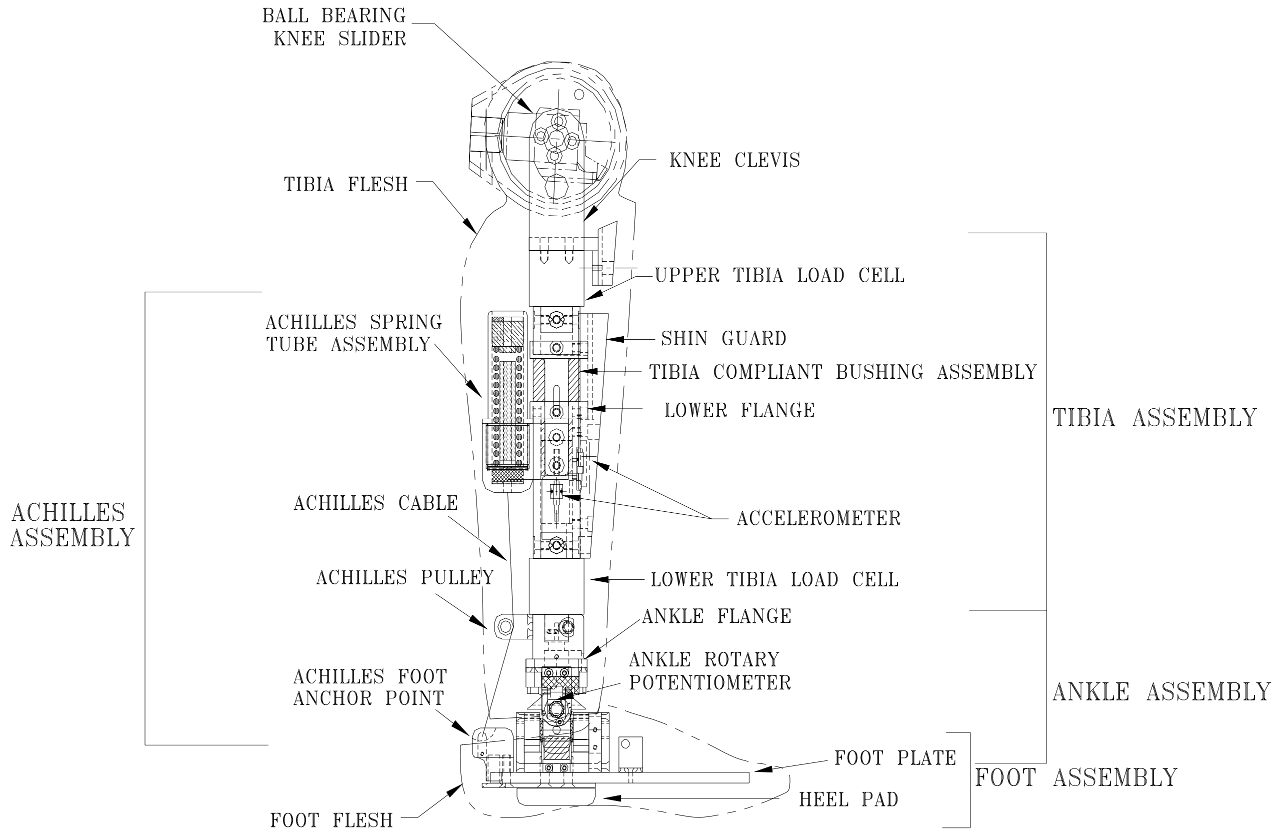

Figure 2. Thor-Lx/HIIIr Schematic

II. PERFORMANCE REQUIREMENTS

The performance of the Thor-Lx/HIIIr is examined with two sets of criteria:

- mandatory certification requirements
- design reference guidelines

For a Thor-Lx/HIIIr to be certified by the manufacturer, it must meet all of the mandatory certification requirements listed below in Table 1. The design reference guidelines are used as an additional functionality check of the product and are listed in Appendix A. Though it is not necessary for certification that the leg meet all of the design reference guidelines, these tests will be performed by the manufacturer. All manufacturer test data from both mandatory certification requirements and design reference guidelines will be released to the customer with the hardware.

The Thor-Lx/HIIIr ankle motion, Achilles tendon contribution, and axial compliance are certified by two quasi-static tests and two dynamic tests. The two quasi-static tests analyze the inversion and eversion ankle motion. One dynamic test consists of a pendulum impact to the ball of the foot and validates the dynamic dorsiflexion behavior and the Achilles tendon contribution. The second dynamic test examines the tibia axial compliance with a pendulum impact to the heel of the foot.

Table 1. Thor-Lx/HIIIr mandatory certification requirements

Quasi-Static Tests	Inversion & Eversion angles	
	At 6 N·m	17.5 - 21.3E
	At 23 N·m	29.3 - 35.9E
Dynamic Ball of Foot Impact	Peak Lower Tibia Compressive Force	3058 - 3738 N
	Peak Ankle Resistive Moment	76.2 - 93.2 N·m
Dynamic Heel of Foot Impact	Peak Lower Tibia Compressive Force	2694 - 3292 N

The test procedures and target response values for the mandatory certification requirements and the design reference guidelines are explained in detail in this document, providing the user an option to repeat tests and verify consistent response.

The knee assembly is examined using the standard calibration tests listed in the Code of Federal Regulations Part 572, Subpart E. The performance of the knee slider is verified with the calibration test in the SAE Engineering Aid 23.

III. DEFINITION OF FOOT POSITIONS

The sign convention utilized during testing follows the standardized dummy coordinate system listed in the SAE Information Report J211, and is shown in Figure 3. The foot is at 0E plantarflexion and dorsiflexion when the bottom of the foot sole plate is 90E relative to the YZ plane. The foot is at 0E inversion and eversion when the bottom of the foot sole plate is 90E relative to the XZ plane. The foot is at 0E rotation about the Z-axis when the midline of the foot sole plate is 90E relative to the XY plane. Neutral position of the foot is defined as 15E plantarflexion (bottom plane of the sole plate is rotated 105E from the midline of the tibia), 0E inversion and eversion, and 0E rotation about the Z-axis. Neutral position is depicted in Figure 4. The sign convention for dorsiflexion is positive rotation about the Y-axis, while plantarflexion is negative rotation about the Y-axis. Inversion is defined as foot rotation about the X-axis toward the midline of the body, and eversion is foot rotation about the X-axis away from the midline of the body. In Figure 3, a right foot is shown.

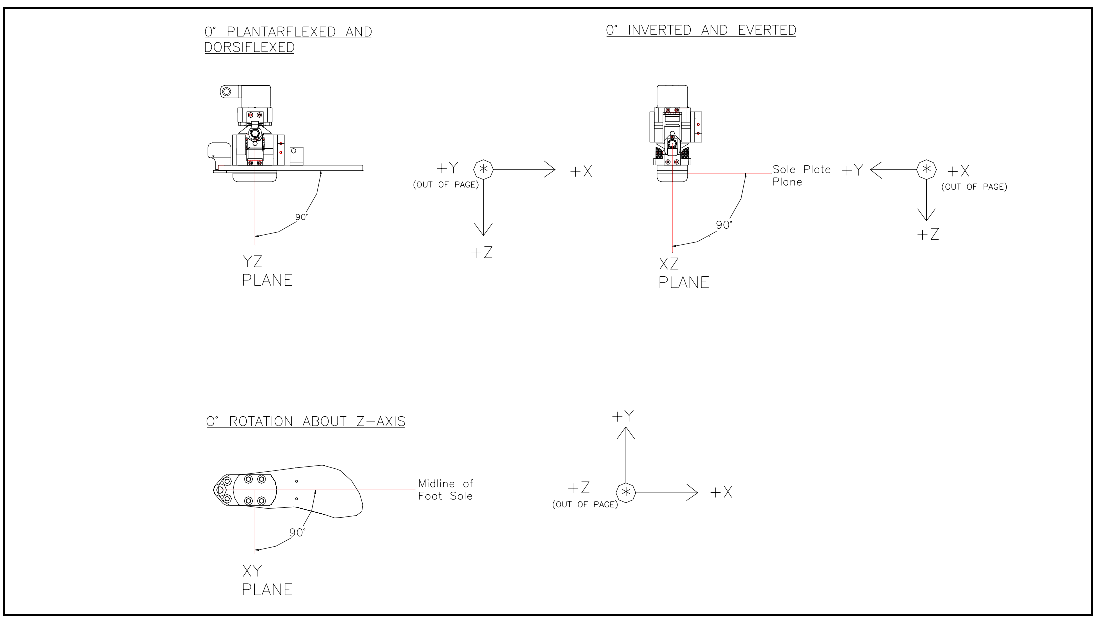

Figure 3. Definition of Foot Positions

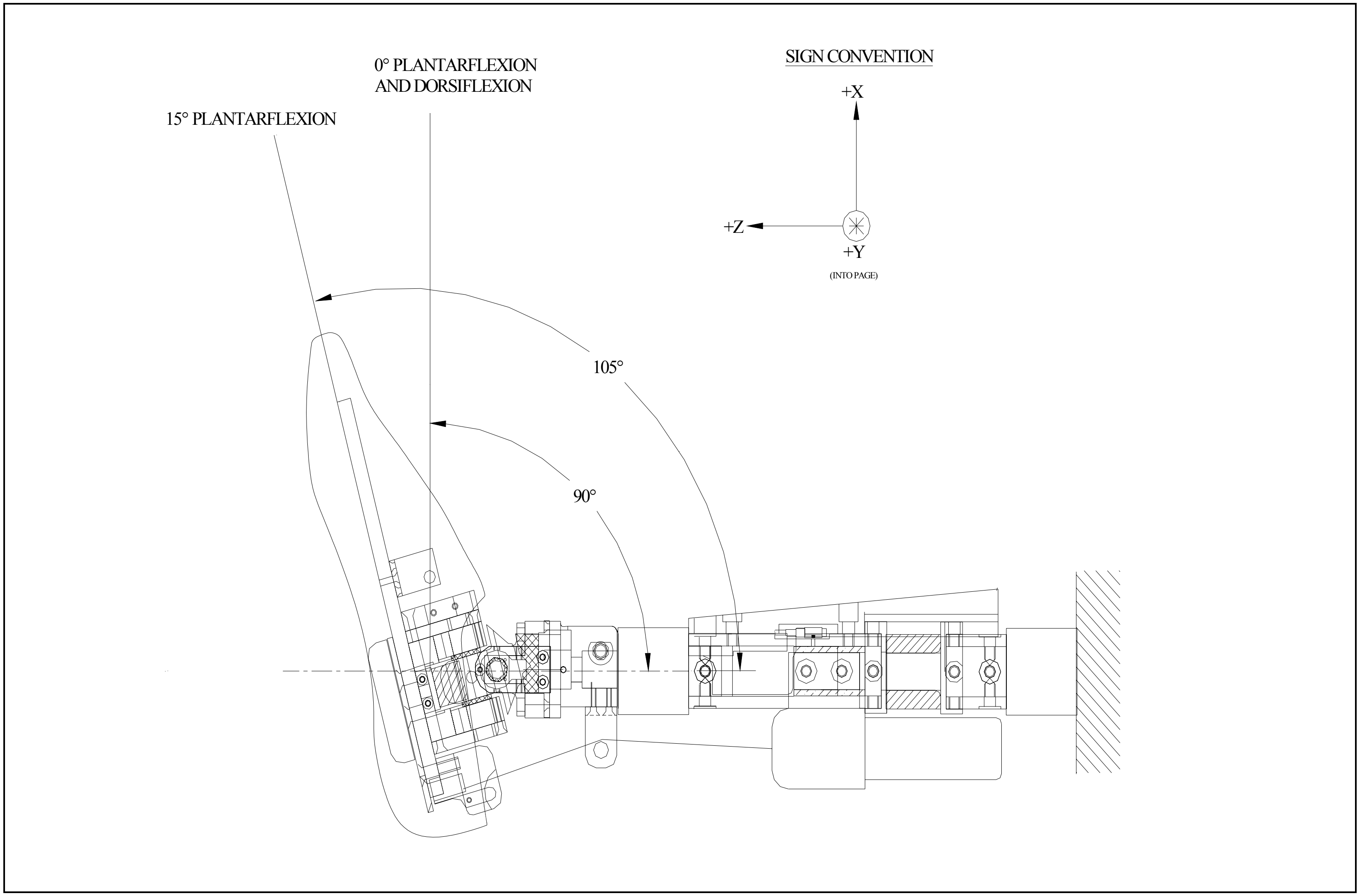

Figure 4. Thor-Lx/HIIIr in neutral position

IV. QUASI-STATIC ANKLE MOTION TESTS

(A) The quasi-static ankle motion tests examine the range of motion and resistance of the ankle joint soft stops in inversion and eversion. Similar tests are used as design reference guidelines for dorsiflexion with the Achilles tendon, dorsiflexion without the Achilles tendon, and plantarflexion. The procedure and corridors for the design reference guidelines are listed in Appendix A.

(B) The test fixtures used in the quasi-static ankle motion test can be determined by the test lab and are subject to variation. The experimental setup used at the NHTSA Vehicle Research and Test Center (VRTC) is explained in detail along with accompanying figures and sample test data in Appendix B.

(C) The Thor-Lx/HIIIr parts required for the quasi-static tests are (See Figure 2):

- Ankle Assembly
- Achilles Assembly
- Tibia Assembly
- X, Y, and Z-axis rotary potentiometers

(D) **Test Procedure - Inversion/Eversion Quasi-Static Tests**

1. Inspect the dorsiflexion/plantarflexion and inversion/eversion soft stop assemblies for uneven wear, tears, or other damage. Check for smooth rotation of the ankle about all three axes.

2. Soak the ankle, foot, and tibia assemblies in a controlled environment at a temperature between 69E and 72EF for at least four hours prior to testing. The test environment should have the same temperature as the soak environment.

3. Rigidly mount the tibia and align the foot at zero position (0E dorsiflexion, plantarflexion, inversion, and eversion, 0E rotation about Z-axis, Figure 5). Since the Thor-Lx/HIIIr naturally rests at 15E plantarflexion, an external device will be necessary to hold the foot at 0E plantarflexion for the inversion/eversion tests. Figure 6 shows an example of a bracket design that can be used to maintain 0E plantarflexion. This bracket is held in tension around the ankle center block dorsiflexion stops and the ankle flange. (Note: Rotation about the Z-axis is undesirable during the quasi-static tests and should be prevented.)

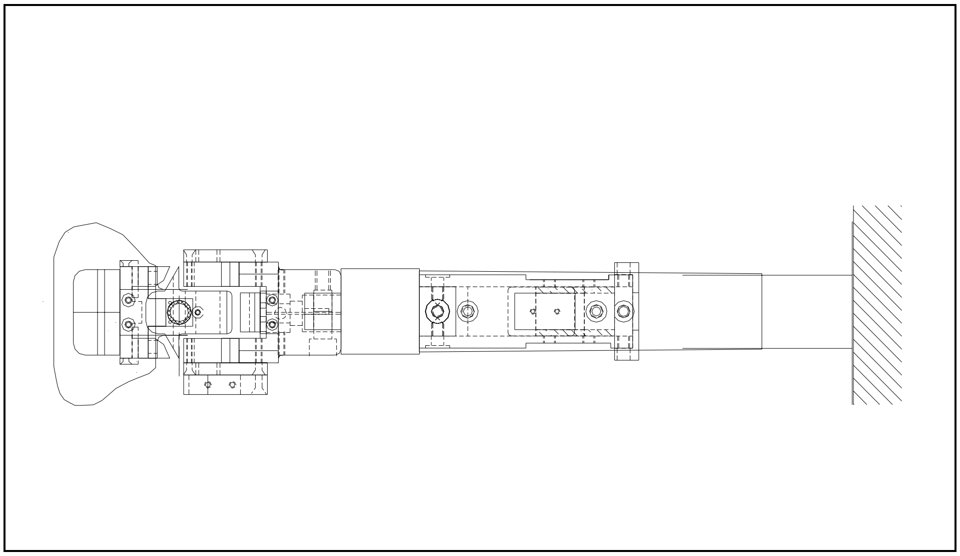

Figure 5. Initial ankle starting position for inversion/eversion quasi-static test

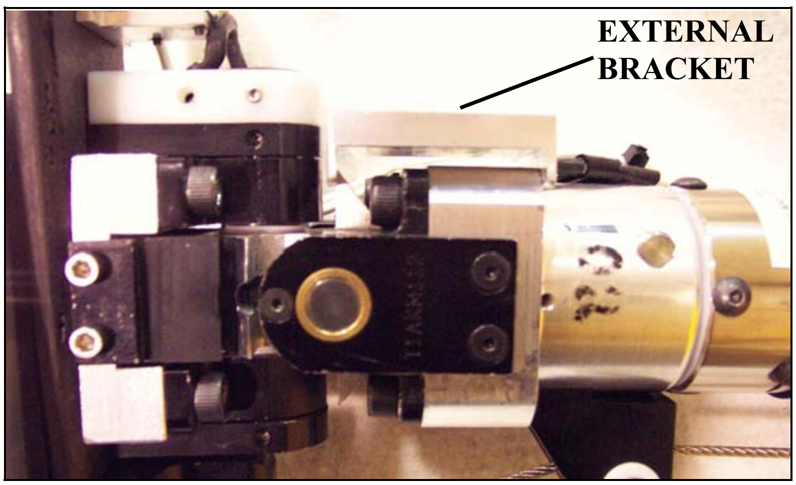

Figure 6. Thor-Lx/HIIIr with example external positioning bracket.

4. Detach the Achilles cable from the Lower Achilles Mounting Post by removing the #4 - 40 x 1/2" socket head cap screw and sliding the ball of the cable out of the slot at the back of the heel. (See Thor-Lx/HIIIr User's Manual)

5. The potentiometer channels should be set according to calibration values provided by the manufacturer and verified for accuracy. (See Thor-Lx/HIIIr User's Manual).

6. Rotate the ankle from the initial starting position to 37-38E inversion or eversion at a rate of 1-2E/second. (Note: Do not rotate beyond 38E to avoid damage as this angle is near the joint mechanical limit.)

7. Calculate the torque at the ankle joint. Sample calculations for the VRTC test setup are shown in Appendix B.

8. Allow at least 30 minutes between successive tests with the same leg assembly.

(E) Performance Specifications - Inversion/Eversion Quasi-Static Tests

1. The angle at which the following torque values are measured should be within the corresponding ranges:

Inversion/Eversion	at 6 N·m:	17.5 - 21.3E
	at 23 N·m:	29.3 - 35.9E

The corridors for the quasi-static test design reference guidelines are listed in Appendix A.

V. DYNAMIC IMPACT TESTS

(A) Two dynamic impact tests validate the performance of the ankle and the compliant elements in the foot and tibia. The anatomical areas of pendulum impact are the ball of foot and heel of foot.

(B) The Thor-Lx/HIIIr components required for the dynamic impact tests are (See Figure 2):

- foot assembly
- ankle assembly
- tibia assembly
- Achilles assembly
- five channel lower tibia load cell
- four channel upper tibia load cell (heel of foot test only)
- X, Y, and Z- axis ankle rotary potentiometers

(C) The required fixtures for this test are:

- NHTSA Dynamic Impactor (TLX-9000-013, Figure 7)
- Tibia Mounting Fixture (TLX-9000-004, Figure C-4, ball of foot test only)

(D) The impactor used for the dynamic strikes to the ball and heel of the foot is shown in Figure 7. The combined mass of the impactor face, ballast, and 1/3 of the supporting tube is 5kg (11 lbs). Because the densities and weights of some materials may vary, slight adjustment of the dimensions may be needed to achieve the same 5kg (11 lbs) mass. Detailed drawings of the individual pendulum arm components are shown in Appendix C. The pendulum arm is mounted to a rigid shaft which is pivoted on low friction ball bearings. The supporting structure for the NHTSA Dynamic Impactor is determined by the test facility.

(E) The data acquisition system must conform to requirements of the 1996 revision of SAE Recommended Practice J211. Filter all data channels using Channel Class 600 phaseless filters.

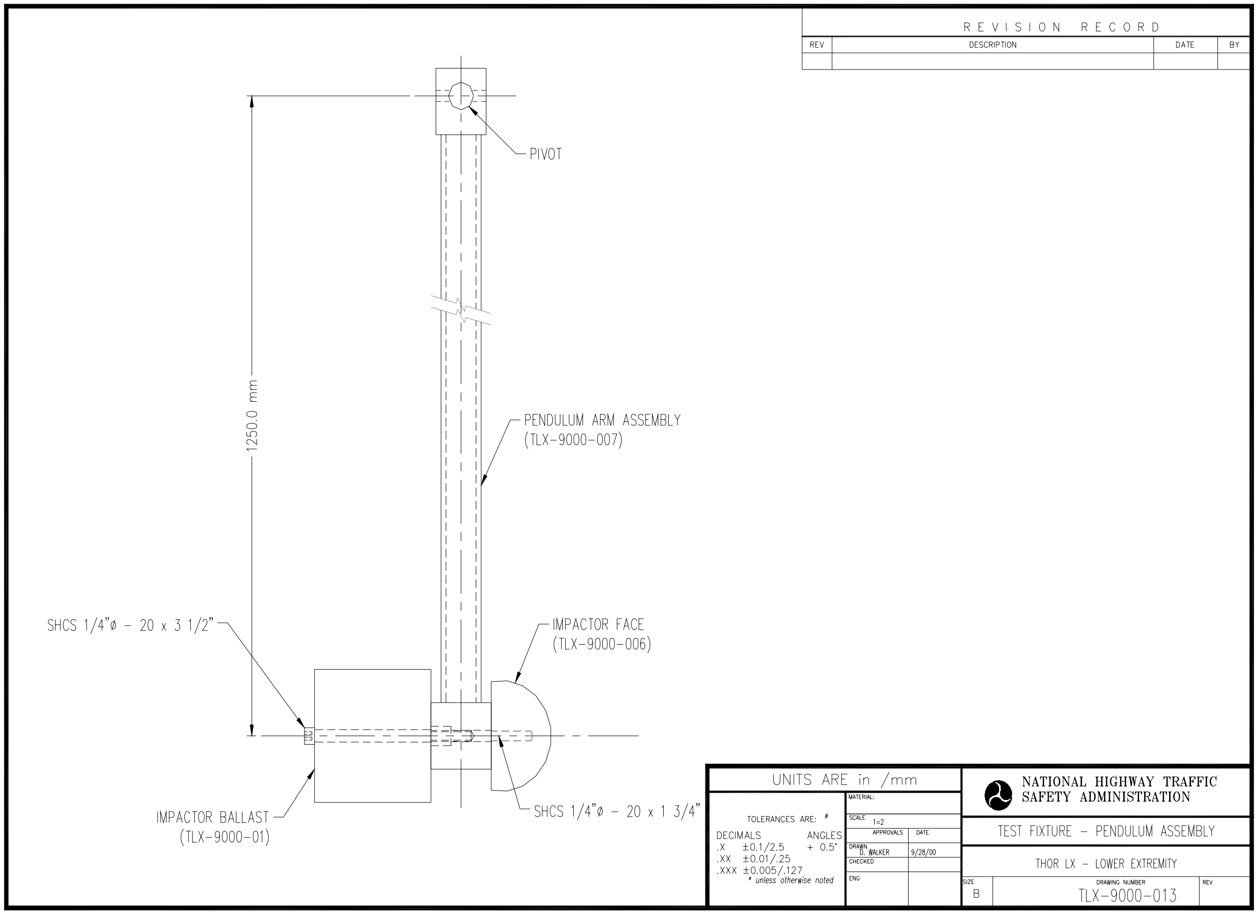

Figure 7. NHTSA Dynamic Impactor

(F) Test Procedure - Ball of Foot Impact (Dorsiflexion)

This test consists of a dynamic impact to the ball of the foot. The leg is held rigidly with the tibia horizontal (Figure 8).

1. Inspect the ankle soft stops for tears, permanent deformations, or separation from the soft stop brackets. Inspect the foot skin for wear and tears.

2. Soak the ankle, foot, and tibia assemblies in a controlled environment at a temperature between 69E and 72E F for at least four hours prior to a test. The test environment should have the same temperature as the soak environment.

3. Remove the Tibia Compliant Bushing Assembly (Figure 2) and mount the leg to the Tibia Mounting Fixture (TLX-9000-004, Figure C-4) at the lower flange, with the toe pointing upward, as shown in Figure 8. The certification corridors were designed with the Tibia Compliant Bushing Assembly removed, and testing with this assembly attached to the leg may alter performance and is not desirable. The behavior of the Tibia Compliant Bushing Assembly is examined in the heel of the foot impact tests. The test fixture must be rigidly secured so that it does not move during impact.

4. Attach the Achilles Spring Cable to the Lower Achilles Mounting Post and verify that the spring cable tension is correctly adjusted. (See Thor-Lx/HIIIr User's Manual).

5. Potentiometer channels should be set according to calibration values provided by the manufacturer and verified for accuracy. (See Thor-Lx/HIIIr User's Manual.)

6. Allow the foot to rest in neutral position (Figure 4). Verify with the Y-axis potientiometer that the foot is at 15 +/- 1E plantarflexion. Leave the foot in neutral position for impact. Readjust the foot to this position if necessary between impacts.

7. Adjust the fixture so that the longitudinal centerline of the pendulum arm is vertical at impact, and the point of impact is 102.6 mm (4.04 in) above the ankle Y-axis pivot point (Figure 8).

8. Wait at least 30 minutes between successive impacts to the same foot.

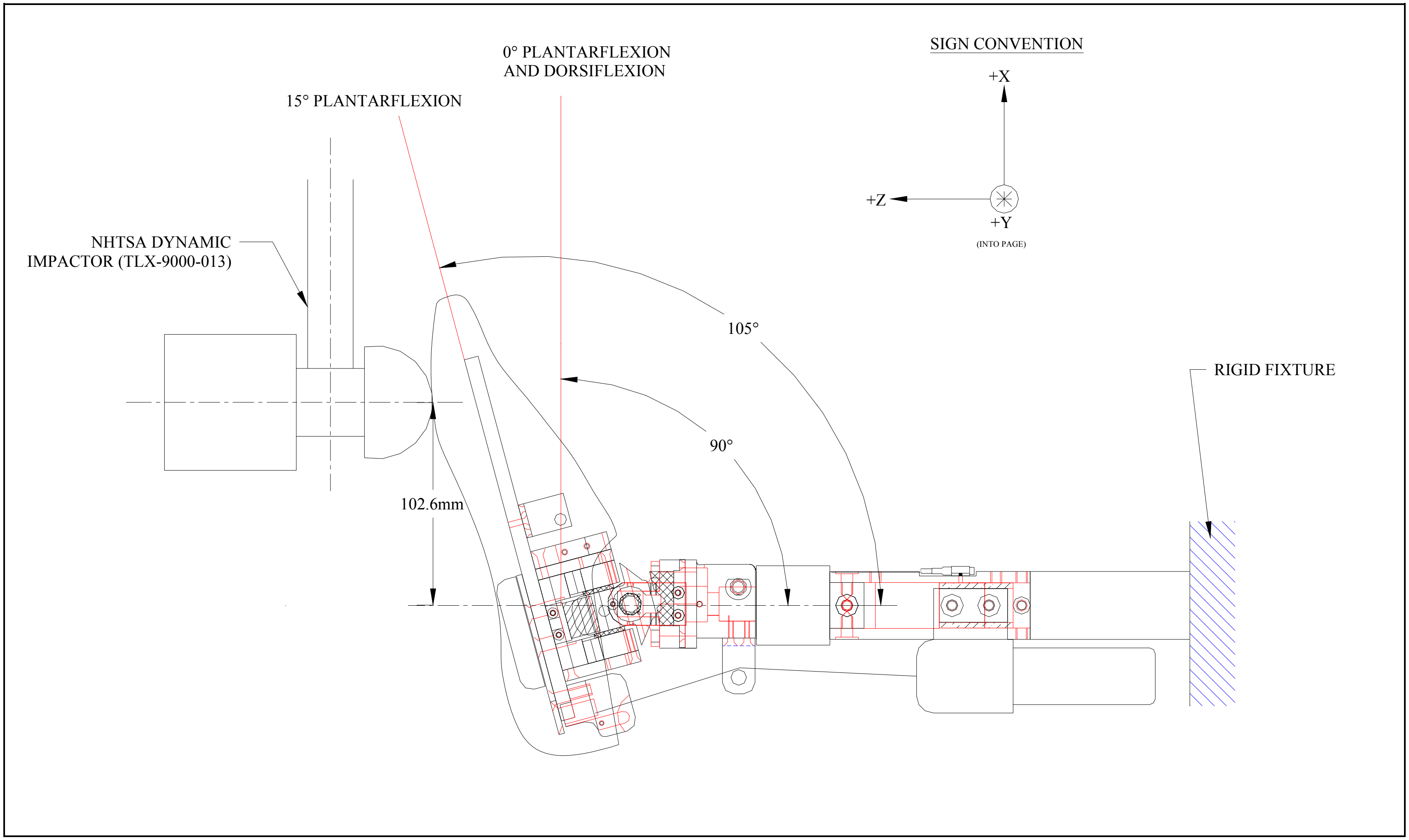

Figure 8. Ball of Foot Impact Test Setup

(G) Performance Specification - Ball of Foot Impact (Dorsiflexion)

1. Release the pendulum and allow it to fall freely from a height to achieve an impact velocity of 5.0 ± 0.1 m/s (16.4 ± 0.3 ft/s).

2. Time-zero is defined as the time of initial contact between the pendulum impactor and the ball of the foot. All channels, except the Y-axis rotary potentiometer, should be zero at this time.

3. Record all data channels.
   - Lower Tibia Load Cell - Fx, Fy, Fz, Mx, My
   - X, Y, and Z-axis Rotary Potentiometers

4. Cross plot the lower tibia compressive force (Fz) and ankle Y-axis potentiometer channel to obtain a lower tibia compressive force vs. dorsiflexion curve (Figure 9, example). Determine the peak lower tibia compressive force from the graph.

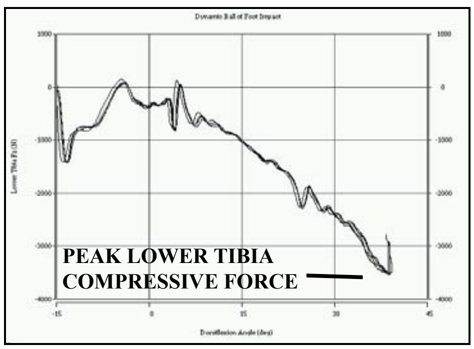

Figure 9. Lower tibia compressive force vs. dorsiflexion angle for ball of foot impact

5. Compute the ankle resistive moment by My - (a * Fx) where:

   My = Moment about Y-axis measured at lower tibia load cell
   Fx = Force measured in X-direction
   a = distance from center of lower tibia load cell to dorsiflexion ankle joint (for Thor-Lx/HIIIr, a = 0.0907m)

6. Plot the ankle resistive moment against the dorsiflexion angle. An example is shown below in Figure 10. Determine the peak ankle resistive moment from the graph.

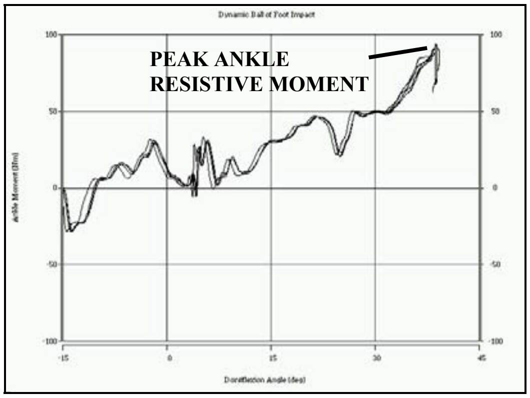

Figure 10. Ankle resistive moment vs. dorsiflexion angle for ball of foot impact

7. The certification corridors for the ball of foot impact tests are listed below in Table 2.

Table 2. Certification corridors for ball of foot impact test.

Peak Lower Tibia Compressive Force	3058 - 3738 N
Peak Ankle Resistive Moment	76.2 - 93.2 N·m

The design reference guidelines for the ball of foot impact test examine performance at lower dorsiflexion angles and are explained in Appendix A.

(H) Test Procedure - Heel of Foot Impact Test (Sole/Tibial Compression)

This test consists of a pendulum impact to the heel of the foot. The leg is held rigidly with the tibia horizontal. (Figure 11)

1. Soak the ankle, foot, and tibia assemblies in a controlled environment at a temperature between 69E and 72E F for at least four hours prior to a test. The test environment should have the same temperature as the soak environment.

2. Inspect the tibia compliant bushing assembly for fatigue and deformation. Check the plunger retaining bolts for wear.

3. Remove the knee clevis and mount the tibia to the test fixture at the proximal end of the upper tibia load cell (Figure 2) with the toe pointing upward, as shown in Figure 11. The test fixture must be rigidly secured so that it does not move during impact.

4. Impact the heel at 0 ± 1E plantarflexion. A piece of tape, string, or wire, etc. extending from the toe to the shin guard or another area below the tibia compressive element will be required to hold the foot at this position (Figure 11). (Note: Attaching the tape, string, etc. to areas on the leg proximal to the tibia compressive element may significantly alter the foot from 0E plantarflexion during heel impact and is not desirable.)

5. Zero the instrumentation channels, excluding the rotary potentiometers. Rotary potentiometer channels should be set according to the calibration sheets provided by the manufacturer and verified for accuracy. (See Thor-Lx/HIIIr User's Manual)

6. Adjust the fixture so that the longitudinal centerline of the pendulum arm is vertical at impact, and the impact point is aligned with the tibia centerline (Figure 11).

7. Wait at least 30 minutes between successive impacts to the same foot.

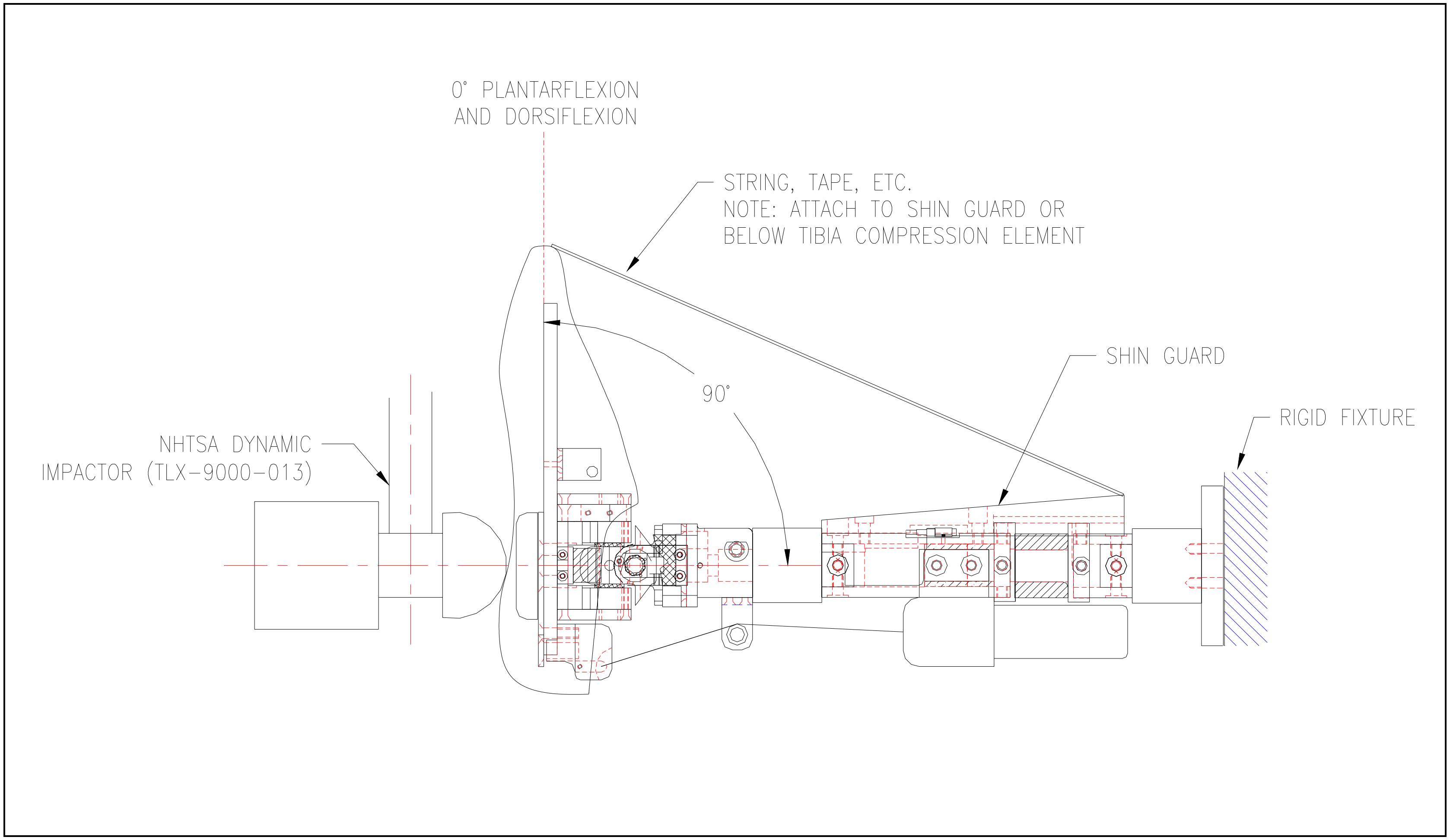

Figure 11. Heel of Foot Impact Test Setup

(I) Performance Specification - Heel of Foot Impact Test (Sole/Tibial Compression)

1. Release the pendulum and allow it to fall freely from a height to achieve an initial impact velocity of 4.0 ± 0.1 m/s (13.1 ± 0.3 ft/s). Time-zero is defined as the time of initial contact between the pendulum impactor and the heel of the foot.

2. Record the following data channels.
   - Lower Tibia Load Cell - Fx, Fy, Fz, Mx, My
   - Upper Tibia Load Cell - Fx, Fz, Mx, My
   - X, Y, Z-axis Rotary Potentiometers

3. The peak compressive force measured by the lower tibia load cell should be within the range of 2694 - 3292 N. The design reference guidelines for the heel of foot impact are explained in Appendix A.

APPENDIX A

Design Reference Guidelines

(A) The design reference guidelines for the Thor-Lx/HIIIr are listed below in Table A-1, along with the corresponding document containing the test description. These tests are performed in addition to the mandatory certification requirements listed above in Table 1. All manufacturer test data from both the mandatory certification requirements and design reference guidelines will be released to the customer with the hardware.

Table A-1. Design reference guidelines for Thor-Lx/HIIIr

Described in this appendix:	*Quasi-Static Tests*	Torque	Angle
	Dorsiflexion with Achilles tendon	40 N·m	16.3 - 19.9E
		92 N·m	33.4 - 40.8E
	Dorsiflexion without Achilles tendon	10 N·m	16.6 - 20.2E
		37 N·m	33.5 - 40.9E
	Plantarflexion	3 N·m	28.2 - 34.4E
		17 N·m	44.0 - 53.8E
	Dynamic Ball of Foot Impact Test		
	Lower tibia My peak between -15 - 0E	74.1 - 90.5 N·m	
	Lower tibia My peak between 0 - 15E	71.3 - 87.1 N·m	
	Dynamic Heel of Foot Impact Test		
	Impulse Loss	2.71 - 3.33 N·sec	
In Drawing Package:	Tibia puck axial static procedure (T1LLM412)		
	Heel pad axial static procedure (T1FTM214)		
	Achilles spring rate axial static procedure (T1LLM300)		
	Achilles spring and tube axial static procedure (T1LLM300)		
	Internal/external rotation moment-angle static procedure (T1LXM001)		
	Rotary potentiometer 10-point calibration procedure (T1AKM000)		
In User's Manual:	Rotary potentiometer zeroing procedure		

(B) QUASI-STATIC TESTS

The design reference guidelines for the quasi-static tests examine the range of motion and resistance of the ankle joint soft stops in dorsiflexion with the Achilles tendon, dorsiflexion without the Achilles tendon, and plantarflexion. The test procedure is similar to that described in Section IV, and is adjusted for the dorsiflexion and plantarflexion tests as follows:

Step 3. Allow the Thor-Lx/HIIIr to rest naturally in neutral position at 15E plantarflexion, 0E inversion and eversion, 0E rotation about Z-axis (Figure 4). This is the initial starting position for the dorsiflexion and plantarflexion tests. The Achilles tendon should be attached only for the dorsiflexion with the Achilles tendon test.

Step 5. Rotate the ankle from the initial starting position to the specified angle at a rate of 1 - 2E/second:

Dorsiflexion: 40-42E

Plantarflexion: 55-57E

(Note: Do not exceed 42E dorsiflexion or 57E plantarflexion to avoid damage as these angles are near the joint mechanical limit.)

The design reference guidelines for the Thor-Lx/HIIIr quasi-static tests are shown above in Table A-1.

(C) BALL OF FOOT DYNAMIC IMPACT TEST (DORSIFLEXION)

To examine the ankle motion response at low dorsiflexion angles, the following analysis is performed:

1. Plot the moment about the Y-axis measured by the lower tibia load cell against the dorsiflexion angle, as shown below in Figure A-1.

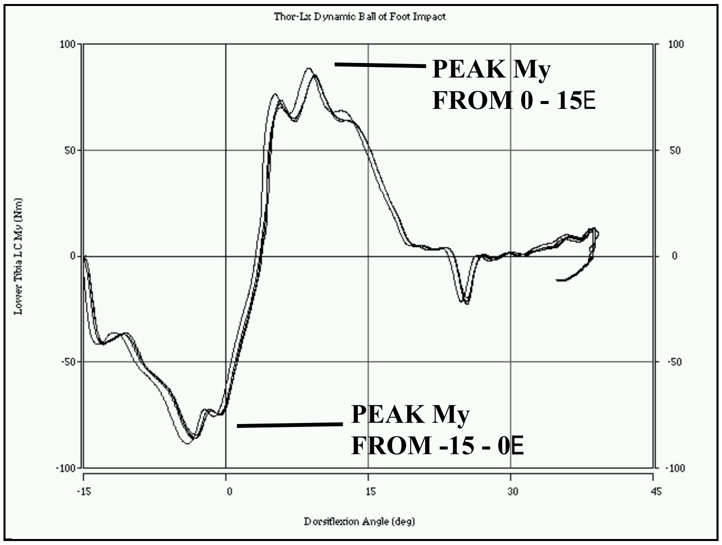

Figure A-1. Moment about Y-axis measured by lower tibia load cell vs. dorsiflexion angle for ball of foot impact.

2. The peak moment about the Y-axis measured by the lower tibia load cell between -15 - 0E dorsiflexion should be between 74.1 - 90.5 N·m.

3. The peak moment about the Y-axis measured by the lower tibia load cell between 0 - 15E dorsiflexion should be between 71.3 - 87.1 N·m.

(D) HEEL OF FOOT DYNAMIC IMPACT TEST (SOLE/TIBIAL COMPRESSION)

As a method for checking the behavior of the tibia compliant bushing assembly, the impulse loss in the dynamic heel impact is calculated as follows:

1. Compute the axial impulse from the lower tibia load cell by $\int F_{ZL}\, dt$ where F_{ZL} is the lower tibial axial force.

2. Compute the axial impulse from the upper tibia load cell by $\int F_{ZU}\, dt$, where F_{ZU} is the upper tibial axial force.

3. Compute the axial impulse loss from the tibia compressive element by $\int F_{ZL}\, dt - \int F_{ZU}\, dt$.

4. The impulse loss during the dynamic heel impact test should be between 2.71 - 3.33 N·sec.

APPENDIX B

VRTC Quasi-Static Test Setup and Fixtures

This appendix describes the experimental setup used for the quasi-static tests at VRTC. The test procedures for mandatory certification requirements and design reference guidelines are explained. This description is meant to be an example; it is not necessary to replicate this setup to run the quasi-static tests. The requirements necessary for certification are explained in Section IV.

(A) The equipment and fixtures utilized in this test are:

- Universal testing machine
- Steel cable of length 559mm (22 in)
- Rigid fixture to horizontally mount Thor-Lx/HIIIr to universal testing machine
- Ankle Moment Arm (TLX-9000-014, Figure B-11)
- Cable Attachment Bracket (TLX-9000-012, Figure B-12)

(B) The data acquisition system must conform to requirements of the 1996 revision of SAE Recommended Practice J211. Filter all data channels using Channel Class 600 phaseless filters.

(C) **Test Procedure**

1. Remove the foot flesh and attach the ankle moment arm (TLX-9000-014, Figure B-11) to the bottom of the Ankle/Achilles mounting plate (T1FTM210) with four 1/4" - 20 x 1-1/4" socket head cap screws, as shown in Figure B-1. The length of the moment arm for this fixture is 254mm (10in).

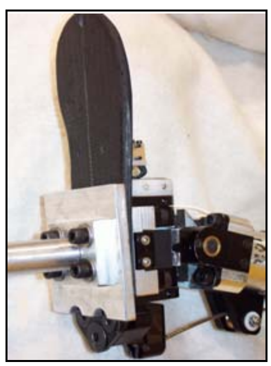

Figure B-1. Quasi-static ankle moment arm attachment.

2. Rigidly and horizontally mount the tibia to the universal testing machine and align the leg as follows:

Dorsiflexion: 15E plantarflexion, 0E inversion and eversion, 0E rotation about Z-axis (Figure B-2)

Plantarflexion: 15E plantarflexion, 0E inversion and eversion, 0E rotation about Z-axis (Figure B-3)

Inversion/Eversion: 0E dorsiflexion, plantarflexion, inversion, and eversion, 0E rotation about Z-axis (Figure B-4)

3. Attach one end of the steel cable to the universal testing machine and the other end to the cable attachment bracket (TLX-9000-012, Figure B-12). The length of the cable assembly is 559mm (22 in).

   The pulling cable should be perpendicular to the ankle moment arm (TLX-9000-014, Figure B-11) at 0E, but will not remain perpendicular to the ankle moment arm throughout the tests. In order to calculate the torque at the ankle joint, the following variables are defined and illustrated in Figure B-2, B-3, and B-5:

   ϕ = angle between pulling cable and vertical
   θ = rotation angle at ankle pivot
   l = length of cable
   a = length of moment arm
   P = pulling force on cable

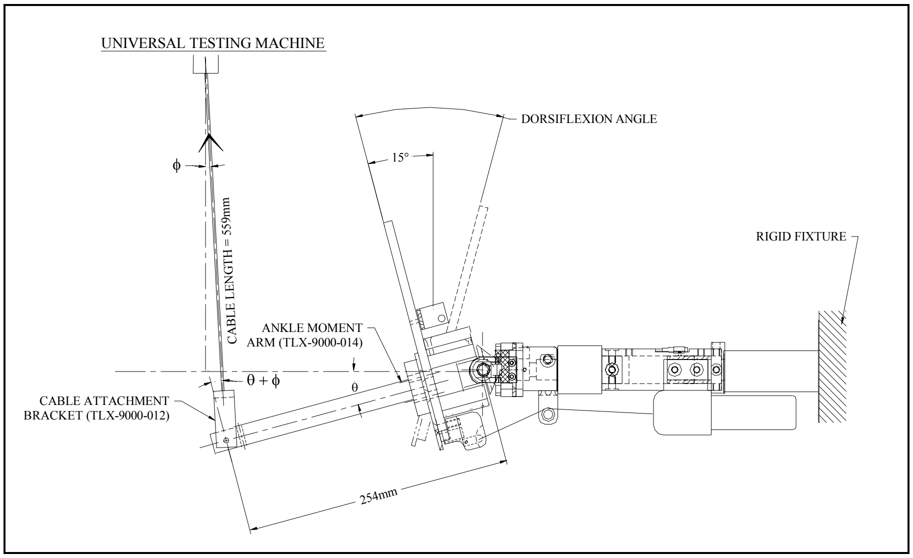

Figure B-2. Quasi-static dorsiflexion test starting position

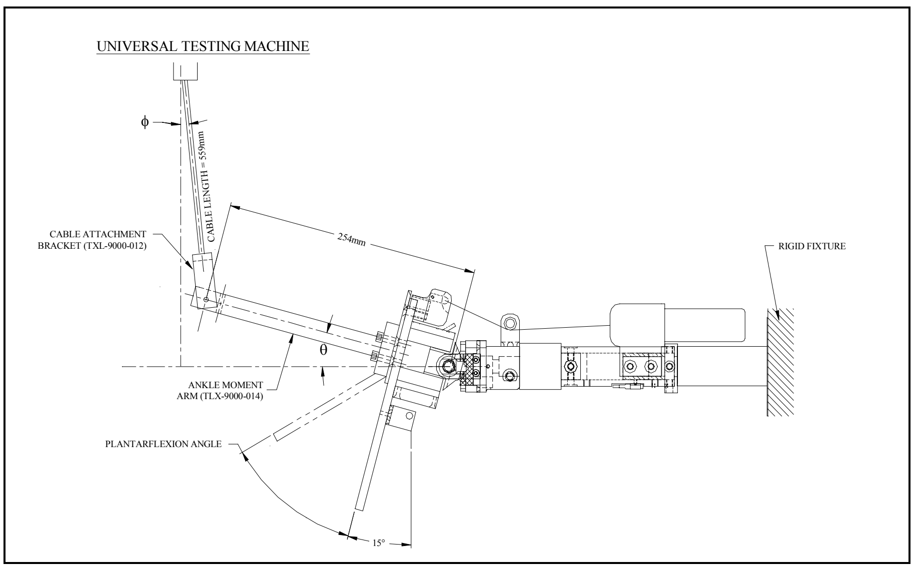

Figure B-3. Quasi-static plantarflexion test starting position

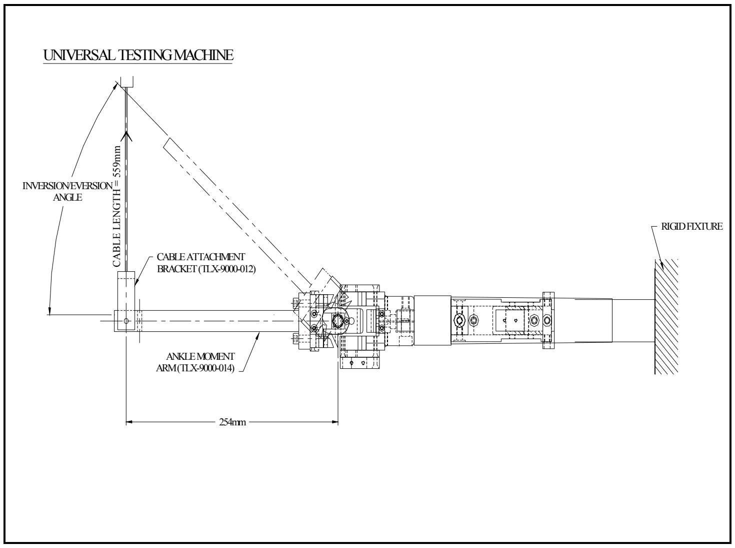

Figure B-4. Quasi-static inversion/eversion test starting position

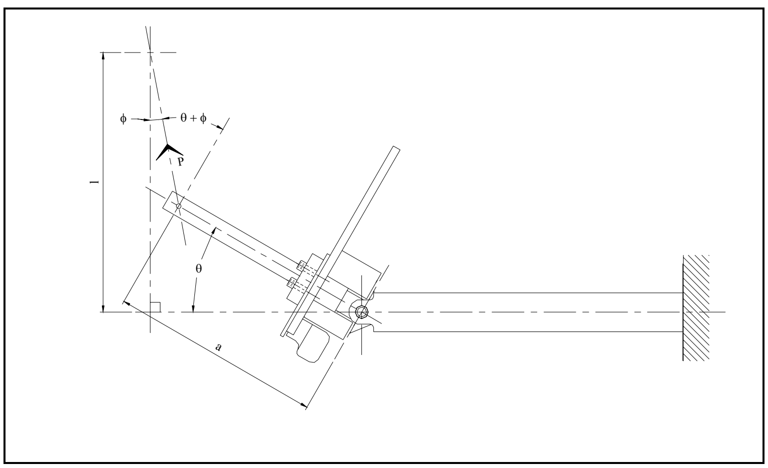

Figure B-5. Geometry setup for quasi-static tests

The torque at the ankle joint is determined as follows:

First, defining ϕ :

$$\phi = \sin^{-1}\left(\frac{a - a\cos\theta}{l}\right) \tag{1}$$

or:

$$\phi = \sin^{-1}\left(\frac{a - a\cos\theta}{l}\right) \qquad (2)$$

The torque about the ankle joint can then be calculated by:

$$Torque(N \cdot m) = P \cdot a\cos(\theta + \phi) \qquad (3)$$

In this test setup, a = 254mm (10in) and l = 559mm (22in).

For example, during the dorsiflexion test with the Achilles tendon, the rotation angle at the ankle pivot point (θ) is 20.08E (0.35 radians) and the cable pulling force (P) is 187.7N. Substituting into equation 2:

$$\phi = \sin^{-1}\left(\frac{254mm - 254mm\cos(0.35rad)}{559mm}\right)$$

$$\phi = 0.0276rad$$

Using equation 3 to determine the ankle torque:

$$Torque(N \cdot m) = 187.7N \cdot 0.254m\cos(0.35 + 0.0276)$$

$$Torque = 44.32N \cdot m$$

4. Verify the potentiometer accuracy using the rotary potentiometer calibration fixture (See Thor-Lx/HIIIr User's Manual).

5. Once the foot is oriented in the proper test starting position, zero all instrumentation channels, except the potentiometers.

6. Pull up on the cable assembly at a rate of 400 mm/min (15.7 in/min) using a moment arm distance of 254mm (10in) until the angle specified below for each test is attained.

Dorsiflexion: 40-42E

Plantarflexion: 55-57E

Inversion/Eversion: 37-38E

(Note: Do not exceed the maximum angles in these ranges to avoid damage.) Using a cable assembly length of 559mm (22in), the true pulling force is the force applied by the universal testing machine.

7. Record all data channels.
   - X, Y, and Z-axis Rotary Potentiometers
   - Displacement
   - Applied Load

8. Calculate the ankle torque as described in Step 4.

9. Allow a minimum of 30 minutes between tests with the same leg assembly.

(D) Performance Specifications

1. Sample Thor-Lx/HIIIr torque-angle plots with biofidelic response specifications are shown in Figures B-6 - B-10.

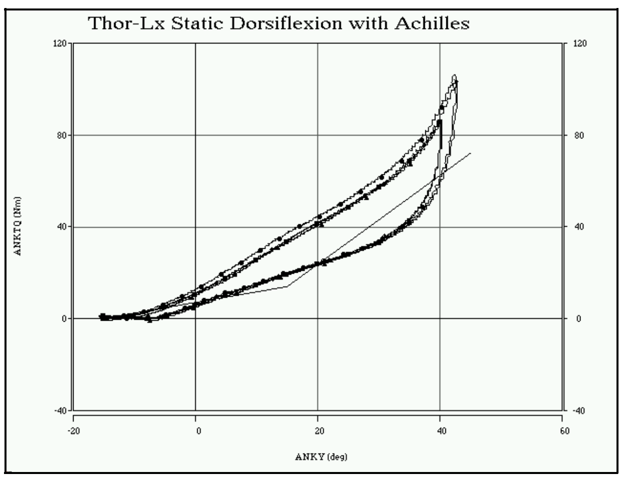

Figure B-6. Thor-Lx/HIIIr dorsiflexion with Achilles tendon torque-angle response with biofidelic specification.

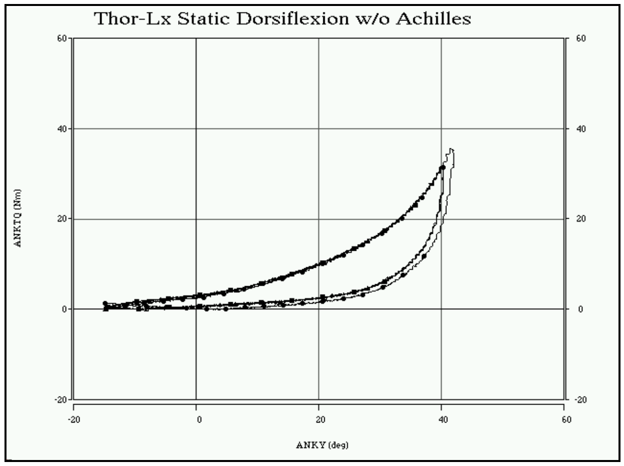

Figure B-7. Thor-Lx/HIIIr dorsiflexion without Achilles tendon torque-angle response.

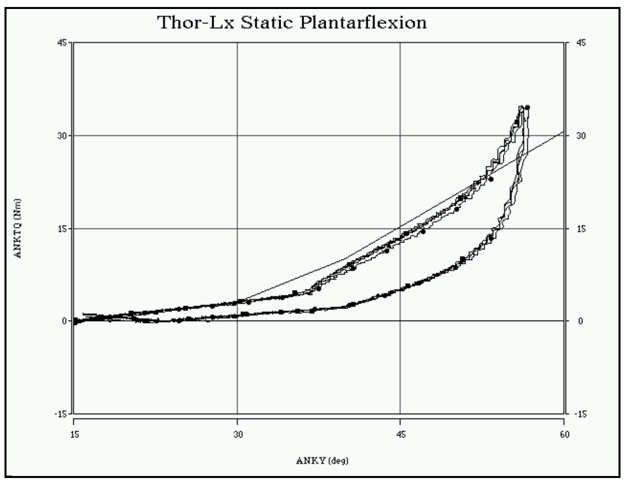

Figure B-8. Thor-Lx/HIIIr plantarflexion torque-angle response with biofidelic specification.

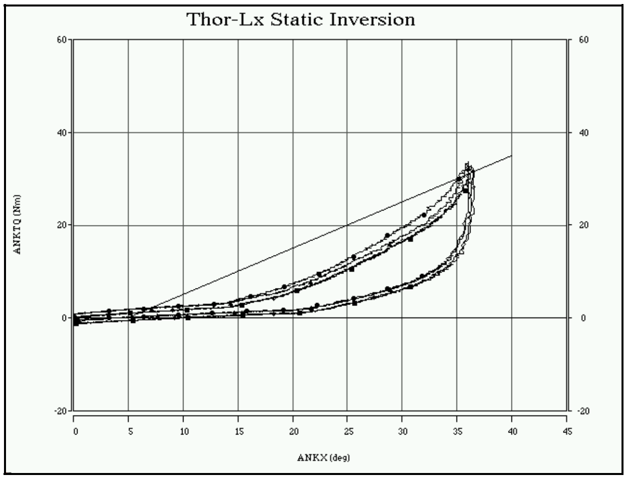

Figure B-9. Thor-Lx/HIIIr inversion torque-angle response with biofidelic specification.

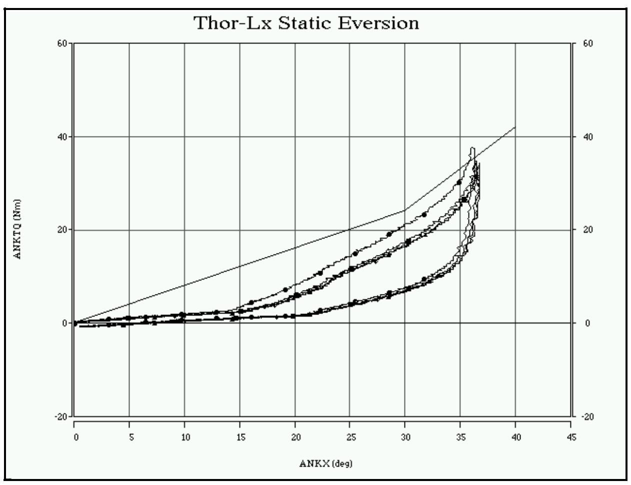

Figure B-10. Thor-Lx/HIIIr eversion torque-angle response with biofidelic specification.

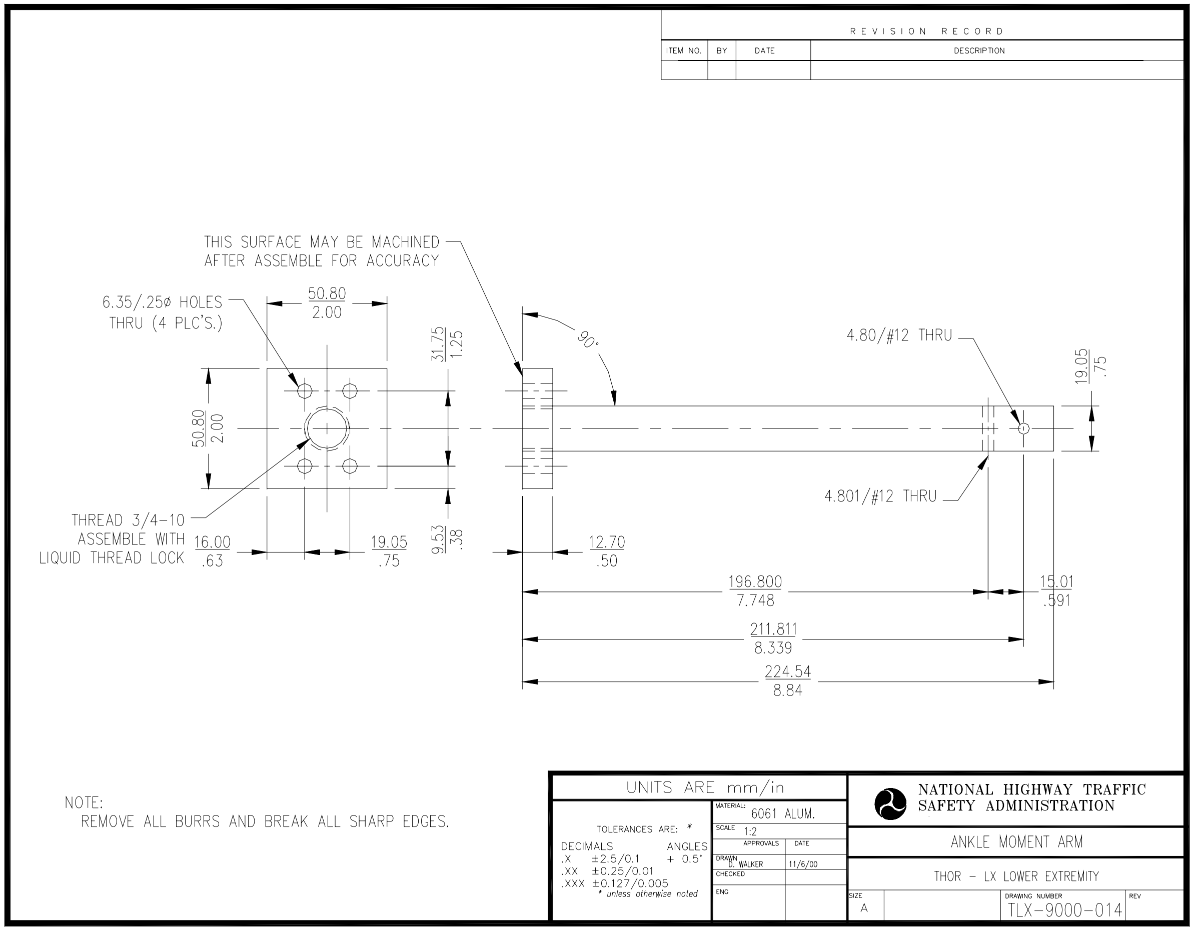

Figure B-11. Ankle moment arm

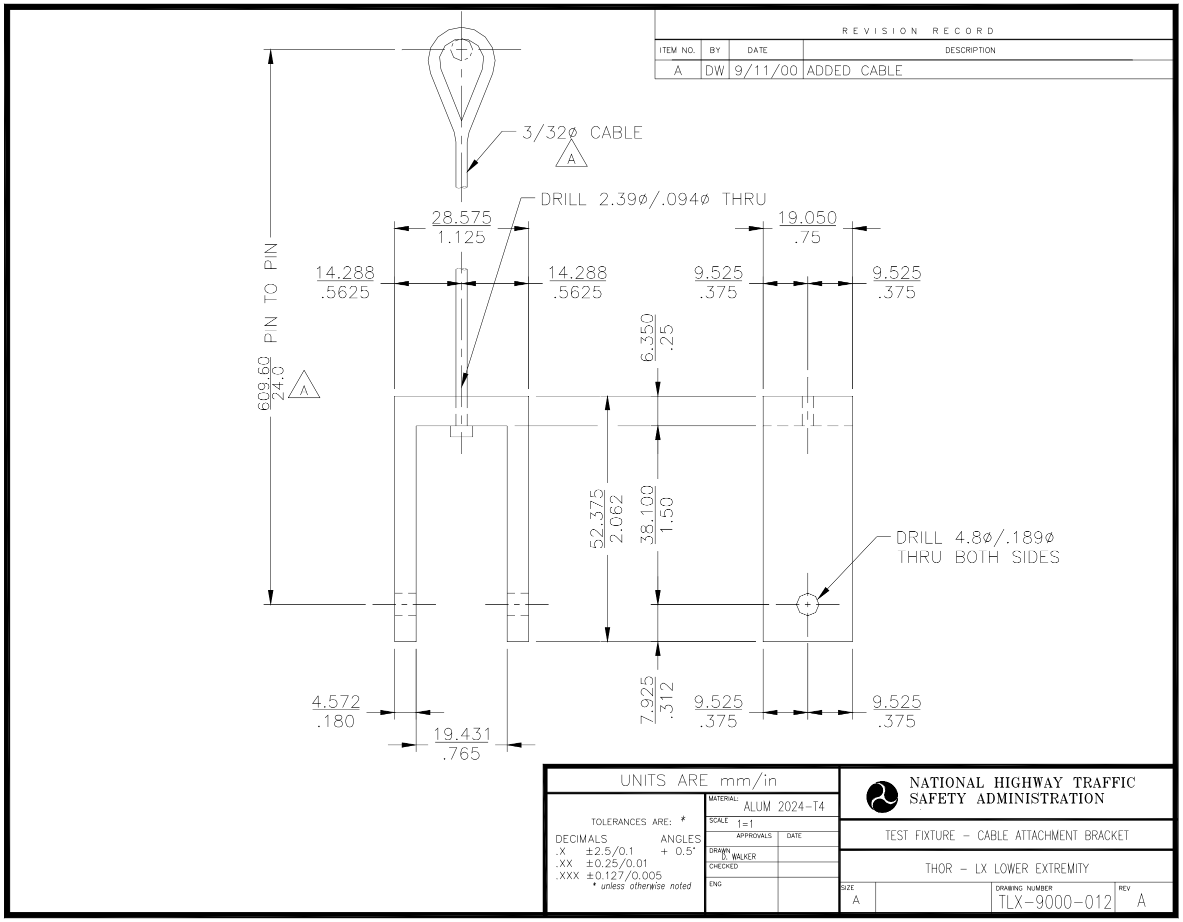

Figure B-12. Cable attachment bracket

APPENDIX C

Dynamic Impact Test Fixtures

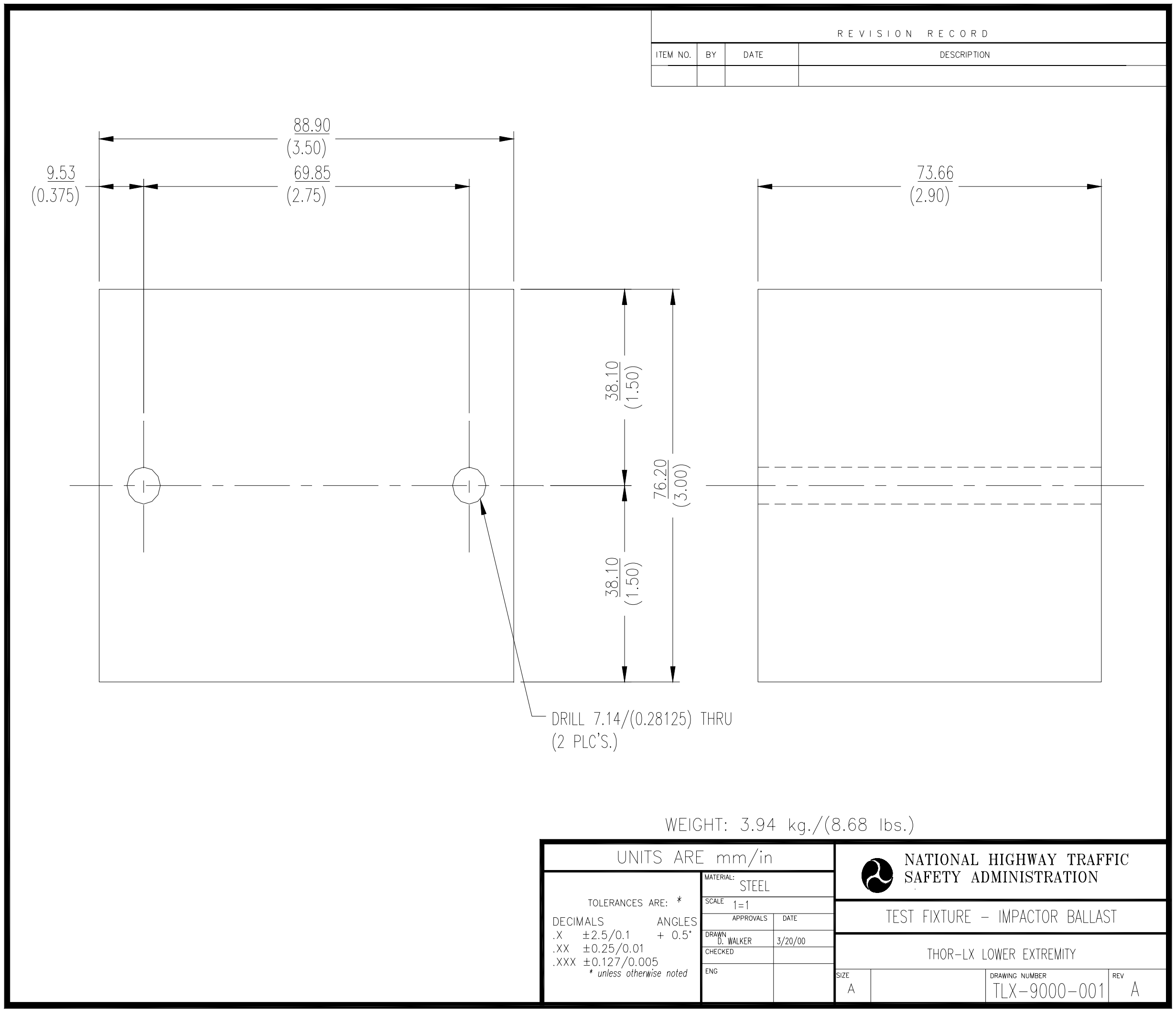

Figure C-1. Impactor ballast

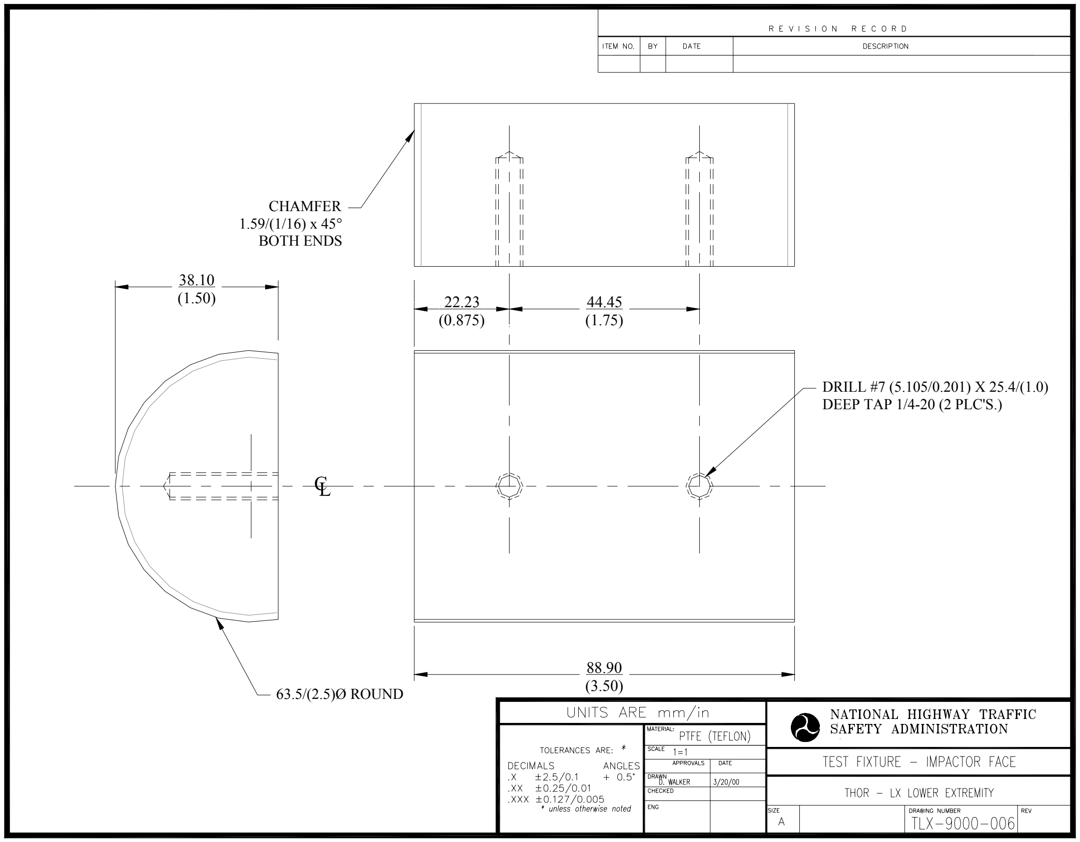

Figure C-2. Impactor face

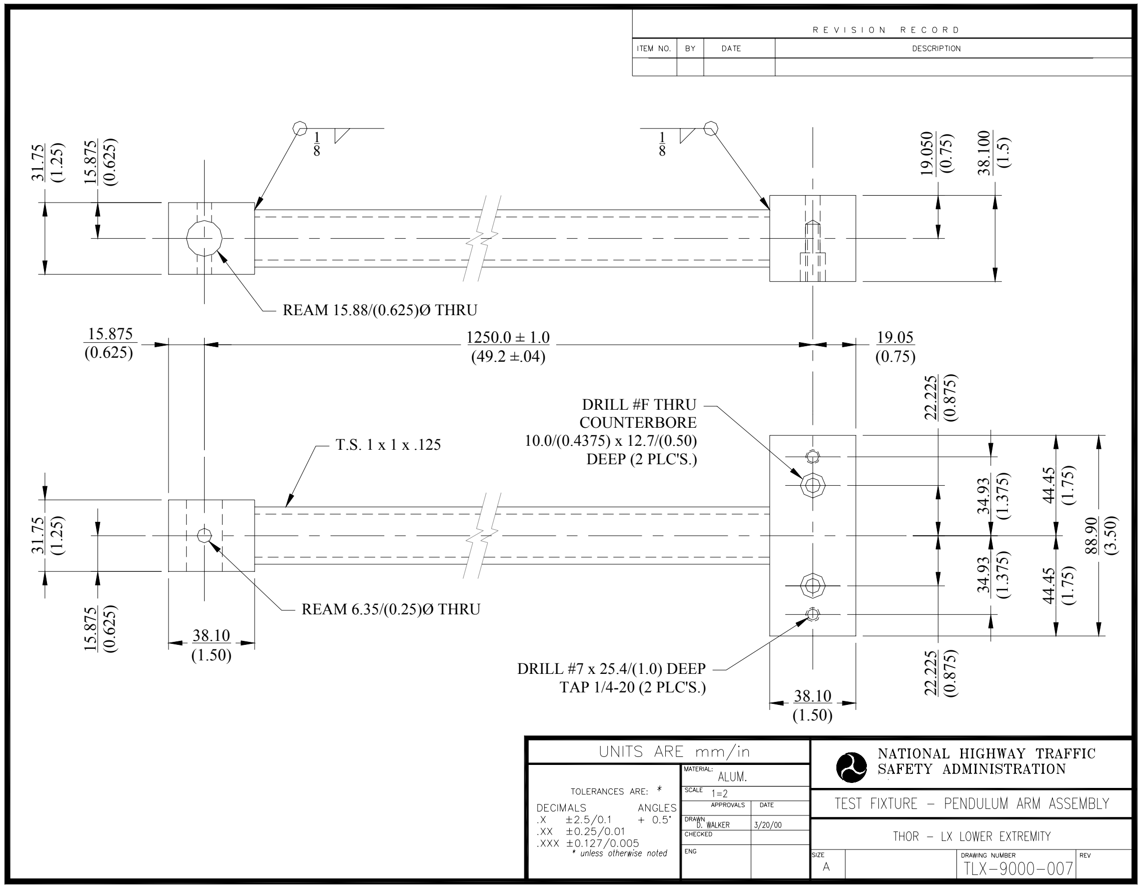

Figure C-3. Pendulum arm

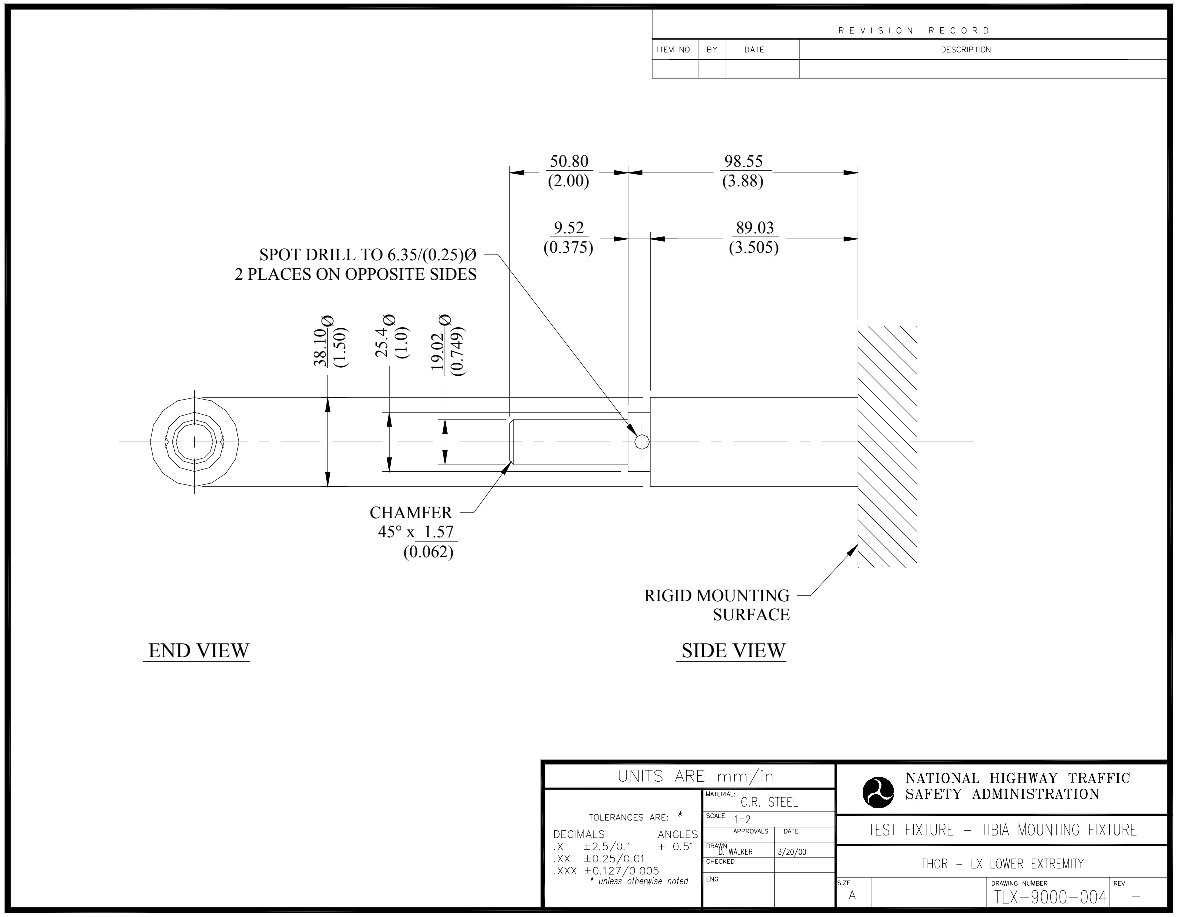

Figure C-4. Tibia mounting fixture