SECTION 13- THOR-LX ASSEMBLY

13.1 THOR-LX Assembly Description and Features

The lower extremity, THOR-LX, of the THOR dummy is a representation of the human lower extremity. The mechanical design of the THOR-LX unit provides several advances over previous lower extremity designs. The stock Hybrid III knee housing is used with the updated ball bearing knee slider assembly. A pair of urethane knee covers are attached to the lateral sides of the knee housing to provide the correct knee profile for knee / bolster interaction. A compliant section was designed into the tibia shaft to provide the correct force transmission from the heel to the knee complex. A spring damper Achilles tendon system was designed to aid in producing the desired ankle motion and torque characteristics. The rotation of the ankle joint about the z-axis (internal and external rotation) has been redesigned to provide a joint torque characteristic which is similar to measured human data. This rotation joint also provides the capability to be locked out for calibration. The new ankle design provides the correct joint axes placement and correct torque vs. angle response for the two primary axes (dorsi / plantar-flexion and inversion / eversion) The range of motion in all three principal directions of rotation was increased to the specifications provided by NHTSA. Soft stop elements were used to provide human-like stiffness at the extremes of motion. The knee, tibia and foot skins were redesigned to be lighter weight and to integrate with the hardware. The mechanical elements of the THOR-LX design can be seen in **Figure 13.1**.

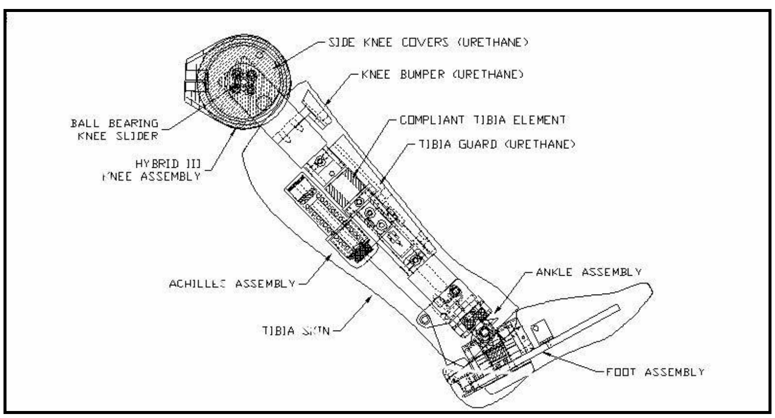


Figure 13.1 - Mechanical THOR-LX

The THOR-LX was also updated with many new sensors to increase the ability of the dummy to measure injury and trauma. Robert Denton Inc. designed a pair of tibia load cells to measure the force and moment data for the tibia shaft. (The upper tibia load cell is a four channel unit, while the lower one provides five channel capability). Three rotary potentiometers were used to measure the rotation of the individual ankle joints, thereby providing complete kinematic data. A pair of uniaxial accelerometers on the tibia shaft provide the acceleration in the X and Y axes to allow the transformation of the measured tibia moment to the calculated ankle moment. Finally, a single triaxial accelerometer unit on the foot was included to enable correlation with prior foot / ankle injury tolerance studies. The instrumentation in the THOR-LX unit is depicted in **Figure 13.2.**

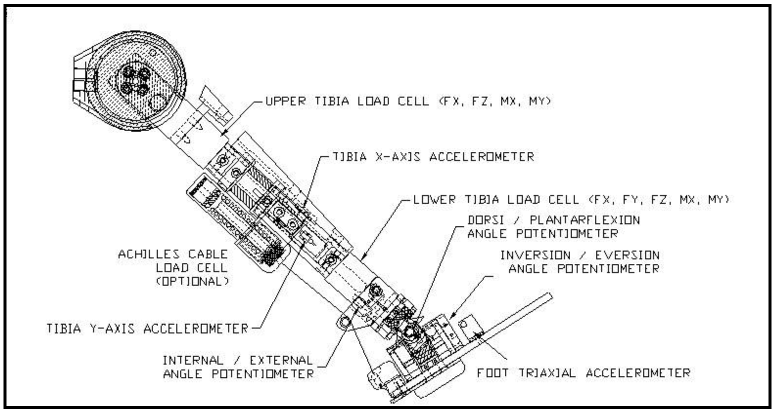


Figure 13.2- THOR-LX Instrumentation

13.2 Assembly of the THOR-LX

13.2.1 Parts List

The part list for the THOR-LX assembly is listed in the drawing package under the Bill of Materials section. All quantities are listed in the Bill of Materials. Refer to drawing T1LXM000 in the THOR drawing set for a detailed mechanical assembly drawing. **Figure 13.3** is a photograph of the exploded lower extremity assembly and hardware.

Figure 13.3- Exploded View of THOR-LX

13.2.2 Assembly of THOR-LX Components

The following procedure is a step-by-step description of the assembly procedure for the THOR-LX components. The numbers provided in ( ) refer to a specific drawing / part number of each particular part. The numbers noted in { } after the bolt size indicate the size of the hex wrench required to perform that step of the assembly. All bolts should be tightened to the torque specifications provided in Section 2.1.3.

1. The Upper Tibia Load Cell (Denton: Model 4353) is connected to the Upper Tibia Tube (T1LLM011) using four 1/4-28 x ½" BHSCS {5/32}, as shown in **Figure 13.4**.

NOTE: THE UPPER LOAD CELL X-AXIS MUST BE ORIENTED TOWARD THE FRONT OF THE LOWER EXTREMITY ASSEMBLY AS IT IS PUT TOGETHER.

Figure 13.4- Upper Tibia Load Cell Connected to Upper Tibia Tube

2. The Upper Tibia Tube is connected to the Upper Flange of the Tibia Compliant Bushing Assembly (T1LLM400) using three 1/4-28 x ½" BHSCS {5/32} and one 1/4-28 x ½" FHSCS {5/32}, as shown in **Figure 13.5**. The flat head bolt is used in the countersunk hole which is oriented to the rear of the leg assembly (-X axis).

Figure 13.5- Upper Tibia Tube
attached to Compliant Bushing

3. Insert the Compliant Bushing Plunger into the linear bearings within the Lower Tibia Tube (T1LLM010). Rotate the Lower Tibia Tube so that there is a flat mounting surface on the left and right sides, as well as, a flat mounting surface on the front, as shown in **Figure 13.6**. (Note, there should be no flat mounting surfaces on the rear side of the tibia tube, since this side will receive the flat head bolt in the next step.)

Figure 13.6- Proper Orientation of the Lower Tibia Tube

4. Secure the Compliant Bushing Assembly to the Lower Tibia Tube using two Plunger Retaining Bolts (T1LLM413) on the Left and Right Sides, one 1/4-28 x ½" BHSCS {5/32} in the front and one 1/4-28 x ½" FHSCS {5/32} in the rear. This assembly is shown in two views in **Figures 13.7**.

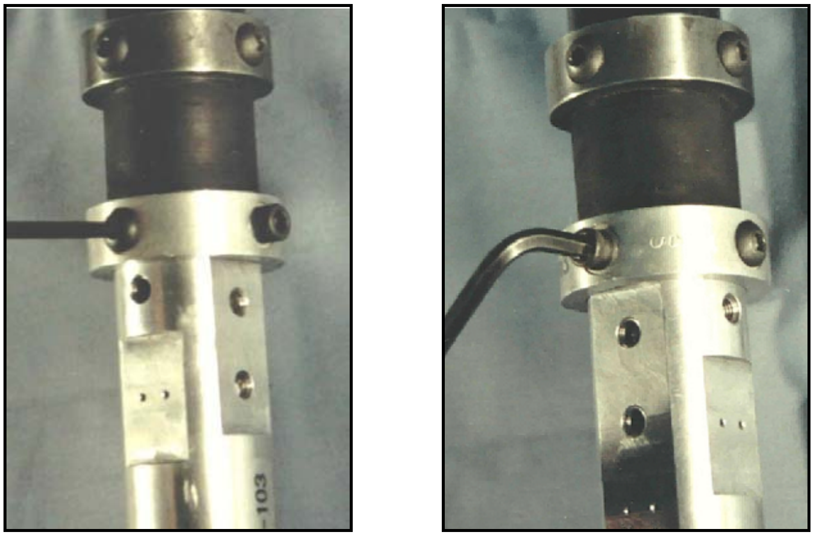


Figure 13.7- Securing the Part # T1LLM413 Compliant Bushing (front) (Left and Right Sides use part # T1LLM413)

5. The Lower Tibia Load Cell (Denton: Model 4929) connected to the bottom of the Lower Tibia Tube using four 1/4-28 x ½" BHSCS {5/32}, as shown in **Figure 13.8**.

NOTE: THE LOWER TIBIA LOAD CELL X-AXIS MUST BE ORIENTED TOWARD THE FRONT OF THE LOWER EXTREMITY ASSEMBLY AS IT IS PUT TOGETHER. THE 3/8" RADIUS NOTCH IN THE LOWER FLANGE OF THE LOAD CELL INDICATES THE POSITIVE X AXIS AND IS ORIENTED TOWARD THE FRONT OF THE ASSEMBLY.

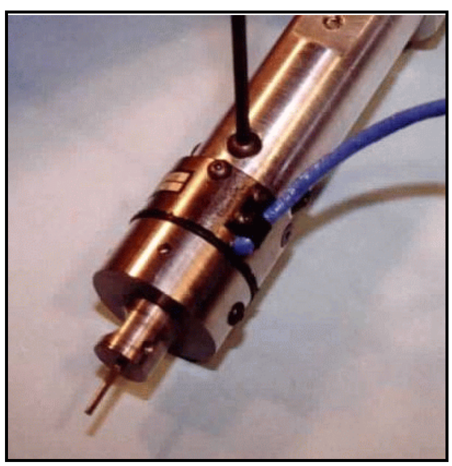


Figure 13.8- Lower Tibia Load Cell attached to Lower Tibia Tube

6. A uniaxial accelerometer unit is attached directly to the mounting location provided on the front of the tibia tube to measure the X-axis acceleration. Use two #0-80 x 1/4" SHCS {0.05} to attach the uniaxial accelerometer to the flat mounting area on the front of the Lower Tibia Tube, as shown in **Figure 13.9**.

Figure 13.9 - Attaching X Axis Accelerometer to Front

7. A uniaxial accelerometer unit can be attached directly to the mounting location provided on the right side of the tibia tube to measure the Y-axis acceleration. Use two #0-80 x 1/4" SHCS {0.05} to attach the uniaxial accelerometer to the flat mounting area on the right hand side of the Lower Tibia Tube, as shown in **Figure 13.10**.

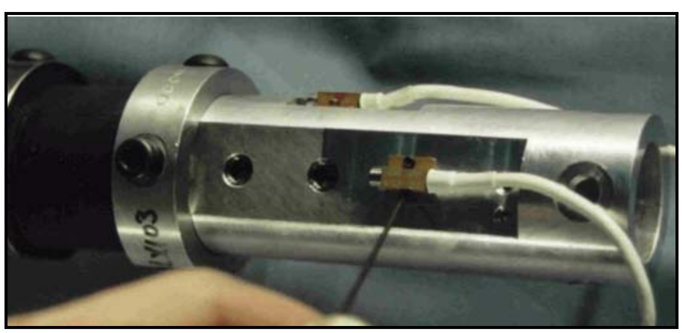


Figure 13.10 - Attaching Y-axis accelerometer

8. The Tibia Guard (T1LLM014) is mounted to the front of the Lower Leg assembly using a 1/4-28 x 7/8" BHSCS {5/32} in the top mounting hole and a 1/4-28 x 5/8" BHSCS {5/32} in the lower mounting hole, as shown in **Figure 13.11**. The triaxial accelerometer wire is routed out the hole in the tibia guard on the right side.

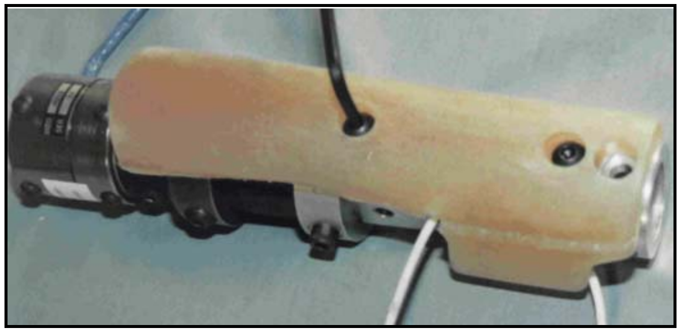


Figure 13.11- Tibia Guard Assembly

9. An exploded view of the Achilles Spring Tube assembly is shown in **Figure 13.12**. Refer to drawing T1LLM300 for further details .

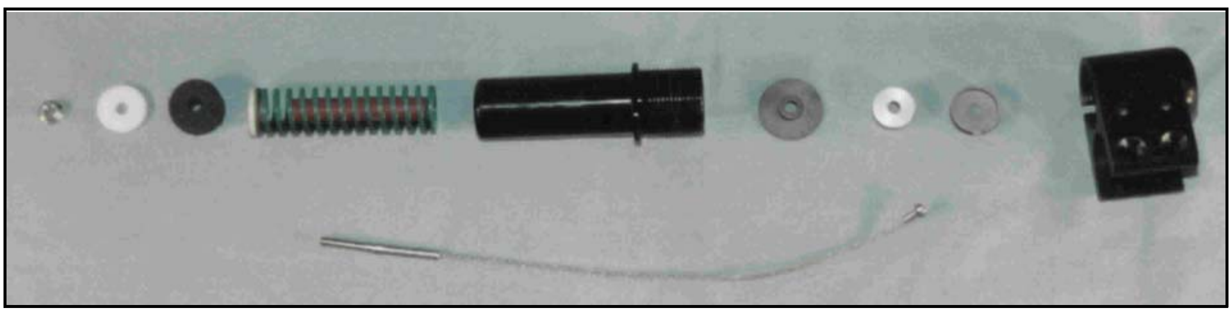


Figure 13.12 - Exploded View of Achilles Spring Tube

10. Place the Load Cell Base Washer (T1LLM315) into the counterbore at the bottom of the Spring Tube Base (T1LLM310), as shown in **Figure 13.13**.

Figure 13.13- Load Cell Base Washer

11. Place the mock uniaxial load cell (T1LLM020) into the bottom of the Spring Tube Base, as shown in **Figure 13.14**.

Figure 13.14- Mock Uniaxial Load Cell

12. Place the Achilles Spring Base Cap (T1LLM314) onto of the Mock Load Cell with the raised button facing away from the load cell, as shown in **Figure 13.15**.

Figure 13.15 - Spring
Base Cap

13. Screw the Achilles Spring Tube (T1LLM311) into the top of the Spring Tube Base and tighten securely as shown in **Figure 13.16**.

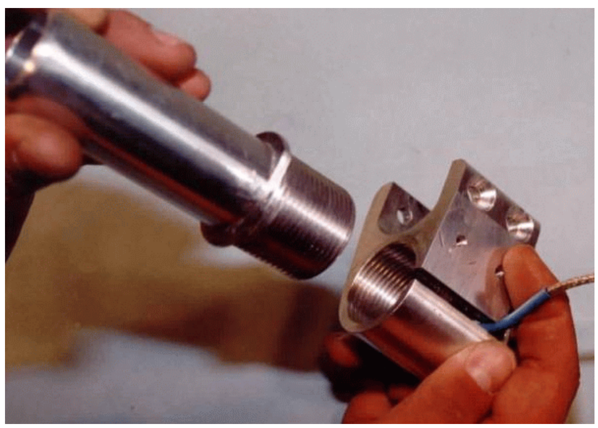


Figure 13.16- Thread Spring Tube into Base

14. Position the Elastomeric Spring Element (T1LLM316) inside the compression spring. Slide the compression spring assembly (MWE#1S26090 & T1LLM313) into the Spring Tube with the Spring Cap toward the open end, as shown in **Figure 13.17**.

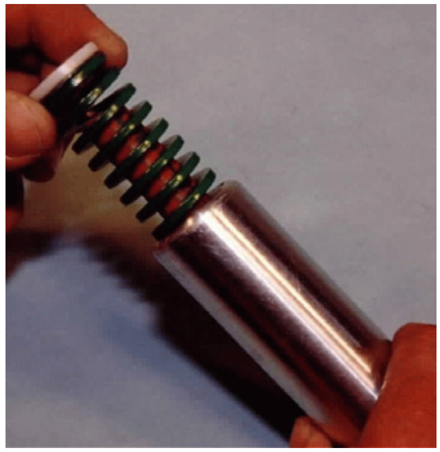


Figure 13.17- Slide compression spring into the Spring Tube

15. Insert the Soft Foam Compression Element (T1LLM317) on top of the Spring, as shown in **Figure 13.18**.

Figure 13.18- Place Soft Foam Compression element on top of spring

16. Position the Primary Load Washer (T1LLM312) on top of the Soft Foam Compression Element, as shown in **Figure 13.19**.

Figure 13.19- Primary Load Washer

17. Pass the threaded end of the Achilles Cable assembly (T1LLM319) up through the Spring Tube Assembly from the bottom side, as shown in **Figure 13.20**.

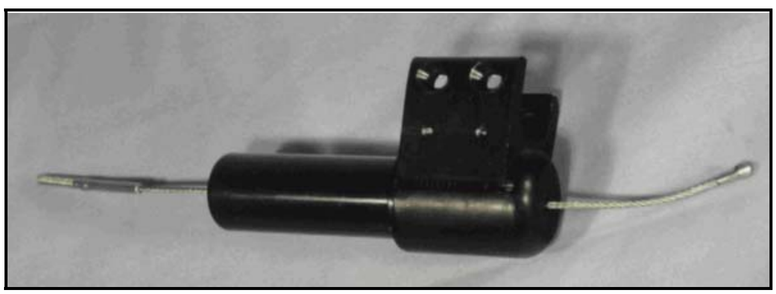


Figure 13.20- Achilles Cable Assembly

18. Secure the cable with the Achilles Retaining Nut (T1LLM318) and tighten the #4-40 x 1/8" Nylon Tipped SSS {0.05} in the retaining nut to secure the position of the nut on the cable, as shown in **Figure 13.21**. The adjustment of the Achilles cable will be discussed in Section 13.3.

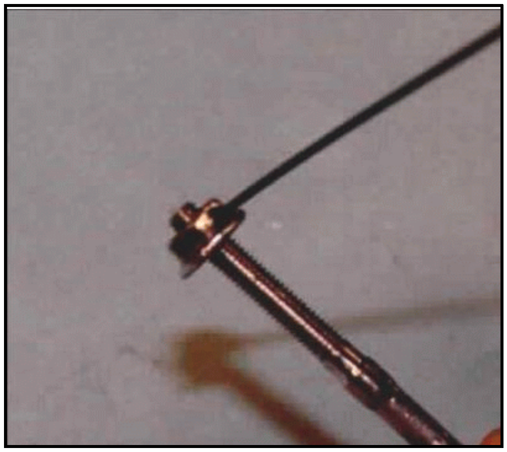


Figure 13.21 - Tighten retaining nut

19. Attach the Achilles Spring Tube assembly to the rear of the Lower Tibia Tube using four 1/4-28 x ½" FHSCS {5/32}, as shown in **Figure 13.22**.

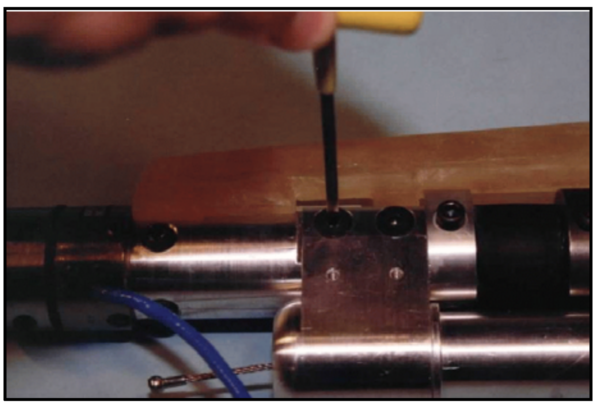


Figure 13.22- Attach the Spring Tube to the Lower Tibia Tube

20. The Z-axis rotation of the THOR-LX / HIIIr is controlled at the joint between the ankle and lower tibia assemblies. This joint is designed to allow +/- 20 degrees of controlled internal / external rotational motion. The components used to control this motion are shown along with the ankle assembly in **Figure 13.23** - the two rubber z-rotation stops (T1AKM027), and Wedge #1 (T1LLM111).

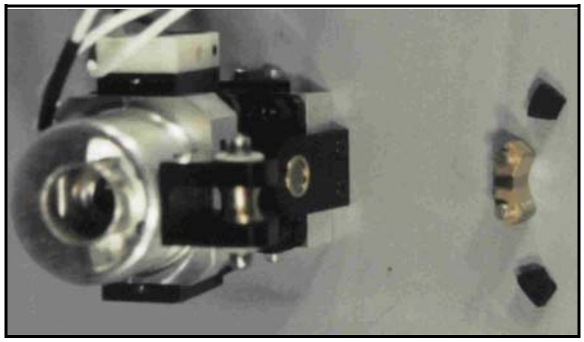


Figure 13.23 - Z-axis rotation components

21. The Z-rotation stops are installed in the top of the Ankle Top Torque Base (T1AKM011) on either side of the annular groove - as shown in **Figure 13.24.** The Wedge #1 is shown in the photograph for illustration purposes only. This wedge is attached to the bottom of the lower tibia load cell assembly with the two dowel pins.

Figure 13.24- Z-rotation Assembly

22. As an option, the Z-rotation axis can be locked for calibration purposes. To lock the axis, remove the rubber z-rotation stops and substitute Wedge #2 (T1LLM112) for Wedge #1, as shown in **Figure 13.25.**

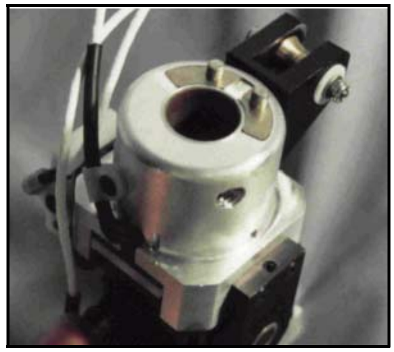


Figure 13.25- Locked

23. Check to ensure that the Teflon Spacer (T1LLM015) is attached to the bottom surface of the lower tibia load cell. Secure the desired Wedge onto the bottom of the lower tibia load cell using the dowel pins, as shown in the left photo of **Figure 13.26**. Slide the mounting post of the lower tibia load cell into the counter bored hole in the Top Torque Base (T1AKM011) of the Mechanical Ankle Assembly (T1AKM000). Place a drop of removable Loctite #242 on the metal potentiometer shaft and spread evenly with your finger. Align the D-shaped hole in the Z-axis potentiometer (located within the Top Torque Base) with the flat on the end of the tibia Rotary Potentiometer Shaft (T1LLM021). Center the z-rotation wedge between the soft stops (if required) and slide the assemblies together as shown in the right photo of **Figure 13.26.**

WARNING: THE D-SHAPED HOLE IN THE POTENTIOMETER MUST BE ALIGNED WITH THE FLAT ON THE POTENTIOMETER SHAFT OR THE POTENTIOMETER WILL BE PERMANENTLY DAMAGED.

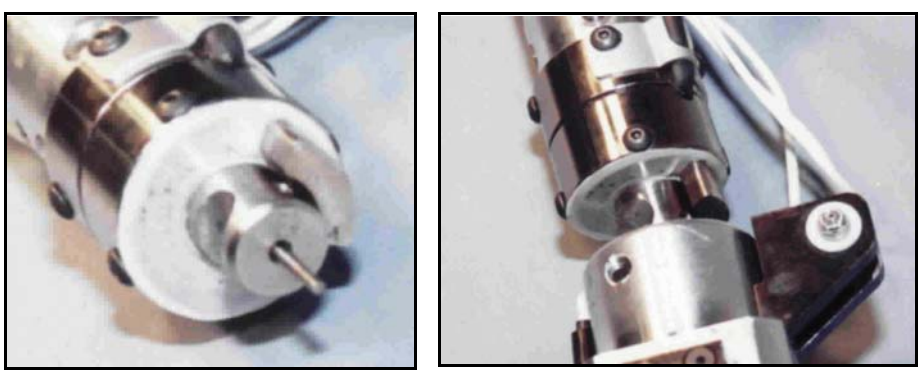


Figure 13.26- Attachment of the Wedge and Teflon Washer to the Base of the Lower Tibia Load Cell / Installation of the ankle components

24. Secure the ankle assembly to the lower leg assembly using a 3/8" x 1" Shoulder Bolt {5/32} which is covered with the delrin Ankle Bolt Sleeve (T1AKM028), as shown in **Figure 13.27**.

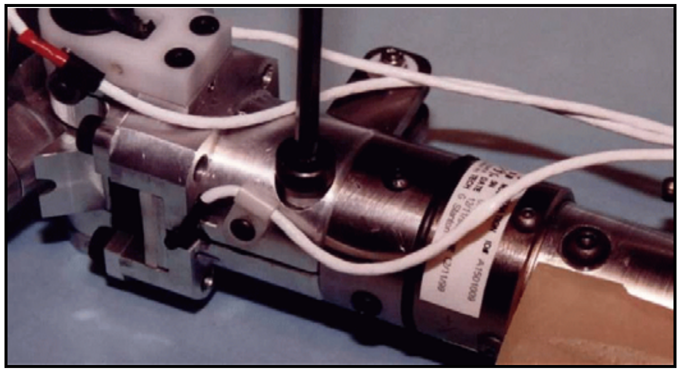


Figure 13.27- Secure the Lower Tibia to the Ankle

25. Position the Ankle / Achilles Mounting Plate (T1FTM210) below the sole plate with the counter sinks toward the bottom of the foot skin. The pointed end of the plate indicates the heel section. Attach the Lower Achilles Mounting Post (T1FTM311) to the top of the sole plate in the heel area using three 1/4-20 x 7/8" FHSCS {5/32}, as shown in **Figure 13.28**. The radius cut-out on the bottom of the Lower Achilles Mounting Post should fit tightly against the composite sole plate.

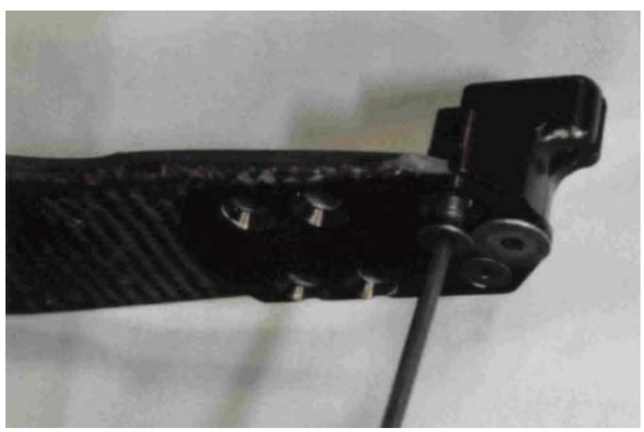


Figure 13.28- Attach Achilles Mount Post

26. The mechanical ankle assembly is attached to the Composite Sole Plate (T1FTM010) by positioning the ankle assembly using four 1/4-20 x 5/8" FHSCS {5/32} which pass through the front four countersunk holes of the Ankle / Achilles Mounting Plate and through the sole plate, as shown in **Figure 13.29**.

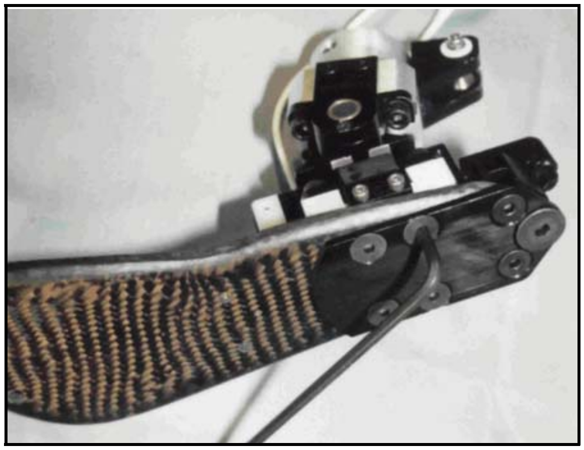


Figure 13.29- Attach Ankle Assembly

27. The THOR-LX foot has been designed to use a triaxial accelerometer array consisting of three uniaxial accelerometers mounted to a tri-pack block which is attached to the sole plate of the foot assembly. The mounting procedure is explained in detail below:

    Tri-Pack accelerometers mounting: Refer to drawing T1LFTM000 for additional details. This type of triaxial accelerometer consists of a Tri-Pack Block (T1INM130) which holds three uniaxial accelerometers (T1INM110) on the outer surface. The three uniaxial accelerometers are mounted on the tri-pack block using six #0-80 x 1/4" SHCS {0.05}. The orientation of the accelerometer units is +X forward, +Y Right, +Z Down, as shown in **Figure 13.30.**

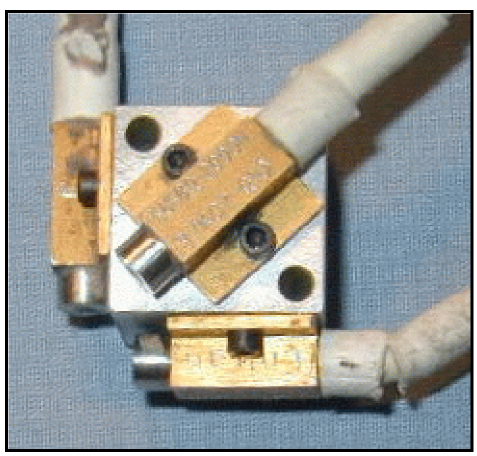


Figure 13.30- Tri-Pack Mounting Block

The Foot Tri-Pack Mounting Plate (T1FTM012) is mounted onto the composite sole plate using two #4-40 x 1/4" FHSCS {1/16}, as shown in **Figure 13.31**.

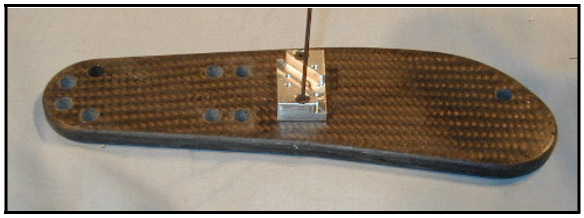


Figure 13.31- Tri-Pack Mounting Plate

The instrumented Tri-Pack block is mounted to the front of the Foot Tri-Pack Mounting Plate using two #2-56 x 9/16" SHCS {5/64}, as shown in **Figure 13.32**.

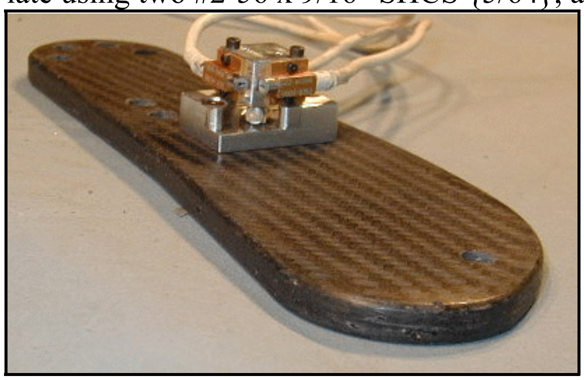


Figure 13.32- Tri-Pack Assembly

28. Insert the rubber Heel Pad (T1FTM214) into the molded pocket on the inside of the foot skin under the ankle mounting area, as shown in **Figure 13.33**. The pad should be positioned with the rounded edge away from the sole plate.

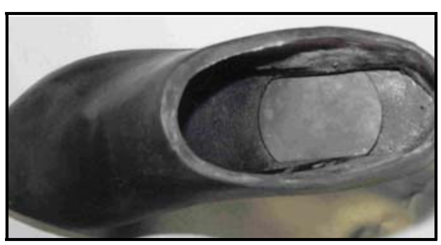


Figure 13.33- Heel Pad Insertion

29. Pass the Achilles Cable behind the Achilles Pulley Wheel which is mounted to the rear of the Lower Tibia Load Cell. Attach the ball end of the Achilles Cable Assembly to the Lower Achilles Mounting Post by sliding the cable section above the ball into the slot on the back of the mounting post, as shown in **Figure 13.34**.

Figure 13.34- Slide cable ball into slot

30. Allow the ball to move up to the top of the recessed area in the mounting post and secure the cable in place by inserting a #4-40 x 1/2" SHCS {3/32} into the hole on the side of the mounting post, as shown in **Figure 13.35**.

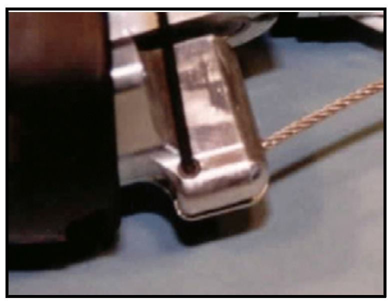


Figure 13.35 - Insert cable locking screw

31. Insert the completed ankle / foot assembly into the foot skin and press the assembly firmly into place within the skin, as shown in **Figure 13.36.**

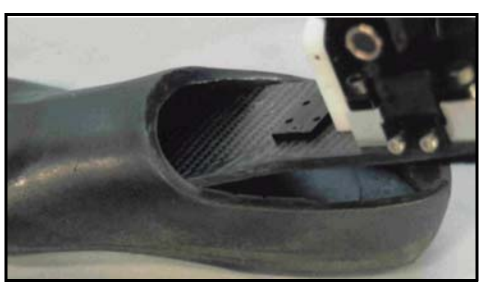


Figure 13.36- Foot Skin Insertion

32. Attach the Knee Clevis Assembly (T1LLM001) to the top of the Upper Tibia Load Cell using four 1/4-28 x 5/8" SHCS {3/16}, as shown in **Figure 13.37**.

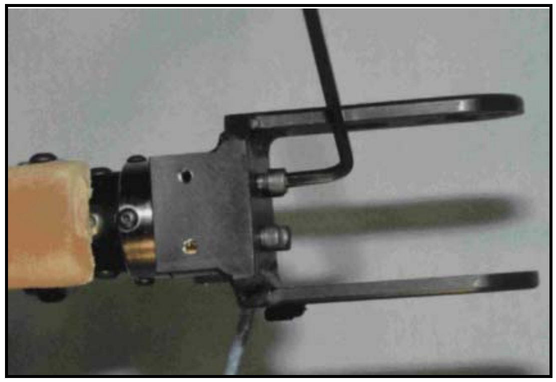


Figure 13.37- Knee Clevis Assembly

33. Attach the Molded Knee Bumper (T1LLM025) to the front of the Knee Clevis Assembly using two #10-32 x 3/8" B.H.S.C.S., as shown in **Figure 13.38**.

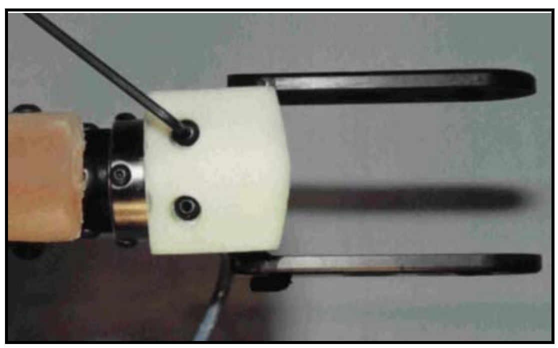


Figure 13.38- Knee Bumper

34. Position the Molded Knee Bumper (T1LLM025) of the Knee Clevis Assembly (T1LLM001) into the molded pocket located on the upper front interior surface of the tibia skin (T1LLS010 and T1LLS011), as shown in **Figure 13.39**.

Figure 13.39- Insert Knee Bumper and Clevis into the molded pocket of the Tibia Skin

35. Route the wires from the instruments into the two wire channels provided within the tibia skin as shown in **Figure 13.40.** The wires are designed to exit the skin at the top - behind the knee assembly.

Figure 13.40- Wire Routing in Tibia Skin

36. Zip the tibia skin around the leg to complete the assembly, as shown in **Figure 13.41**.

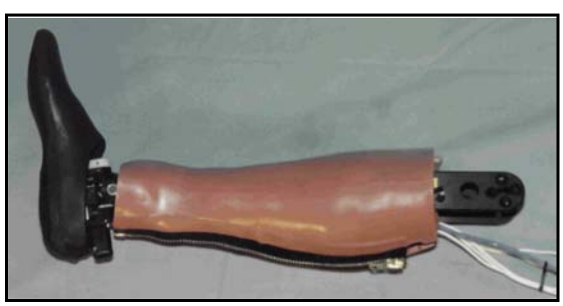


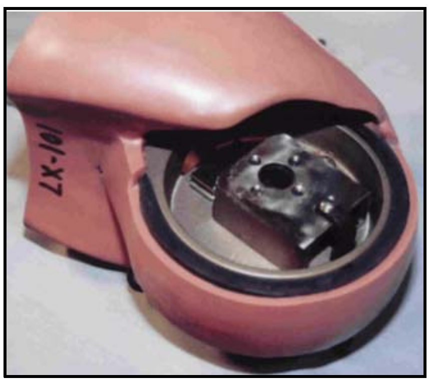
Figure 13.41- Completed THOR-LX Foot, Ankle and Lower Leg Assembly

13.2.2.1 Assembly of the THOR-LX Unit to the Knee

The following procedure is a step-by-step description used to install the completed THOR-LX to the knee assembly. This unit was designed to be installed on the Hybrid III 50% male knee assembly which has been upgraded to the ball bearing slider, as specified in the drawing package and bill of materials. The numbers provided in ( ) refer to a specific drawing / part number of each particular part. The numbers noted in { } after the bolt size indicate the size of the hex wrench required to perform that step of the assembly. All bolts should be tightened to the torque specifications provided in Chapter 2.

1. Insert the modified THOR-LX knee skin (T1KNS010) onto the knee assembly prior to attaching the knee clevis.

2. Rotate the inboard and outboard Knee Slider Assemblies to position the slider base toward the femur load cell mounting hole, as shown in **Figure 13.42**.



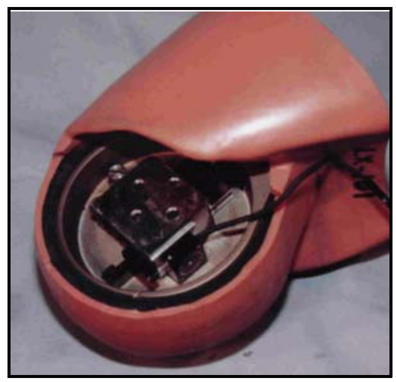


Figure 13.42- Ball bearing slider positioning for the right knee assembly (outside view / inside view)

3. With the foot oriented in the correct position, and the tibia at right angles to the axis of the femur, slide the Knee Clevis over the rotary knee blocks of the ball bearing slider assembly, as shown in **Figure 13.43**. The knee shear string pot wire is routed out through the hole in the side of the clevis and secured with a strain relief as shown.

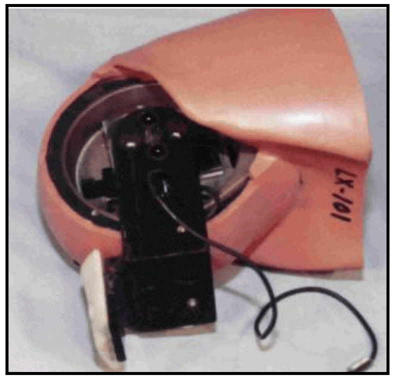


Figure 13.43- Knee Clevis

4. Attach the knee clevis to the slider mechanism using two 1/4-28 X 3/8" FHSCS on each side of the clevis. These bolts are placed in the vertical countersunk holes as shown in **Figure 13.43.** Position the corresponding knee cover over each side of the knee assembly and secure the covers with four 1/4-28 x 3/4" S.H.C.S. {3/16}. The screws pass through the covers, through the holes in the knee clevis and into the ball bearing slider block, as shown in **Figure 13.44** for the outside and inside of the right knee assemblies.

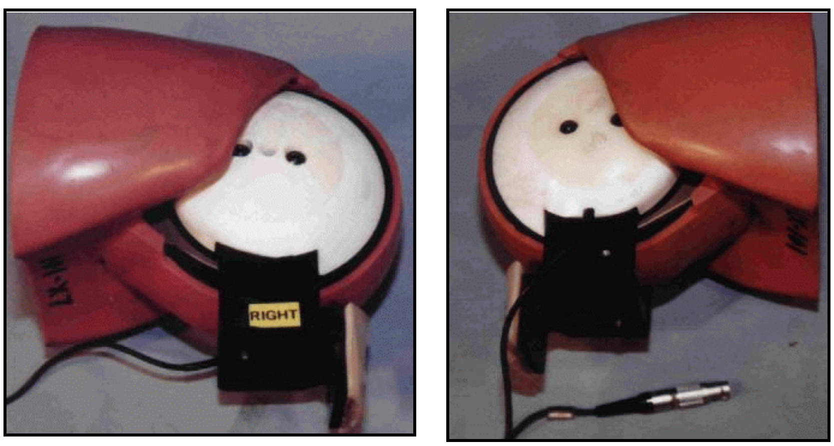


Figure 13.44- Knee Covers

NOTE: WHEN THE LOWER LEG IS ATTACHED TO THE KNEE, THE KNEE JOINT SHOULD NOT EXCEED THE NORMAL RANGE OF MOTION OF A HUMAN KNEE. IF THIS OCCURS IT INDICATES THAT THE KNEE SLIDER MECHANISM WAS NOT PROPERLY POSITIONED AS DESCRIBED IN STEP #2. DETACH THE LOWER LEG FROM THE KNEE ASSEMBLY AND ROTATE THE KNEE SLIDER ASSEMBLIES TO GIVE PROPER RANGE OF MOTION.

5. Repeat the procedure for the Left Lower Extremity Assembly.

6. The completed THOR-LX Assembly is shown in **Figure 13.45.**

Figure 13.45- Completed THOR-LX Assembly

13.2.3 Attaching the THOR-LX to the Femur

The following procedure is a step-by-step description of how to attach the completed THOR-LX Assembly (T1LXM000) to the completed Femur Assembly (T1FMM000). The numbers provided in ( ) refer to a specific drawing / part number of each part. The numbers noted in { } after the bolt size indicate the hex wrench size required to perform that assembly step. All bolts should be tightened to the torque specifications provided in Section 2.1.3- Bolt Torque Values.

1. At this point, the Right Lower Extremity Assembly is attached to the distal end of the right femur at the 6 Axis Femur Load Cell. Using a 3/8" lock washer and a Femur Load Cell Bolt (T1FMM019) {5/16}, secure the right lower extremity assembly to femur as shown in **Figure 13.46**.

Figure 13.46- Attaching THOR-LX to the Femur

2. Repeat this procedure for attaching the Left Lower Extremity to the left femur.

13.3 Adjusting the THOR-LX Assembly

The THOR-LX 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 THOR-LX was designed to have a neutral position (zero resistive torque in the ankle joints) at an angle of 15 degrees in plantar flexion. The motion of the foot from this neutral position to zero degrees dorsiflexion (tibia and foot are perpendicular) was designed with a minimum torque contribution from the Achilles tendon. This initial 15 degrees of rotation is allowed by the soft foam compression element of the Achilles Spring Tube. At the position of zero degrees dorsiflexion, the soft foam element must be fully bottomed and the Compression Spring should begin to load. The following steps will describe the correct preliminary adjustment of the Achilles Spring Cable tension. Further fine tuning of this adjustment may be required for dynamic performance response - this procedure is designed to set the nut in the correct general position.

<u>Equipment Needed:</u>

1. THOR-LX Unit
2. Voltmeter and Power Supply
3. Handheld Digital Scale (0-50 lb capacity, 0.1 lb resolution)
4. Calibration Cable Loop (T1CEM410)

1. Securing the lower leg to a stationary fixture will make the calibration much easier to perform. The leg can be secured by bolting the upper tibia load cell to a rigid structure.

2. Adjust the power supply to provide an excitation of 10.00 +/- 0.05 V. Connect the Ankle Y Rotary potentiometer to the power supply, and use the volt meter to monitor the Output signal from the potentiometer.

3. Loosen the the #4-40 x 1/8" Nylon Tipped SSS in the Achilles Retaining Nut to allow the nut to be adjusted. This was shown in **Figure 13.21.**

4. Remove the foot skin from the dummy's foot to expose the carbon fiber foot plate.

5. Position the foot in the neutral position of 15 degrees plantar flexion as shown in **Figure 13.46**. Adjust the Achilles Retaining Nut to remove the slack from the cable and the spring tube assembly. The soft foam compression element should have a very small amount of compression at this time - just touching.

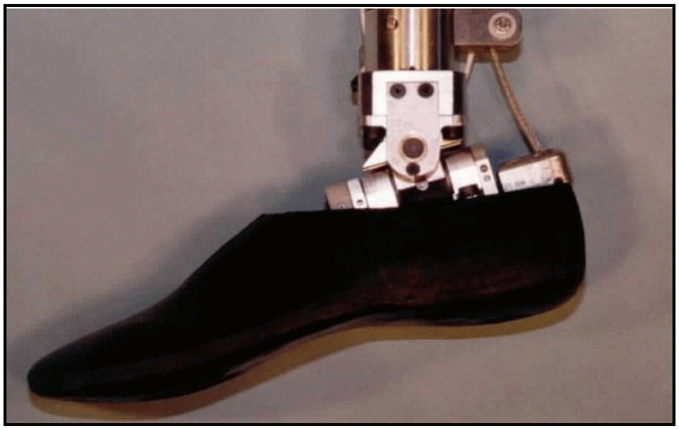


Figure 13.46- Neutral position of foot

6. Pass the Achilles Cable Calibration Loop (T1CEM410) through the calibration hole in the toe section of the foot plate - the swaged end should rest on the inferior aspect of the sole plate. Attach a hand held force scale (accuracy: +/- 0.2 lbf) to the calibration loop, as shown in **Figure 13.47.**

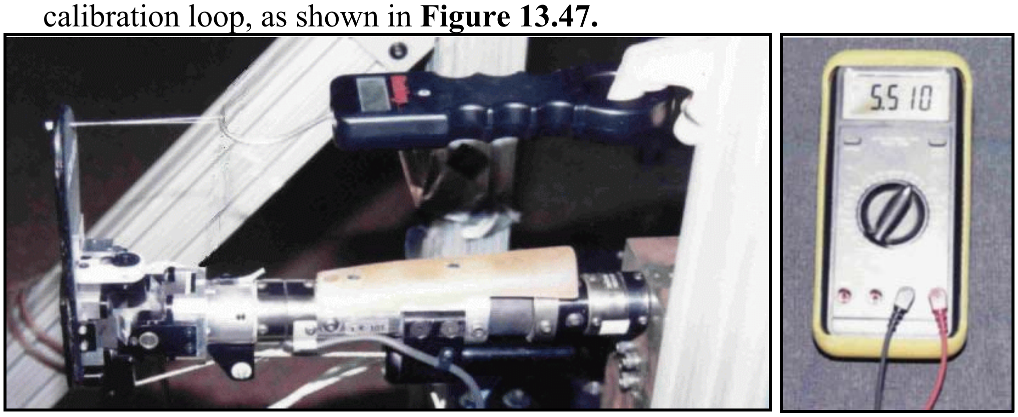


Figure 13.47- Calibration of Achilles Cable Nut

7. Pull on the hand-held force scale until the foot is in the calibration position - perpendicular to the tibia assembly (0 degrees dorsiflexion or plantar flexion), as shown in **Figure 13.47**. This position is verified by matching the Ankle Y potentiometer reading with the calibration value provided by the zeroing procedure in **Section 13.3.1**. The ankle Y potentiometer reading is measured with the

voltmeter (5.51 V in the example photo). The reading on the force scale should be 17.5 +/- 1.0 lbf. Adjust the position of the Achilles nut to achieve the desired force setting.

13.3.1 Ankle Rotary Potentiometer - Zeroing Procedure

The rotation of the THOR-LX ankle joint is measured about three principal axes using precision rotary potentiometers. The calibration of these potentiometers is carried out in two stages - the primary calibration is performed prior to installation in the ankle unit - a secondary calibration is performed once the ankle unit is assembled. The primary potentiometer calibration is carried out on a fixture which rotates the potentiometer to 13 known angular positions - the output voltage for each position is recorded and a numerical regression is performed to determine the calibration value in degrees per volt (for a 10V excitation). See drawing T1AKM000 for additional details of the primary calibration. The second stage of the potentiometer calibration takes place after the unit is installed into the appropriate ankle joint. This calibration is used to determine the voltage output of the potentiometer when the ankle is locked in a known calibration position. This value is used to determine the angular position of the foot relative to the tibia. This value is critical to the accurate evaluation of the ankle performance, since the corridors require a very precise measurement of the foot rotation. All calibration tests are conducted with an excitation voltage of 10.00 +/- .0.05 V.

The calibration position used for this second stage of calibration is with the foot perpendicular to the tibia tube in all three principal rotation directions. The various calibration positions are indicated in **Figure 13.48**.

Equipment Needed:

- THOR-LX Unit
- Voltmeter and Power Supply
- THOR-LX Ankle Rotary Pot Calibration Fixture (T1CEM420 - Available separately from the manufacturer)
- Mounting Bolts and Hardware (See T1LXC000)

1. Remove the tibia skin and tibia guard from the THOR-LX assembly.

2. Remove the foot skin and unbolt the composite plate (with the Achilles mounting post attached) from the base of the ankle unit..

3. Refer to drawing T1LXC000 for a complete drawing showing the proper attachment of the calibration fixture. Attach the bottom of the calibration fixture to the lower ankle base using four 0.312" diameter shoulder bolts. Attach the top of the calibration fixture using two shoulder bolts and two 1/4-28 x 3/4" SHCS. See **Figure 13.49**.

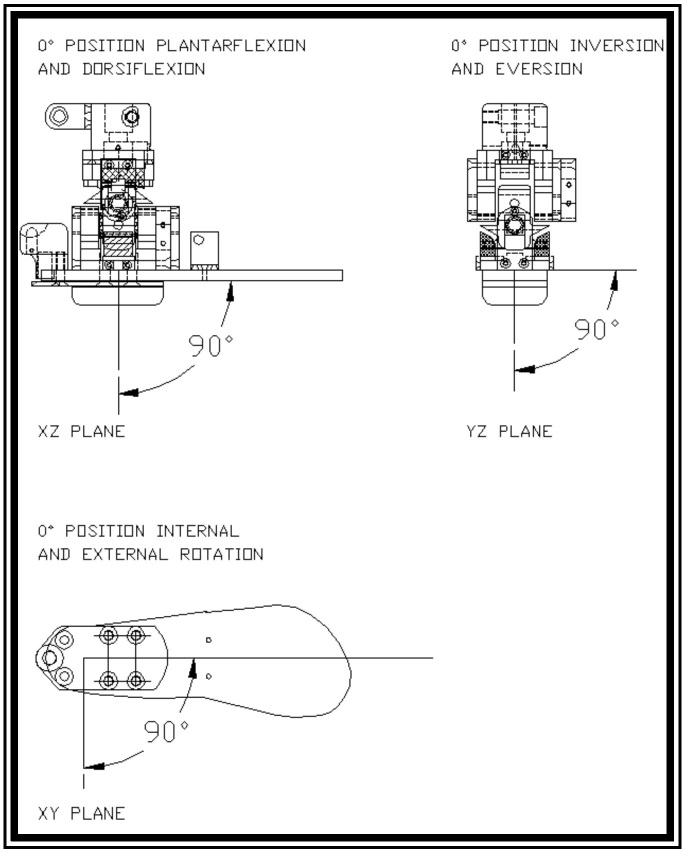


Figure 13.48- Calibration Positions for Ankle Joint

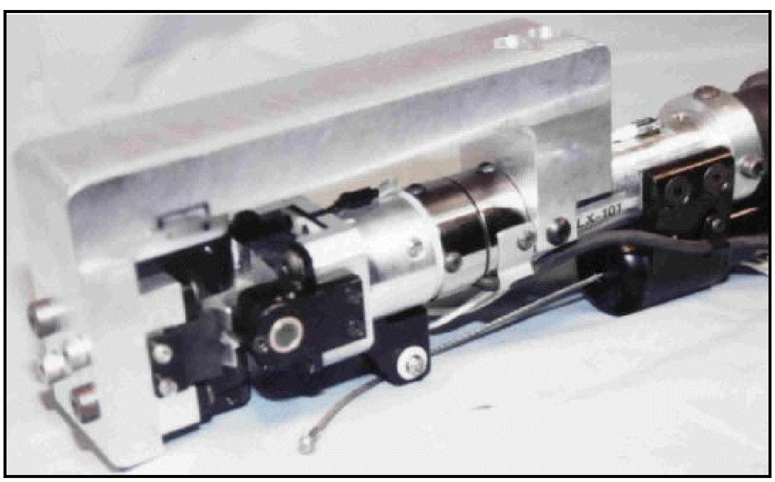


Figure 13.49- Calibration Fixture Orientation

4. Record the potentiometer voltage output at this position - this is the zero position for all rotation directions.

NOTE:
The manufacturer will provide the offset values of the potentiometers in the different directions (for excitation of 10V). These offset values are the potentiometer voltages when the foot is kept perpendicular to the tibia. It has been noted experimentally that the static response is sensitive to the offset values, such that if there was a change of .06V or more, then there would be change in the response curve. During development testing, the offset value was found to be stable during the course of the testing, but it may be worthwhile to make a measurement of it, if a significant number of tests are being conducted, in order to ensure that there is no drift. Drift would normally indicate that there is some slip occurring between the D-shaft and the corresponding hole in the potentiometer. Similarly, when the potentiometer rotation direction is changed (to change between dorsiflexion and plantarflexion, or between inversion and eversion), the offset value should not change by more than 0.01 - 0.02 V. Larger offset values would indicate a backlash problem between the potentiometer and the shaft. A drop of removable loctite #242 will usually cure any problems with backlash or slip. If the problem persists, the potentiometer should be replaced with a new unit.

13.4 Wire Routing and Strain Relief

The wire routing and strain relief for the instrumentation in the THOR-LX / HIIIr assembly is fairly straightforward. Each instrument is first strain relieved to a mechanical component to prevent damage to the wiring during testing. Then the wires are grouped into bundles and further strain relieved at various points in the assembly. The skin was designed to provide a wire channel up each side of the tibia assembly, as described in Section 13.2.2, Step #35 describes this routing and provides a photo. Additional information is provided for each instrument below:

Upper Tibia Load Cell: The wire from this load cell exits through the hole provided at the rear of the tibia skin - just below the knee. The hole is at the top of the tibia skin zipper assembly.

Lower Tibia Load Cell: The wire from this load cell is routed up the right side of the lower leg and is bundled with the wires from the Y & Z axis rotary potentiometers. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee.

Tibia Uniaxial Accelerometers: The wires from these accelerometer units exit the right side of the tibia guard and are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. See **Figure 13.50** for additional details.

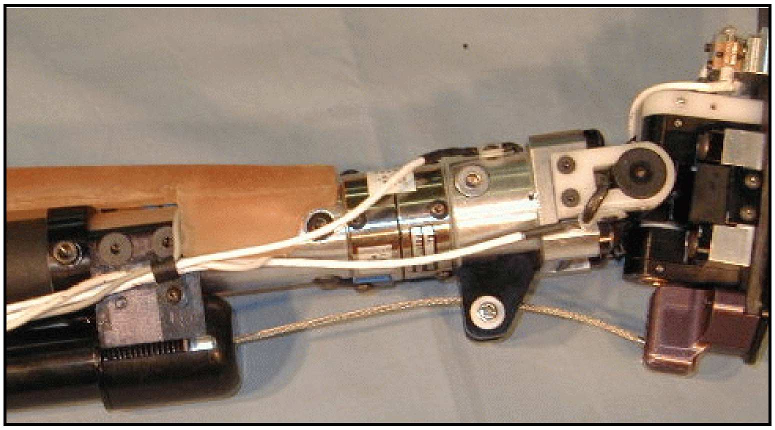


Figure 13.50- Tibia Uniaxial Accelerometers

Foot triaxial Accelerometer Array: The wires from this accelerometer cube exits the molded foot cavity to the left and are bundled with the X-axis potentiometer wire and strain relieved to the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. **Figure 13.51** shows additional details of this wire routing. A small amount of slack must be provided in this wire between the instrument and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are then routed up the left side of the leg tube and are strain relieved to the left side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin below the knee.

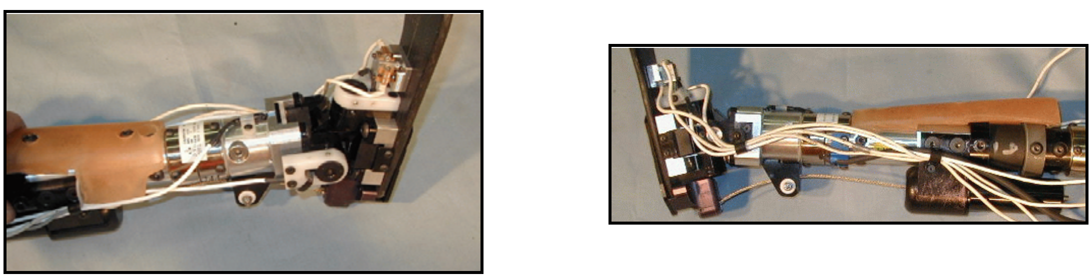
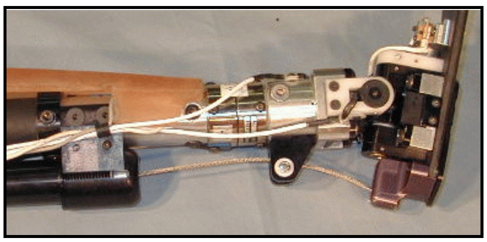


Figure 13.51- Foot Accelerometer and X-axis potentiometer routing

X axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire is bundled with the foot triaxial accelerometer wires and strain relieved again at the front left side of the Y axis bearing housing with a 1/4" wire clamp using a #6-32 x 3/8" BHSCS {5/64}. A small amount of slack must be provided in this wire bundle between the instruments and the strain relief to allow for dorsi / plantar flexion motion of the foot. These wires are routed up the left side of the tibia tube and strain relieved to the left side of the Achilles Spring Tube Base using a 1/4" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 13.51** for additional information.

Y axis rotary potentiometer: This wire is strain relieved to the potentiometer housing with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. This wire then runs up the right side of the leg and is bundled with the wire from the Z axis potentiometer. These wires are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 13.52** for additional information.



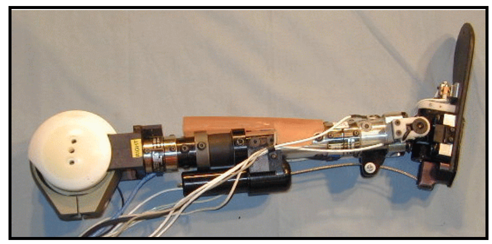


Figure 13.52- Y & Z Potentiometer Wire Routing

Z axis rotary potentiometer: This wire is strain relieved to the front of the Upper Joint Base with a 1/8"wire clamp using a #6-32 x 3/8" BHSCS {5/64}. The wire is routed up the right side of the lower leg and is bundled with the wire from the Y axis rotary potentiometer. These wires are strain relieved to the right side of the Achilles Spring Tube Base using a 3/16" wire clamp and a #6-32 x ½" BHSCS {5/64}. These wires continue up and exit through the hole provided at the rear of the tibia skin - just below the knee. Refer to drawing T1AKE000 and **Figure 13.52** for additional information.

13.5 THOR-LX Certification

A series of static and dynamic tests are performed on each THOR-LX assembly prior to shipment from the manufacturer. Static testing is performed on many of the materials and parts prior to assembly to ensure consistency and repeatability. Calibration procedures for these tests are described in the THOR-LX Certification Manual - available from the manufacturer as a separate publication.

13.6 Inspection and Repairs

After a test series has been performed, there are several inspections which may be made to ensure that the dummy integrity has remained intact. Good engineering judgement should be used to determine the frequency of these inspections, however the manufacturer recommends a through inspection after every twenty tests. The frequency of the inspections should increase if the tests are particularly severe or unusual data signals are being recorded. These inspections include both electrical and mechanical inspections. These inspections are most easily carried out during a disassembly of the dummy. The disassembly of the THOR-LX components can be performed by simply reversing the procedure used during the assembly.

13.6.1 Electrical Inspections (Instrumentation Check)

This inspection should begin with the visual and tactile inspection of all of the instrument wires from the neck instrumentation. The wires should be inspected for nicks, cuts, pinch points, and damaged electrical connections which would prevent the signals from being transferred properly to the data acquisition system. The instrument wires should be checked to insure that they are properly strain relieved. A more detailed check on the individual instruments will be covered in Section 15 - Instrumentation.

13.6.2 Mechanical Inspection

Several components in the THOR-LX assembly will need a visual inspection to determine if they are still functioning properly. This mechanical inspection should also involve a quick check for any loose bolts in the main assembly. Each area of mechanical inspection will be covered in detail below. Please contact the manufacturer regarding questions about parts which fail the mechanical inspection.

Achilles Tendon Cable: The following check should be performed when inspecting for post-test damage:

- Check for kinks and broken strands

.

Ankle Soft Stops: The following check should be performed when inspecting for post-test damage:

- Check for permanent compression, nicks or tears

Ankle Torque Cylinders: The following check should be performed when inspecting for post-test damage: (These can be viewed with the potentiometers and bearing housings removed from each side of the ankle assembly.)

- Check for permanent compression, nicks or tears

Tibia Compliant bushing Assembly: The following checklist should be used when inspecting for post-test damage:

- Check for alignment and correct motion in the lower tibia bearing housing.
- Check the condition of the linear bearing lining.
- Check the rubber bushing for signs of permanent compression, debonding

Tibia Skin: The following check should be performed when inspecting for post-test damage:

- Check for holes, tears and cuts.

Foot Skin: The following check should be performed when inspecting for post-test damage:

- Check for holes, tears and cuts.