



## **Booster Seat Belt Fit Evaluation Protocol (Version III)**

**September 2014**

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## DOCUMENT REVISION HISTORY

A document revision history is provided in the Appendix.

## OVERVIEW

The objective of the Insurance Institute for Highway Safety's booster seat belt fit evaluation program is to quantify the ability of booster seats to provide proper seat belt positions on children, across a range of potential lap and shoulder belt anchorage locations. The purpose of this protocol is to describe the method used to obtain lap and shoulder belt scores that represent the quality of seat belt locations on children. The protocol is based largely on research conducted by the University of Michigan Transportation Research Institute, with some modifications made to standardize the procedure.

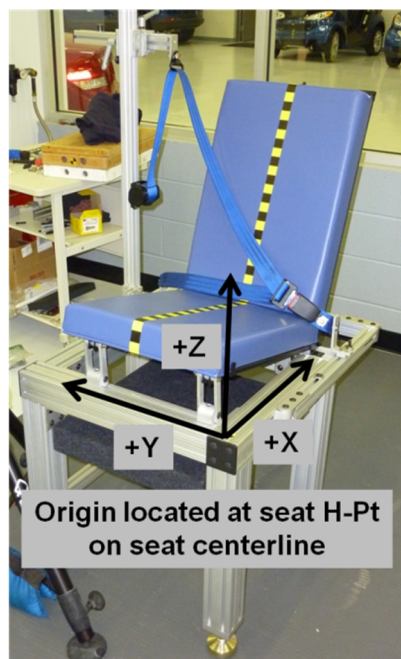
## TEST FIXTURE

### Test Seat

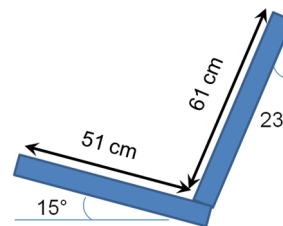
The test fixture (Figure 1) consists of a representative test seat and a three-point lap/shoulder belt system with adjustable belt anchorage locations.

The seat bottom is  $51 \pm 1$  cm long (measured from the seat bight, defined as the intersection of the seat bottom and seat back) and is reclined  $15 \pm 1$  degrees from horizontal (Figure 2). The seat back is  $61 \pm 1$  cm long (measured from the seat bight) and is reclined  $23 \pm 1$  degrees from vertical. The total seat bottom length is greater, where it extends below the bottom surface of the seat back. Both the seat cushion and seat back are  $42 \pm 1$  cm wide.

**Figure 1**  
**Test Fixture**



**Figure 2**  
**Test Seat**



The seat bottom and seat back are both constructed from a 5 cm thick polyurethane foam, identical to the Foam A "Extra Firm High Density Grade" foam specified in Federal Motor Vehicle Safety Standard No. 213. Sources for this foam, as well as other materials and supplies used in this protocol, are listed in the

Appendix. Both cushions are supported by a wood (plywood or MDF) section with a minimum thickness of 1.3 cm. Each cushion then is covered in a marine vinyl (see Appendix).

The coordinate system for the test rig is shown in Figure 1. The positive X axis points toward the rear of the seat, the positive Y axis points toward the right side of the seat, and the positive Z axis points upward vertically. The origin for this reference frame is located at the resulting H-point location for the seat (SAE J826 MAR2008), at the seat centerline. Once the H-point location was determined for the test seat during the design process, a simplified test device was created to locate this same origin. For the purposes of the official protocol, this simplified test device (Booster Seat H-Point Origin Device, or BPOD) is used to locate the origin. Drawings for BPOD are located in the Appendix.

To determine the origin of the test fixture, place the BPOD on the seat cushion forward of the seat bight, and slowly slide it rearward until contact is made with the seat back. Use a force gauge to push the BPOD into the seat, parallel to the seat cushion at a location approximately 6 cm above the base, at a force of 40 pounds. The position of the BPOD reference point defines the location of the origin.

### Seat Belt System

The frame used to support the test seat also supports the anchorage locations for the seat belt system. Any rigid frame can be used to support the test seat and seat belt system. These anchorages must be adjustable because they are moved to different positions during testing. Coordinates for the anchorage locations are listed in Table 1. The seat belt system (see Appendix) includes an inboard female buckle, webbing extender, retractor, D-ring anchor with bolt, and outboard end fitting. The test fixture was based on the geometry of a right, rear passenger seat. The right side of the seat, with D-ring and retractor, is considered to be the outboard side, whereas the left side of the seat is referred to as the inboard side.

**Table 1**  
**Seat Belt System Anchor Coordinates (mm)**

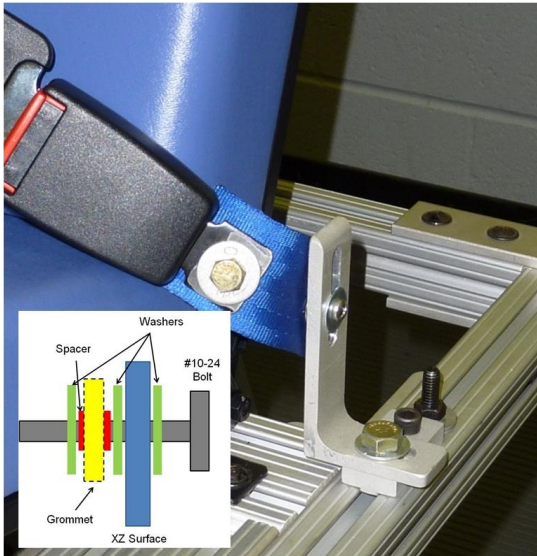
<b>Anchorage</b>	<b>Location</b>	<b>X</b>	<b>Y</b>	<b>Z</b>
Inboard	Maximum angle (83°)	15	-250	-125
	Minimum angle (41°)	144	-250	-125
Outboard	Maximum angle (68°)	57	330	-141
	Minimum angle (35°)	201	330	-141
D-ring	Fore/outboard/low	258	312	524
	Aft/inboard/high	560	214	668

The coordinates for each position (lap belt maximum vs. minimum angles, D-ring fore/outboard/ low vs. aft/inboard/high) are based on the range of positions found in current model test vehicles, which approximates the full range allowed by federal standards. The angle of the lap belt is defined as the angle (with respect to horizontal) of a line from the seat H-point to the anchorage location.

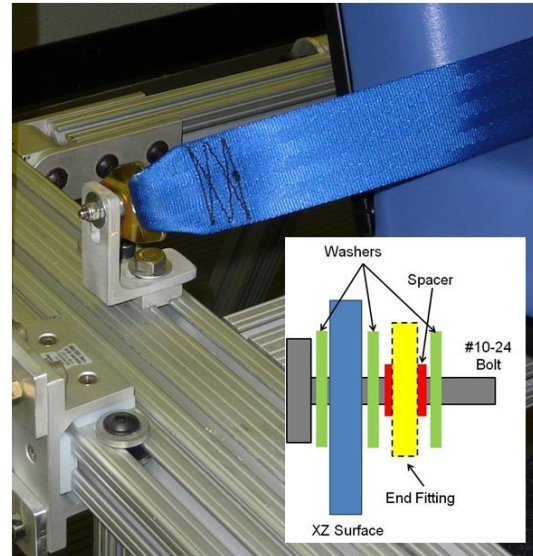
The female buckle is attached to the webbing extender with a 3/8 inch bolt, tightened sufficiently to prevent rotation between these two pieces, with the long axis of the buckle in line with the two grommets. The other end of the webbing extender is attached to the test fixture at a vertically oriented surface in the X-Z plane (see Figure 3). A #10-24 bolt passes through the grommet and serves as the axis around which the webbing extender can rotate. A spacer is required inside the grommet to (a) prevent the nut from being tightened to the point of preventing the webbing from rotating and (b) reduce the amount of play between the grommet and the bolt. The spacer should have a length of  $0.22 \pm 0.02$  inch, an ID of  $0.228 \pm 0.01$  inch, and an OD of  $0.36 \pm 0.02$  inch. Washers are located on either side of the spacer.

The outboard lap belt anchorage has a metal end fitting that is attached to the test fixture at a vertically oriented surface in the X-Z plane (Figure 4) with a #10-24 bolt. As on the inboard side, a spacer is required between the end fitting and the bolt. The spacer should have a length of  $0.22 \pm 0.02$  inch, an ID of  $0.228 \pm 0.01$  inch, and an OD of  $0.5 \pm 0.02$  inch. Washers are located on either side of the spacer.

**Figure 3**  
Inboard Belt Anchor (diagram not to scale)

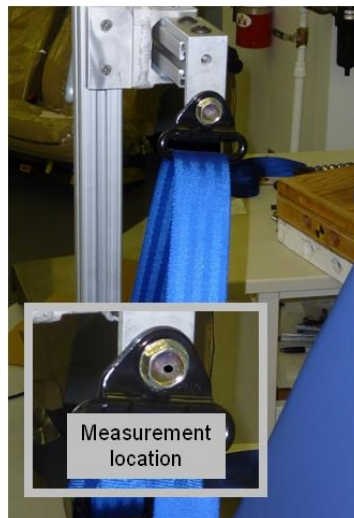


**Figure 4**  
Outboard Belt Anchor (diagram not to scale)



The D-ring assembly is mounted so that the attached mounting bolt (included in assembly) is attached to a vertically oriented surface in the X-Z plane, with the measured coordinates referring to the center of the head of the mounting bolt (Figure 5). The bolt, which is included in the seat belt assembly, requires a 7/16 inch  $\times$  20 nut to be attached to the mounting plate.

**Figure 5**  
D-Ring Anchor



The actual inboard and outboard lap belt anchor locations cannot be directly measured. The X and Z coordinates are identical to the X and Z coordinates of the centerline of the bolt about which the hardware rotates. The Y coordinates of the inboard anchor (webbing extender grommet) and outboard anchor (end

fitting) must be measured separately. The Y coordinate should be measured at the edge of the spacer closest to the seat centerline (also the face of the washer that contacts the spacer on this edge). The coordinates for the D-ring anchorage refer to the center of the mounting bolt. After purchase of the system, a punch (or other method) should be used to create a permanent location at the center face of the bolt for measurement (Figure 5). Each booster is tested in four combinations of lap and shoulder belt anchor locations. The test matrix is shown below in Table 2.

**Table 2  
Test Matrix**

Condition	Description (Lap/Shoulder)	Lap – Inboard	Lap – Outboard	Shoulder
1	Minimum/Fore	Minimum angle 41°	Minimum angle 35°	Fore/outboard/low
2	Maximum/Fore	Maximum angle 83°	Maximum angle 68°	Fore/outboard/low
3	Minimum/Aft	Minimum angle 41°	Minimum angle 35°	Aft/inboard/high
4	Maximum/Aft	Maximum angle 83°	Maximum angle 68°	Aft/inboard/high

## ANTHROPOMORPHIC TEST DEVICE

### Prepare ATD

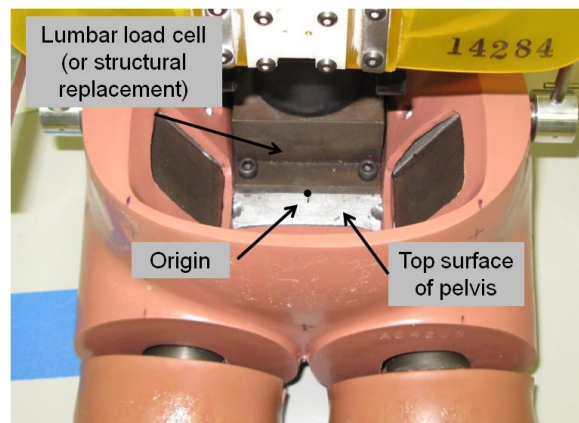
A Hybrid III 6-year-old anthropomorphic test device (ATD) is used in this procedure to represent a booster-age child. No instrumentation is required.

*ATD Head* – The center of gravity locations on each side of the ATD’s head should be noted and marked with test stickers. This procedure should only need to be performed once.

*ATD Pelvis* – An important aspect of the procedure involves locating the reference points on the surface of the ATD’s pelvis. Reference points only need to be located and marked once (with occasional verification that the ATD’s pelvis skin has not shifted with respect to the rigid base).

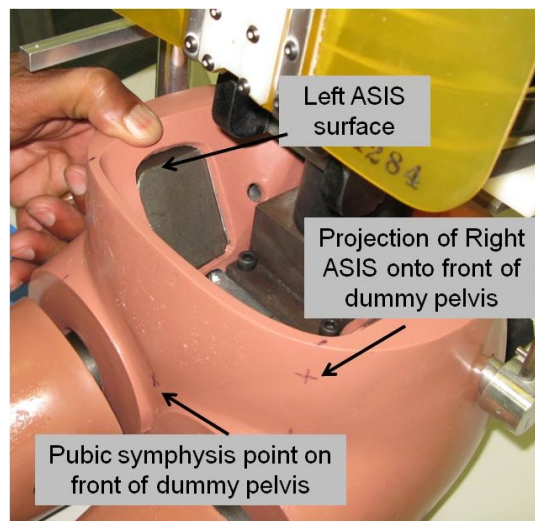
- 1.1. Remove the ATD abdominal insert.
- 1.2. Set the ATD on a rigid surface and secure it in a stationary position. Ratchet straps are useful in attaching the ATD to the test surface to prevent movement. Because the orientation of the reference frame is determined by the location of the top surface of the pelvis (Figure 6), the ATD’s position in space is not critical, as long as it does not move.

**Figure 6  
Pelvic Reference Frame**



- 1.3. Insert the H-point offset tools (see Appendix) in each side of the ATD's pelvis. The purpose of the tools is (a) to allow measurement of the ATD's pelvis angle and H-point location and (b) to allow use of a coordinate measuring machine (CMM) to measure the lap belt position with respect to the pelvis (and lap belt score). If only hand measurements are used (discussed later in the protocol), the H-point tools are not necessary.
- 1.4. The coordinate system for the pelvis is identical to the test fixture (X rearward, Y rightward, Z upward). The X-Y plane is defined as the top surface of the pelvis (rigid metal base). The origin is located at the intersection of this top surface of the pelvis and the lumbar load cell (or structural replacement), at the ATD's centerline (measured as the midpoint of the lumbar load cell) (Figure 6).
- 1.5. Once the reference frame has been determined, the ATD equivalent pubic symphysis point and anterior superior iliac spines reference points are projected onto the front surface of the molded ATD pelvis.
  - 1.5.1. Pubic symphysis (PS-ATD) – The point on the front surface of the ATD's pelvis skin with a Z value of 0 (same plane as the rigid base of the pelvis) and a Y value of 0 (midpoint of the ATD). Mark this point on the ATD skin (Figure 7).
  - 1.5.2. Anterior superior iliac spines (ASIS-ATD) – The actual ASIS on the rigid ATD pelvis must be located first. The left ASIS landmark is shown in Figure 7. The upper edge should have consistent Y and Z values along its length. Only measure the top edge, staying rearward of the front corner. The point on the front surface of the ATD pelvis with the same Y and Z values represents the ASIS-ATD. Mark these points on the ATD skin.

**Figure 7**  
**ATD Anterior Superior Iliac Spines and Pubic Symphysis**

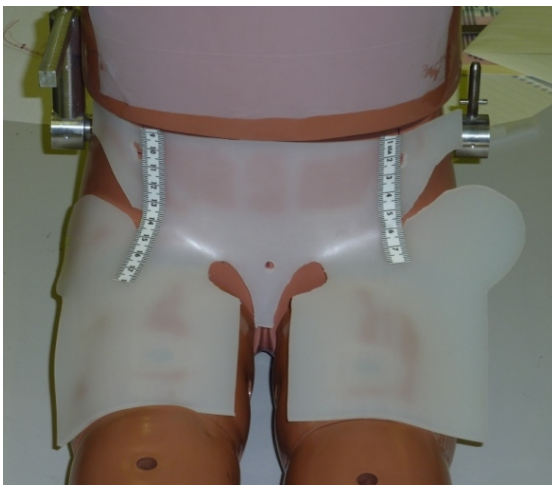


- 1.5.3. Additional points should be placed on the ATD skin with the same Y values as the ASIS-ATD, from the anterior superior edge of the pelvis to the thigh/pelvis gap. When the lap belt is digitized later in the protocol, the belt is measured at the lateral location where it crosses this X-Z plane.
- 1.6. Reference points on the hip-offset tools should be digitized at this time, if a coordinate measuring machine (CMM) is to be used to record measurement data. When the lap belt position is digitized later in the protocol, these hip-offset reference points are used to determine the correct pelvis reference frame for taking lap belt measurements.

## Final ATD Setup

- 2.1. All limb joints should be tightened to just greater than 1 g so that the limbs do not rotate after being positioned, but do not require excessive force to change position.
- 2.2. The ATD is tested without clothing. Make sure the abdominal insert has been installed.
- 2.3. The ATD's design results in a large gap between the thigh flesh and pelvis flesh, which can result in nonbiofidelic lap belt positions. This is corrected by adding a lap shield to provide a smooth surface from the upper surface of the pelvis to the mid-thigh region. The lap shield material and dimensions are listed in the Appendix. One purpose of the lap shield is to provide a low-friction surface for better positioning of the lap belt. A thin layer of baby powder should be added to the lap shield surface prior to use.
- 2.4. With the ATD seated upright on a flat surface, apply double-sided tape to the surface of the lap shield that will be in contact with the pelvis (Figure 8). The top edge of the lap shield should be aligned with the anterior superior edge of the ATD pelvis skin. It also may be useful to cut small holes (approximately 5 mm in diameter) where the lap shield covers the left and right ASIS. These provide a direct view of the ASIS during hand measurements of the lap belt position.
- 2.5. The lap shield has a tendency to separate from the pelvis even when taped, due to the low friction coefficient of the silicone. Additional tape can be used to attach the shield to the pelvis, although the tape should be applied in areas that are not in contact with the lap belt. Flexible measuring tape also can be applied, at the lateral location of the ASIS to assist in hand measurements (Figure 8).
- 2.6. To better mimic how real children sit in vehicle seats (Reed et al., 2006), a pelvis positioning pad is attached to the rear surface of the pelvis. The pelvis positioning pad material and dimensions are listed in the Appendix. Using double sided tape, position the pad in a centered location on the posterior of the ATD pelvis, with the top edge of the foam aligned with the superior edge of the ATD pelvis skin (Figure 9).

**Figure 8**  
**Lap Shield**



**Figure 9**  
**Pelvis Positioning Pad**



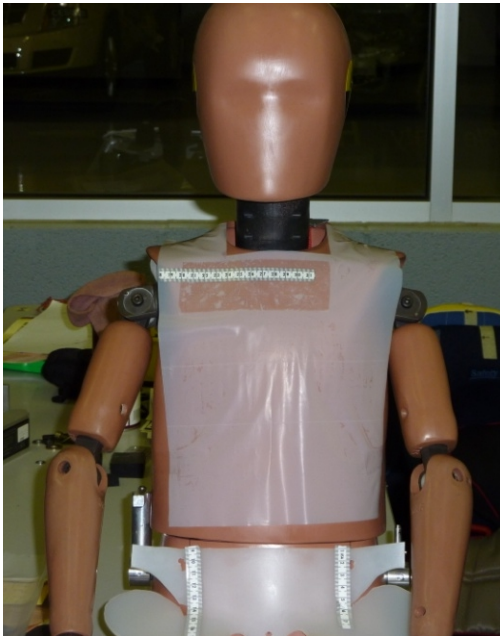
- 2.7. To reduce friction between the shoulder belt and ATD chest jacket during the procedure, a thin Teflon sheet (see Appendix) is taped to the front edge of the ATD chest jacket. Double sided tape should be placed in the approximate location of the chest reference point to adhere the Teflon sheet

to the chest jacket. Additional one-sided tape can be used as necessary at the edges of the Teflon sheet (Figure 10).

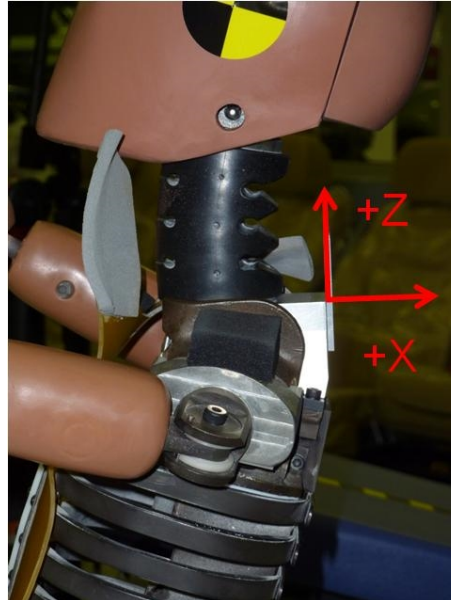
2.8. The chest reference point is located on the front of the ATD chest jacket, but its position is based on the location of the ATD spine.

2.8.1. Place the ATD torso in an upright position, defined as the superior face of the lower neck load cell (or structural replacement) being horizontal. The orientation of the reference frame is identical to that for the test fixture (X-Y plane parallel to the superior face of the load cell), and the origin is the posterior superior edge of the load cell, at the midline of the ATD (Figure 11). (Note that when using a CMM, the torso position does not need to be exactly vertical because the reference frame is determined by the orientation of the lower neck load cell. If a CMM is not used, the ATD spine may need to be more precisely positioned to accurately position the chest reference point).

**Figure 10**  
Chest Reference Point and Tape



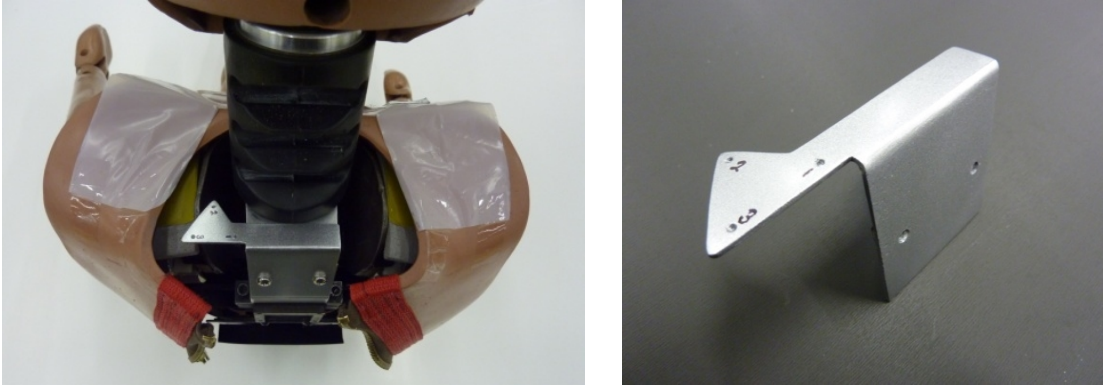
**Figure 11**  
ATD Reference Frame for Locating  
Chest Reference Point



2.8.2. A thin aluminum (recovery) plate can be attached to the rear surface of the lower neck bracket, projecting above the top surface, to assist in establishing the correct reference frame (Figure 12). During the evaluation process, it is difficult to reach the neck bracket to establish the correct reference frame. The neck bracket recovery plate provides easier access to digitizing points that can be used to recover the reference frame when the chest reference point is verified.

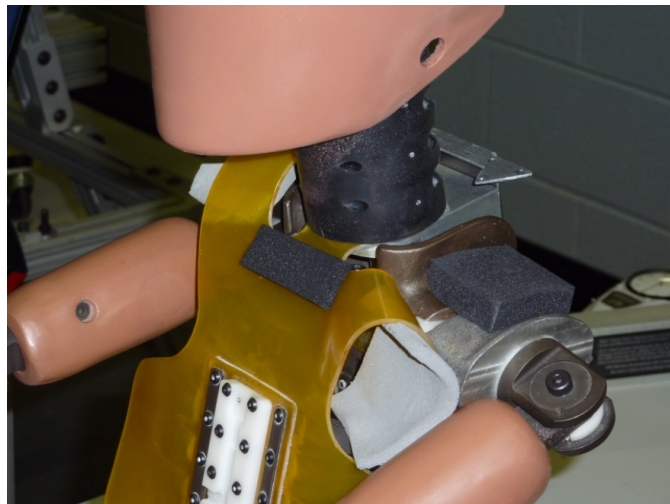


**Figure 12**  
**Neck Bracket Recovery Plate**



- 2.9. With the chest jacket properly installed (snugly pushed in the inferior and posterior directions), the chest reference point is defined as the location on the anterior surface of the chest jacket, at the ATD centerline, which has a Z coordinate of 0 (same plane as the load cell surface). The coordinate of this point should be  $(-110 \pm 5, 0, 0 \text{ mm})$ .
- 2.10. To ensure consistency among different chest jackets, a second reference point should be checked, verifying the chest jacket coordinates at the ATD shoulder. At the midline of the ATD neck (approximate X value of 53 mm ), measure laterally 4 cm (from the outer edge of the neck). The top surface of the chest jacket at this location should have a value of  $(-53, 72, 10 \pm 5 \text{ mm})$ .
  - 2.10.1. If the ATD chest jacket does not meet these requirements, spacers must be placed on top of the chest bib (below the chest jacket). An example of the spacers used for the ATD is shown in Figure 13. The spacers should be the same material as that designated for the pelvis positioning pad (see Appendix), but in the necessary thickness required to properly position the jacket. A first attempt at spacers should include the two shoulder spacers with a thickness of  $\frac{1}{2}$  inch, and the front chest spacer with a thickness of  $\frac{3}{8}$  inch.

**Figure 13**  
**Example Spacer Arrangement Used to Position Chest Jacket**



- 2.11. Mark the chest reference value on the Teflon sheet, and mark a second point closer to the ATD's right shoulder with the same Z value. These points are used to locate a piece of flexible, vinyl, adhesive ruler. This piece of tape should extend across the chest, with the top edge in the same plane as the chest reference point ( $Z=0$ ) (Figure 10). During the final measurement procedure, the inboard edge of the shoulder belt is measured where it crosses this reference line. Due to the possible shifting of the chest jacket during installation of the ATD in the booster, the position of the chest reference point (and horizontal reference tape) must be verified after ATD installation.

## MEASUREMENT PROTOCOL

- 3.1. Position the D-ring and inboard and outboard anchors in the correct positions. See the Appendix for photographs and diagrams illustrating the Measurement Protocol section.

### Position Booster

Read and follow the booster manual instructions for proper use. Make any booster adjustments (if applicable). If after the final measurements are taken it is determined that additional modifications to the booster (as allowed and instructed by the booster manual) would improve belt fit, make these adjustments and begin the Position Booster section again. Verify and note all booster adjustment positions.

- 4.1. Place the adjusted booster on the test seat such that the center plane of the booster is aligned with the center plane of the test seat and the base of the booster is flat on the test seat cushion.
- 4.2. Move the booster rearward on the test seat until some part of the booster touches the seat back, keeping the booster centered and vertical.
- 4.3. If the booster has a back with belt positioning guides, route the shoulder belt through the appropriate guide at this time so that the final position of the ATD will not be disturbed.
- 4.4. Apply 133 N (30 lb) of force to the front of the booster seat cushion in a direction parallel to the test seat cushion, moving the booster rearward into the vehicle seat.
  - 4.4.1. All forces in this protocol should be applied with a force gauge having a flat, square contact surface with a surface area of 2,580 square mm (4 square inches).
- 4.5. To reduce the effects of friction during positioning of the ATD, a Teflon sheet is placed on the booster seat cushion (between the ATD and booster seat). The sheet (see Appendix) should be placed in the center of the seat, with approximately 5 cm of the sheet extending past the booster seat bight (intersection of the seat bottom and seat back).

### Position ATD

- 5.1. Verify the position of the pelvis positioning pad, lap shield (apply baby powder), chest jacket, abdominal insert, and hip offset tools fully inserted into the ATD's pelvis.
- 5.2. Hold the ATD above the booster seat cushion such that the plane of the posterior pelvis is parallel to the plane of the booster seat back (or test seat back for backless boosters), but not touching.
  - 5.2.1. It may be necessary during ATD installation to have assistance when positioning webbing-mounted shoulder belt clips on backless boosters to prevent artificial interactions with the pelvis positioning pad.

- 5.2.2. Hold the ATD below the outstretched legs and the neck. Supporting the ATD by its back causes the chest jacket to ride up and makes the position of the chest reference point less consistent.
- 5.3. Move the ATD rearward, maintaining the parallel planes, until the pelvis positioning pad and booster seat back (or test seat back for backless boosters) are in minimal contact. At the conclusion of this step, the pelvis positioning pad should not be pressed firmly against the seat back, but rather should only touch the seat back.
- 5.4. Set the ATD down in the seat. If during the process some part of the booster seat back moves the pelvis away from parallel to the booster seat back (e.g., the structure of the seat back forces the torso forward before the pelvis touches the seat back, thereby tilting the pelvis relative to the seat back), move the ATD rearward keeping the pelvis as parallel as possible to the seat back until some part of the pelvis pad is in light contact with the seat back.
- 5.5. Straighten and align the arm segments so that the ATD's forearms and hands are in neutral positions (elbows and wrists extended, joints in the X-Z plane, palms facing inward). Rotate the arms upward at the shoulder as far as possible without contacting the booster seat.
- 5.6. Straighten and align the ATD's legs and extend the lower legs as far as possible in the forward horizontal direction, with the feet perpendicular to the axis of the legs.
- 5.7. Center the ATD's pelvis and align the ATD with the centerline of the booster and test seat. A CMM can be used to digitize the reference points on the booster and ATD to verify correct positioning. Identical left/right locations on the H-point tools are particularly useful when performing this step.
  - 5.7.1. Because the ATD's neck is rubber, the head angle may not always correctly reflect the angle of the torso. CMM Y values of the centerline of the neck (seam on front) is a better indicator of the ATD being vertical.
- 5.8. For highback boosters, Verify the seat back is vertical and centered. If it is not and the seat back can be adjusted slightly left or right, stabilize the ATD and make the adjustment. If the seat back is not able to be corrected, remove the ATD and repeat installation of the booster (step 4.1).
- 5.9. Apply a force of 177 N (40 lb) perpendicular to the back of the booster (or seat back for backless boosters) first against the ATD's lower pelvis and then at the thorax on the centerline of the ATD.
- 5.10. Stabilizing the ATD and booster with one hand, rotate the arms down, at the shoulder joint, so that they are perpendicular to the torso (i.e., upper extremities are horizontal, elbows and wrists are straight). Even at low levels of joint torque, moving the shoulder joints can shift the ATD's position.
- 5.11. Bend the knees until the back of the lower legs are in minimal contact with the booster or vehicle seat.
- 5.12. Position the legs such that the outer edges of the central portion of the femur are 14 cm apart.
- 5.13. Position the feet such that the soles are perpendicular to the centerline of the lower legs.
- 5.14. Verify that the ATD torso is vertical (Y coordinate of the center of the neck is  $\pm 2$  mm).

- 5.15. Verify that the chest reference point is in the correct location (using the neck bracket recovery plate to establish the ATD's spinal reference frame) and the tape is horizontal (i.e., the chest jacket has not shifted). Re-mark the reference point and re-positioning the chest jacket if necessary. For hand measurements, it may be helpful to note the position of the chest reference point on the flexible ruler at this time, in case this point is covered by the belt at the time of measurement.

### **Apply Seat Belt**

- 6.1. Stabilize the ATD and booster and pull the belt out of the retractor in a direction across the front of the ATD and booster so that the latch plate ends up above the ATD's inboard foot.
- 6.2. If there is a belt positioning attachment guide/clip on a backless booster, route the shoulder belt through the attachment as instructed in the booster manual.
- 6.3. If the ATD has to be moved (minor bending of the torso is acceptable, but the pelvis cannot be moved) to position the belt in the guide/clip, adjust the guide/clip to the shoulder as instructed in the booster manual then remove the ATD and repeat installation procedure (step 4.1)
- 6.4. Route the lap belt as instructed by the booster manual on the outboard side.
- 6.5. Leaving enough slack in the lap belt to hold the lap belt approximately 15 cm from the front edge of the pelvis, route the lap and shoulder belts as instructed by the booster manual on the buckle side of the booster and buckle the belt.
- 6.6. With one hand, pull the slack portion of the lap belt between the lower belt guides forward along the midsagittal plane of the pelvis so that the belt is approximately 2 cm above the top surface of the thighs. This can be accomplished by grasping the belt with the palm up, such that the back of the hand is resting lightly on top of the ATD thighs.
- 6.7. With the other hand, grasp the torso portion of the belt approximately 15 cm above the latch plate and slowly pull upward in the direction of the shoulder belt path. Allow the hand holding the lap belt to be pulled toward the pelvis with minimal resistance, keeping the lower edge of the lap belt just clear of the thighs.
- 6.8. When the leading edge of the lap portion of the belt reaches the gap between the pelvis and thigh flesh, release the lap belt and pull on the shoulder belt until the lap belt has no slack. (This is only the preliminary step for positioning the lap belt).
- 6.9. Stabilizing the ATD and booster with one hand, rotate the outboard arm down toward the seat surface until the 5th metacarpal contacts the booster surface and the palm contacts the outside of the thigh, or stopping prior to making contact with the H-point offset tools.
- 6.10. Stabilizing the ATD and booster with one hand, grasp the torso portion of the belt 15 cm above the latch plate and slowly pull upward in the direction of the shoulder belt path with a force no greater than approximately 44 N (10 lb). Continue repeated pulls on the belt until there is no additional visually apparent movement of the lap belt.
- 6.11. If the ATD is observed to move during this step (minor bending of the torso is acceptable, but the pelvis cannot be moved) repeat the installation procedure (step 4.1).
- 6.12. Feed any excess shoulder belt slack into the D-ring retractor.

- 6.13. Position the section of the shoulder belt between the buckle/lower guide and the upper guide or D-ring so that the belt routes through the shortest (or most natural) path between the two locations. (This is only the preliminary step for positioning the shoulder belt).
  - 6.13.1. For backless boosters with a shoulder belt guide/clip, keep the clip in position at the shoulder as instructed by the booster manual during preliminary positioning.
- 6.14. Feed any excess belt into the retractor. Attach a clamping device onto the webbing section between the D-ring and retractor (see Appendix). Stabilizing the ATD and booster with one hand, slowly pull this device, in the direction of the webbing, downward at a force of 22 N (5 lb). Only pull the webbing once.
- 6.15. Check the shoulder belt routing and determine if it is in the location specified by the booster instruction manual or in the desired location for the test. If the adjustments are not correct, make these adjustments and then repeat the installation procedure (step 4.1).

### **Final ATD Positioning**

- 7.1. Legs – Check the ATD leg and feet positions and make any necessary adjustments to achieve the positions described in steps 5.10 and 5.11.
- 7.2. Arms – Stabilizing the ATD and booster with one hand, keep the elbow straight and rotate the inboard arm from the shoulder down toward the seat surface until the 5th metacarpal contacts the booster surface and the palm contacts the outside of the thigh. If the shoulder belt interferes with this motion, stop the rotation 1 cm short of the point of contact with the belt or H-point tool.
- 7.3. Verify the lap and shoulder belt routings are correct.

## **MEASUREMENTS**

### **Lap Belt Score**

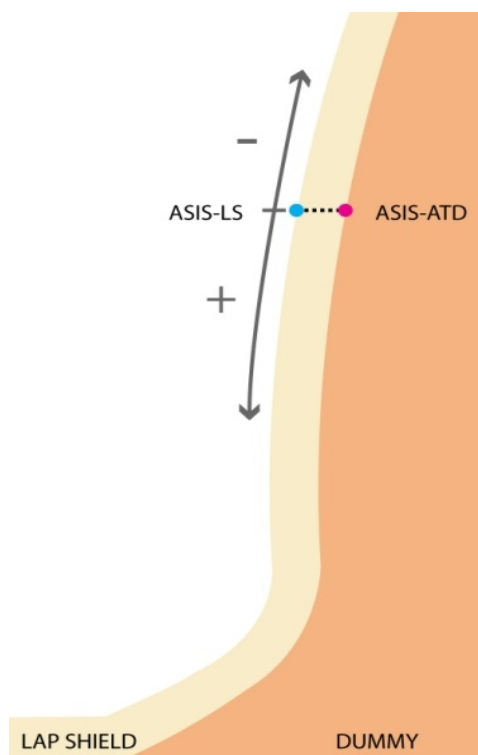
The Lap Belt Score (LBS) is defined as the distance from the ASIS to the top edge of the lap belt (Figure 14). The actual reference point for this measurement is the point where the ASIS on the surface of the ATD's skin (ASIS-ATD) is projected onto the lap shield (ASIS-LS). This is a horizontal projection when the ATD pelvis is positioned on a flat, horizontal surface. The distance is measured along the surface of the lap shield to the top edge of the lap belt, at the lateral location of the ASIS. Values are positive when the belt is positioned below the ASIS and negative when the belt is positioned above the ASIS.

On some boosters, the bottom edge of the lap belt is in greater tension than the top edge, and the top edge may not actually be in contact with the lap shield. This tends to happen in cases with large (good) belt scores. When this occurs, lightly press on the lap belt to flatten it out against the ATD's pelvis contour prior to taking measurements.

The official LBS will be determined by measurements taken with a CMM. This procedure uses a set of points representing the contour of the lap shield and the positions of the ASIS-LS reference point. These points are measured once during initial dummy setup. For this procedure, a digitized profile of the front edge of the lap shield is measured at the lateral location of the ASIS. A curve fit procedure is performed to fit an equation (or set of equations) to this set of points. The equation (or set of equations) then is used to produce a series of points on this line, with equidistant Z coordinates at 0.5 mm intervals. The procedure for measuring this contour is contained in the Appendix, and the IIHS contour data are available in a separate document.

After conducting the measurement protocol including measurement of the upper edge of the lap belt, the point on the lap shield contour with the smallest resultant distance (X and Z coordinates only) to the lap belt point is selected. The LBS is the distance from the ASIS-LS to this point, measured along the curve.

**Figure 14**  
**Lap Belt Score (illustration shown with ATD pelvis on flat/horizontal surface)**



If a CMM is not used, the LBS can be approximated by attaching a flexible ruler to the lap shield, at the lateral location of the ASIS. The LBS is the distance along this ruler, measured from the ASIS-LS. However, there will be some error in this measure due to (a) the approximation of the location of the ASIS-LS and (b) the difficulty in maintaining a complete attachment between the ATD's pelvis and lap shield particularly in area with curved surfaces.

### **Shoulder Belt Score**

The Shoulder Belt Score (SBS) is the distance from the chest reference point to the inboard edge of the shoulder belt (where it crosses the chest reference tape), with only the lateral component of this distance (Y axis) being included.

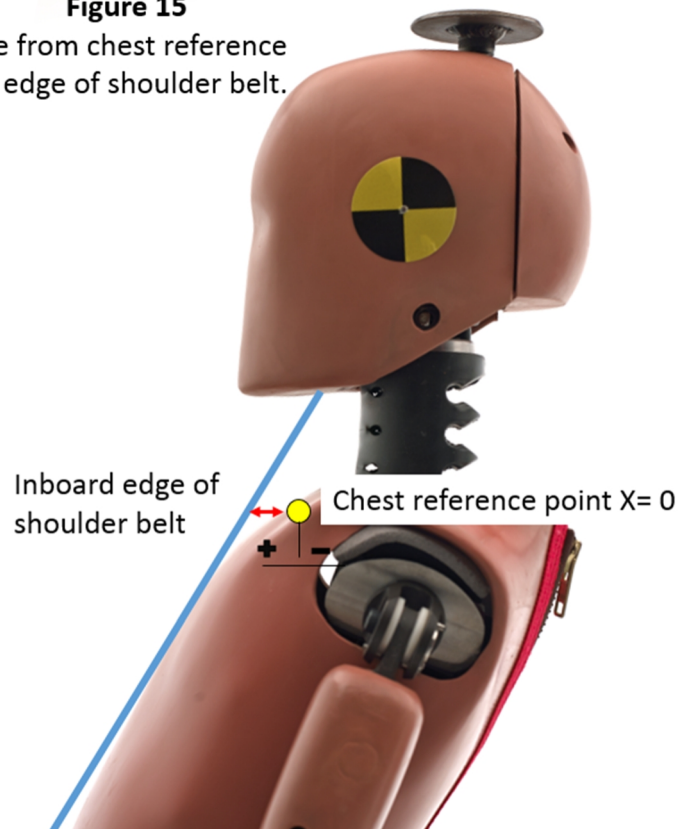
If a CMM is not used, an approximation can be made by measuring this distance along the chest jacket surface (e.g., with a flexible ruler), but there will be some error.

### **Shoulder Belt Fore-Aft Distance**

The shoulder belt fore-aft distance is the longitudinal distance (X axis) from the chest reference point to the inboard edge of the shoulder belt (where it crosses the chest reference tape), Figure 15.

If a CMM is not used, an approximation can be made by measuring this distance along the chest jacket surface (e.g., with a flexible ruler), but there will be some error.

**Figure 15**  
Fore/Aft distance from chest reference point to inboard edge of shoulder belt.



### Record Measurements

Record coordinates of the following seatbelt, booster, and ATD landmarks.

- 8.1. Head angle – negative angles are inclined forward, positive angles are reclined rearward.
- 8.2. Lap and shoulder belt hand measurements.
- 8.3. Neck – Verify that the Y value of the center of the neck is still  $\pm 2$  mm. If this tolerance is not met, adjust the ATD and re-apply the belt (6.1).
- 8.4. **Seatbelt reference points** – The following reference points are measured in the pelvis reference frame.
  - 8.4.1. Left upper edge of lap belt at lateral location of ASIS
  - 8.4.2. Left lower edge of lap belt at lateral location of ASIS
  - 8.4.3. Right upper edge of lap belt at lateral location of ASIS
  - 8.4.4. Right lower edge of lap belt at lateral location of ASIS

The following reference points are measured in the fixture reference frame

- 8.4.5. Inboard edge of shoulder belt where it crosses chest reference line
  - 8.4.6. Outboard edge of shoulder belt where it crosses chest reference line
  - 8.4.7. Upper edge of shoulder belt where it crosses ATD centerline
  - 8.4.8. Lower edge of shoulder belt where it crosses ATD centerline
- 8.5. **Booster reference points** – The following reference points are measured in the fixture reference frame.
- 8.5.1. Left reference point #1
  - 8.5.2. Left reference point #2
  - 8.5.3. Left reference point #3
- 8.6. **ATD landmarks** – The following reference points are measured in the fixture reference frame.
- 8.6.1. Left head center of gravity
  - 8.6.2. Neck bracket rear
  - 8.6.3. Neck bracket forward (Note: these 2 points are used to measure the neck bracket angle)
  - 8.6.4. Chest reference point
  - 8.6.5. Left hip offset top
  - 8.6.6. Left hip offset front
  - 8.6.7. Right hip offset front
  - 8.6.8. Left ASIS-ATD
  - 8.6.9. Right ASIS-ATD
  - 8.6.10. Pubic Symphysis (PS-ATD)
  - 8.6.11. Lower inboard anchorage point XZ (centerline of bolt, correct X and Z)
  - 8.6.12. Lower outboard anchorage point XZ (centerline of bolt, correct X and Z)
  - 8.6.13. D-ring (center of bolt face)
  - 8.6.14. Buckle reference point
  - 8.6.15. Test fixture reference point



## **Photography**

Photograph the final booster and ATD setup from both sides and the front, at a height approximately equal to the chest reference point, in perpendicular planes. Take additional photographs if necessary.

## APPENDIX

### Document Revision History

Revision to Version III of the protocol compared with Version II.

- Adds the shoulder belt fore-aft distance into the measurement protocol

Revision to Version II of the protocol compared with Version I.

- Includes information on the document revision history
- Adds more detail on creating the lap shield contour data in the Measurements section and in the Appendix

### Seat Foam

FMVSS 213 Foam A “Extra High Density Grade,” 5 cm thick  
Penn foam, [www.pennfoam.com](http://www.pennfoam.com)  
Bob Fromknecht (bob@pennfoam.com)

### Seat Vinyl

Jo-Ann Fabric and Craft Stores, [www.joann.com](http://www.joann.com)  
<http://www.joann.com/joann/catalog.jsp?CATID=cat3081&PRODID=prd23669>  
Med Blue Marine Vinyl  
SKU# CIP120 3526415

### Seat Belt System

Three-point belt (retractor, D-ring, sliding latch plate, lower outboard anchor), female buckle, webbing extender

Beam’s Industries, Inc. (<http://www.seatbelts.net/>)

Part #I2476-001 Item # DSCH14154

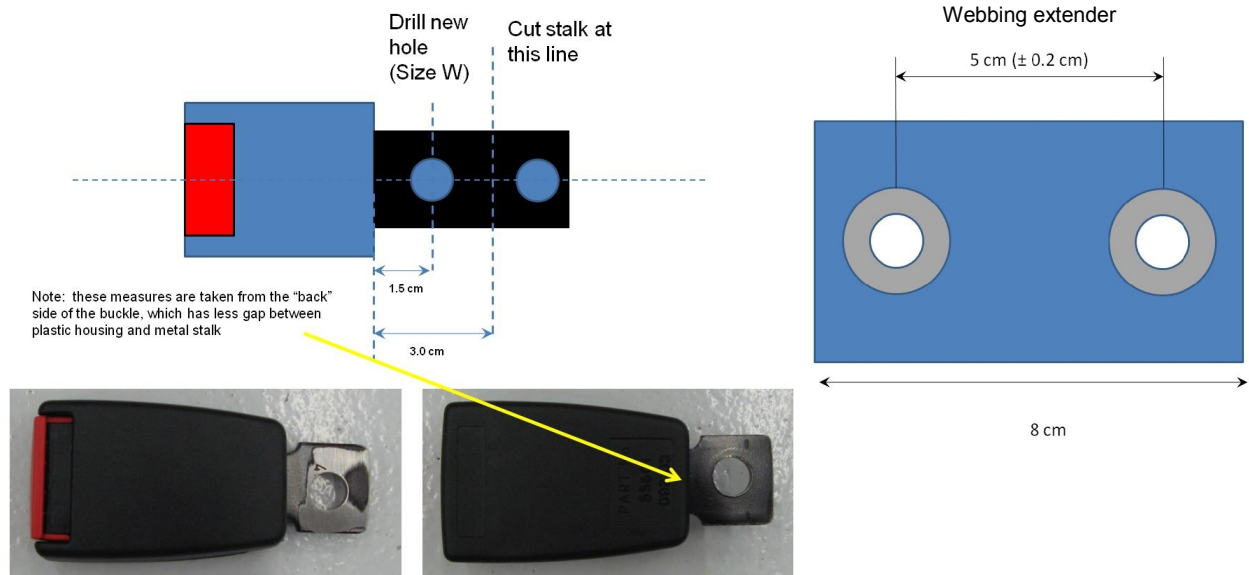
Includes three-point belt system and webbing extender

Wade Johnson

Tel: (405)793-0505

[wadejohnson@seatbelts.net](mailto:wadejohnson@seatbelts.net)

The inboard female buckle requires a minor modification prior to installation. An additional mounting hole must be drilled, and the end of the stalk (with the existing hole) must be cut off. The new hole is 0.386 inch (size W, clearance hole for a 3/8 inch × 16 bolt). The hole is centered on the stalk at a distance of 1.5 cm from the bottom edge of the plastic housing. The excess stalk is removed at a distance of 3.0 cm from the bottom edge of the housing.



The webbing extender is included in the part number. The information below is included for reference purposes only.

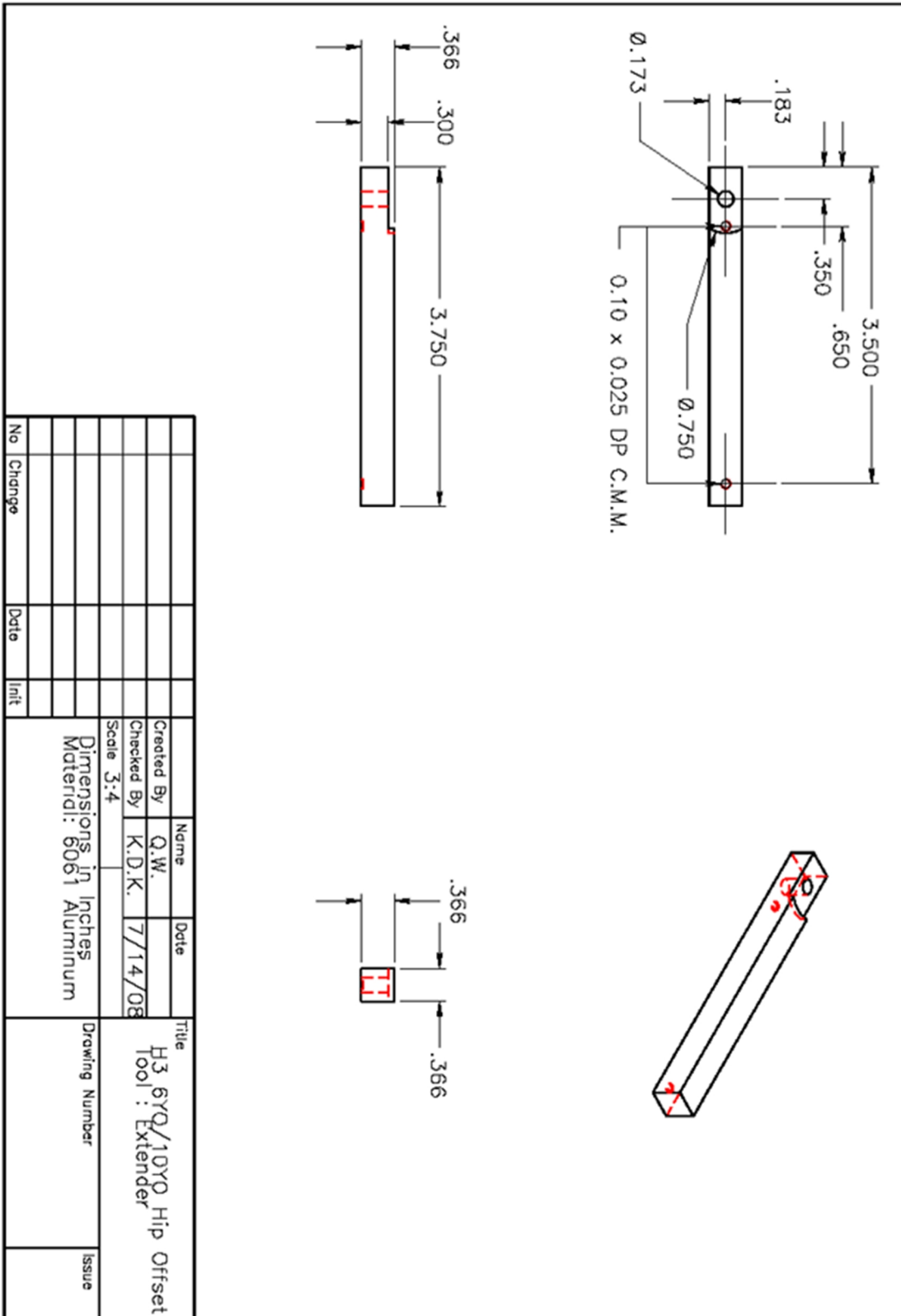
A piece of seatbelt webbing (same material as the three-point belt system) is used to link the female buckle to the anchor location on the test fixture. The webbing is 8 cm long, and has two grommets added with centers  $5.0 \pm 0.2$  cm apart, centered on the webbing. The grommets are rolled-rim grommets with a spur/extended neck, Trade Size 1 (13/32 inch hole size).

Grommets – McMaster Carr, Rolled Rim Grommets w/ Spur/Extended Neck, nickel-plated, Trade Size 1, 13/32 inch hole size, Part # 87995K52 (<http://www.mcmaster.com/#87995k52/=3ad4t2>)

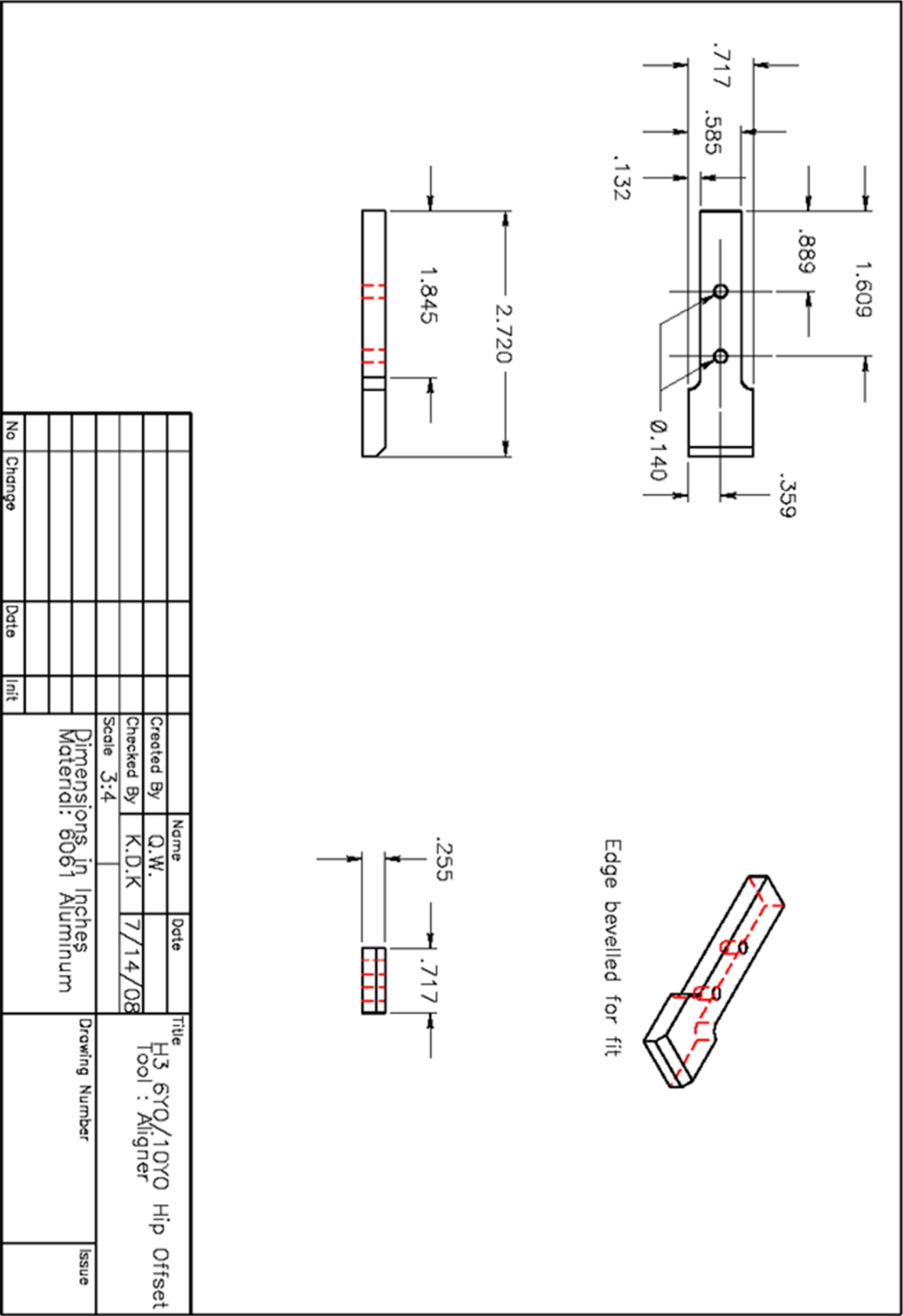
## H-Point Tools

Drawings courtesy of UMTRI (see pages 18-21)







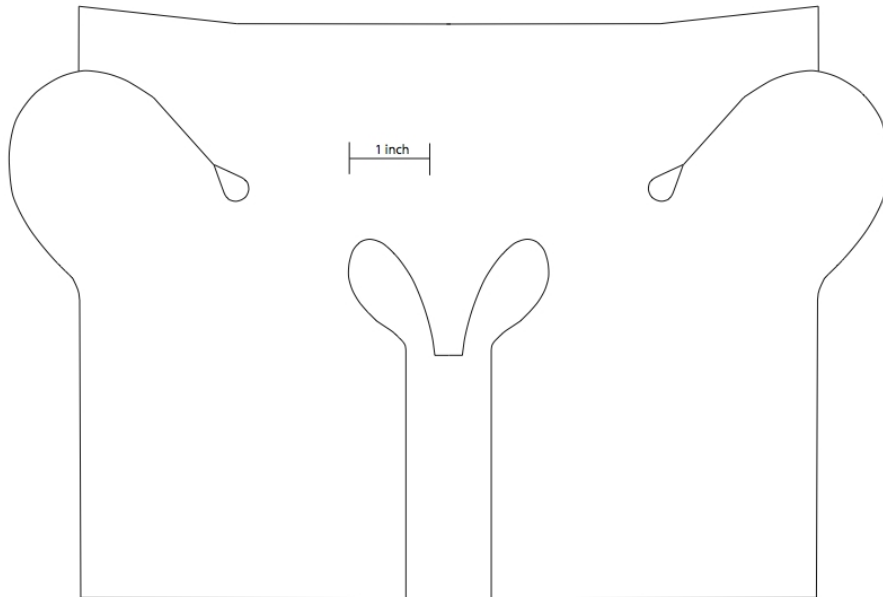


## Lap Shield

1/8-inch thick silicone rubber (11 × 7 inch), 50A Durometer, translucent white  
McMaster Carr, part #5827T23

<http://www.mcmaster.com/#5827t23/=3cfvvt>

### Template



## Pelvis Positioning Pad

3/4-inch thick oil-resistant (125 × 90 mm) neoprene/vinyl/Buna-N Foam, Firm  
McMaster Carr, part #85175K95

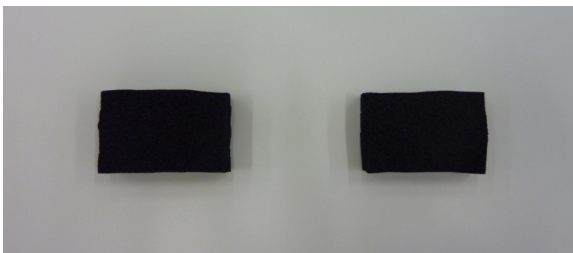
<http://www.mcmaster.com/#85175k95/=3cggw0>

## ATD Jacket Pads

Same material as pelvis positioning pads, but in varying thicknesses.

### Examples

Shoulder spacers: 1/2-inch thick, 2 × 1-3/4 inch



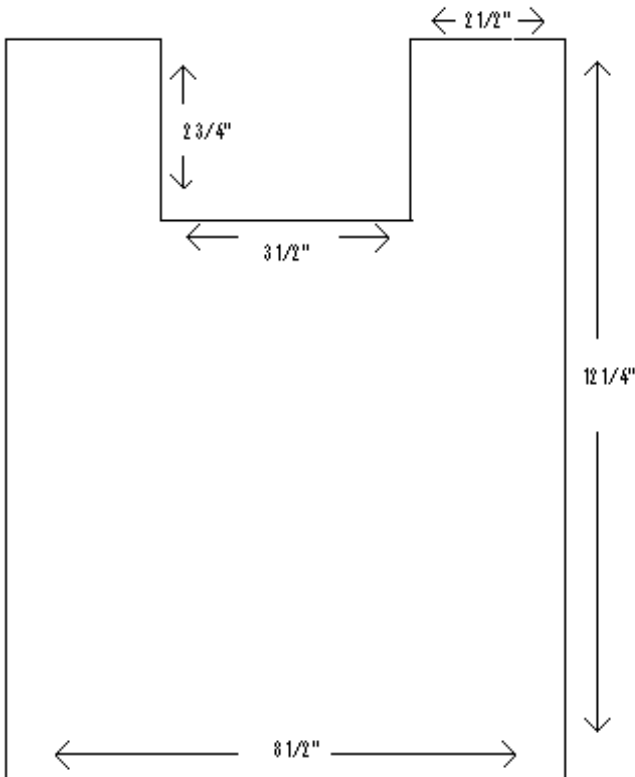
Chest spacer: 3/8-inch thick, 2-5/16 × 1 inch





### Teflon Chest Bib

Teflon Film, 0.002-inch thick, 12-1/4 × 8-1/2 inch  
McMaster Carr, part # 8569K34

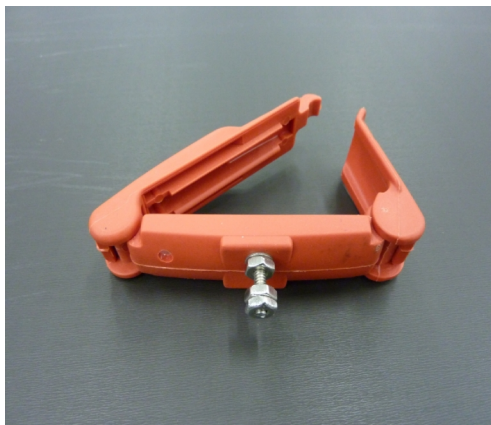


### Teflon Sheet for Booster Seat

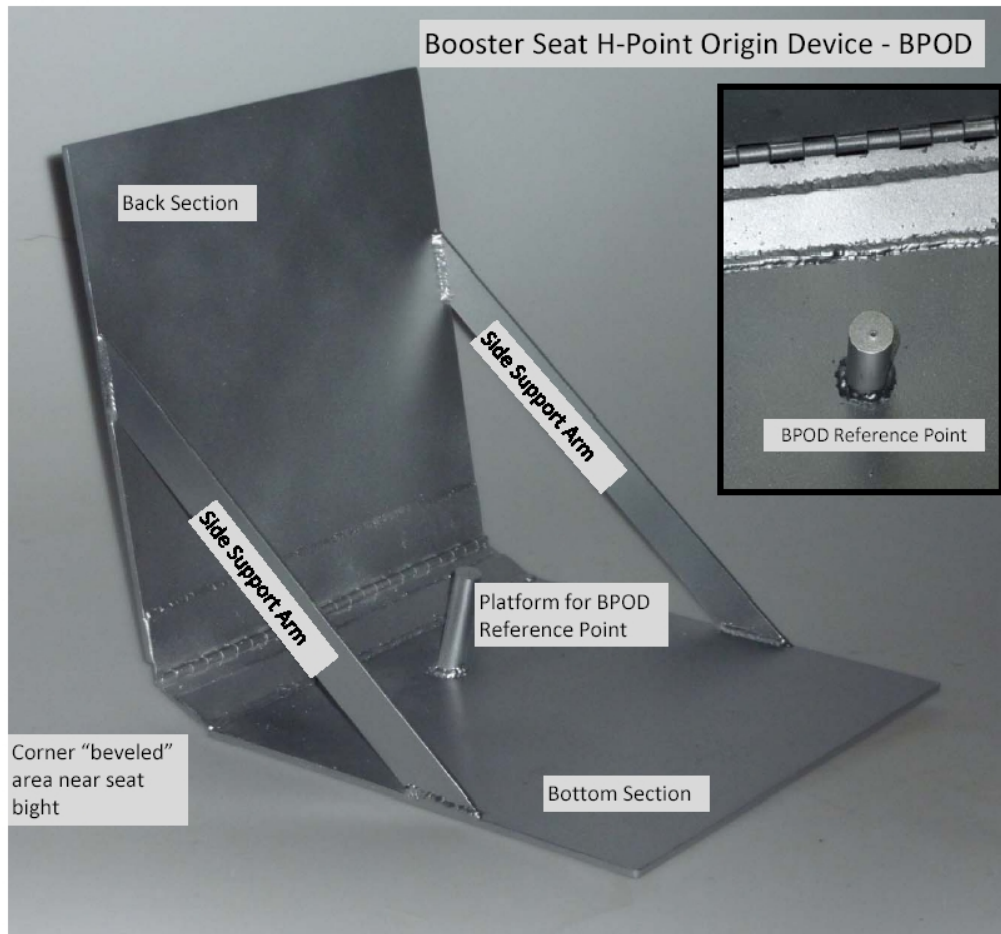
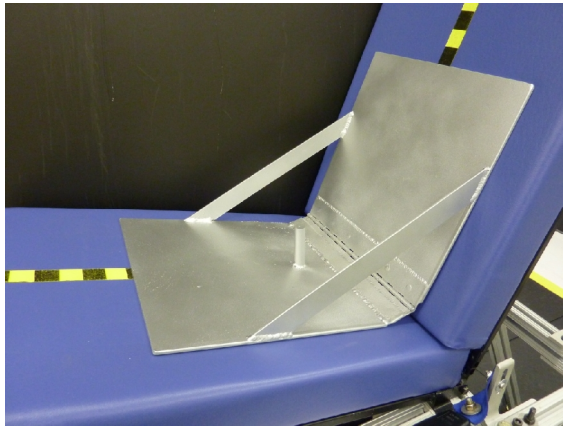
Teflon Film, 0.005-inch thick, 15 × 8-1/2 inch (length × width)  
McMaster Carr, part #8569K38

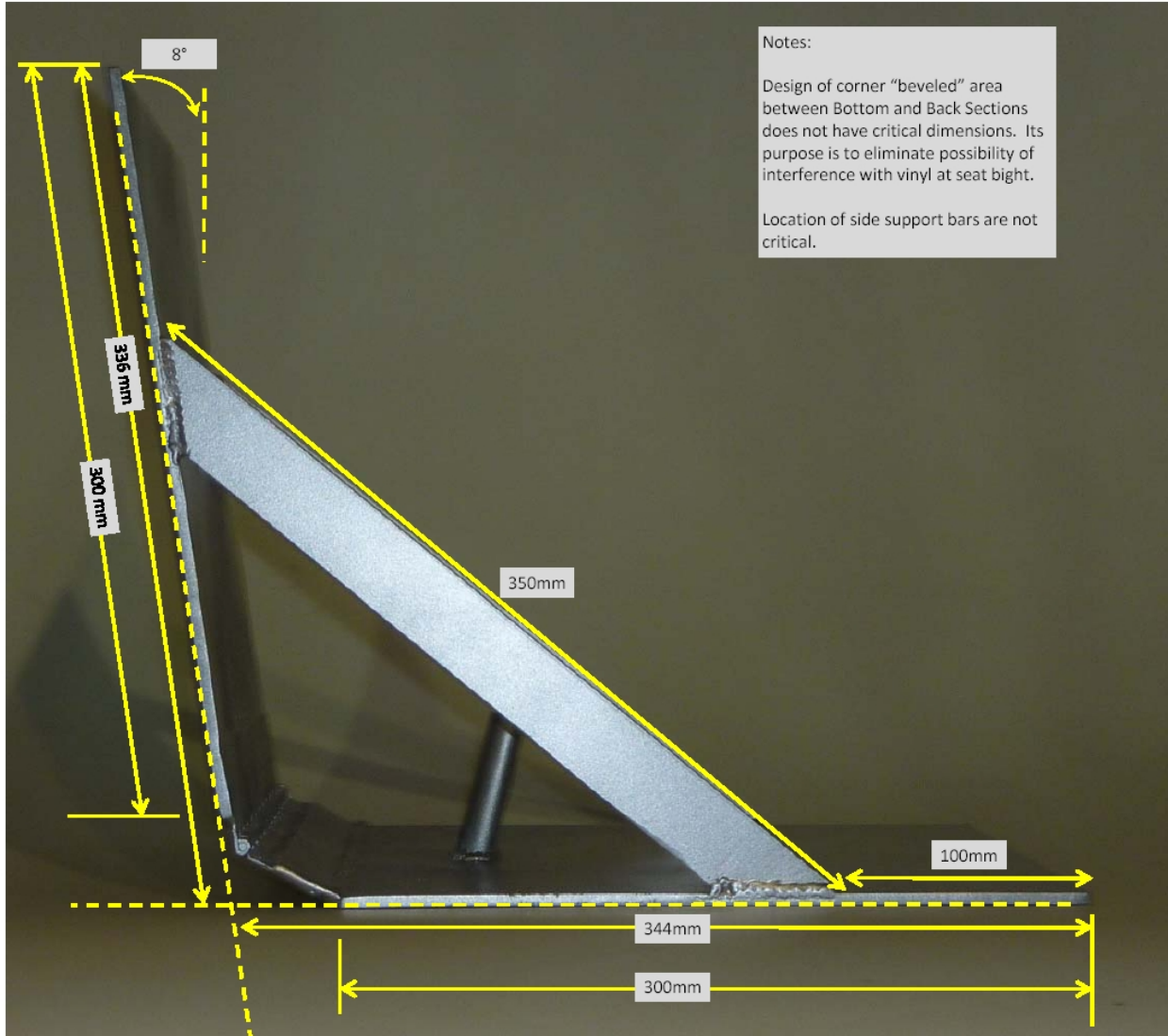
### Clamp for Loading Shoulder Belt

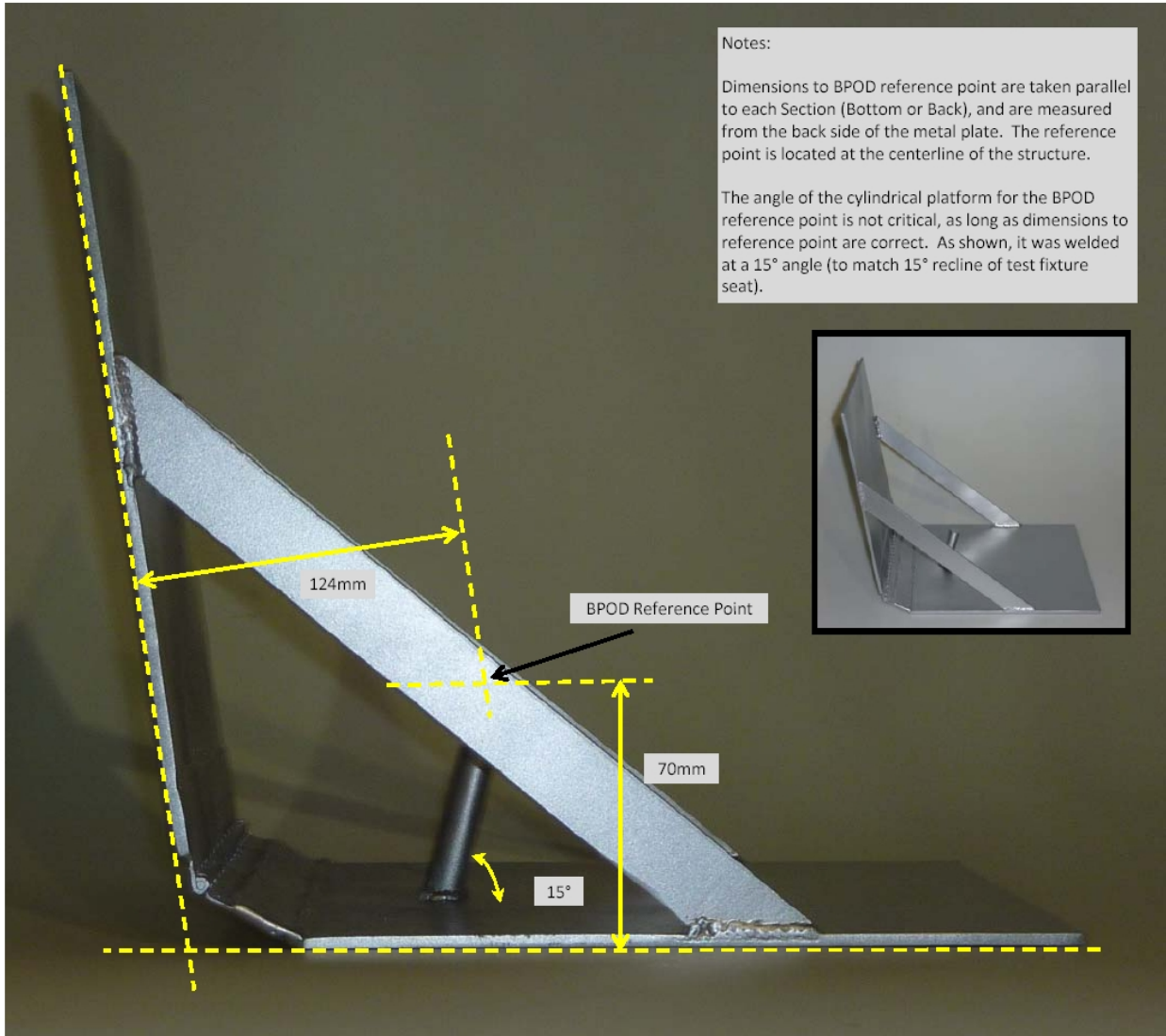
Older model belt guide from Combi Dakota  
Modified by adding short bolt for application of force gauge

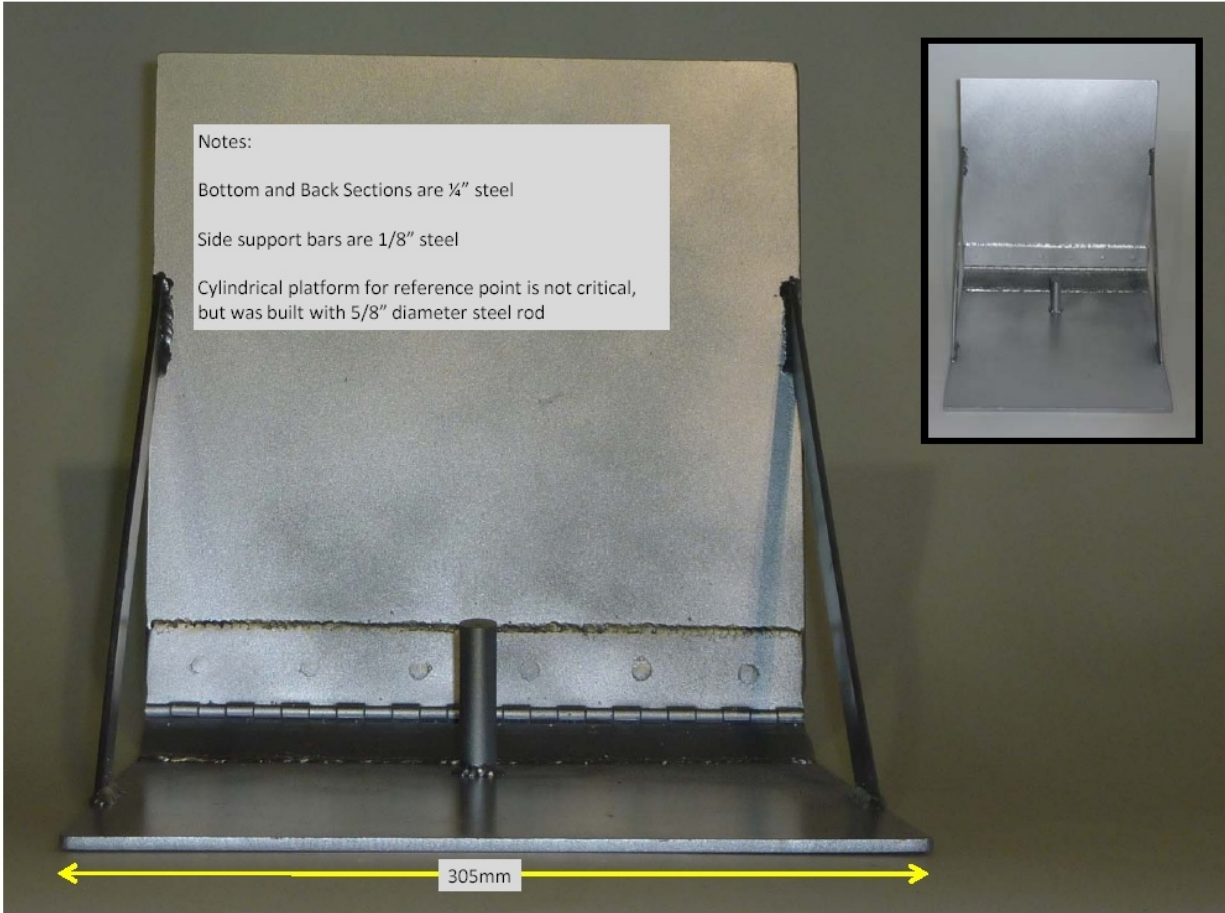


## Booster Seat H-Point Origin Device (BPOD)









## Photographs Illustrating Measurement Protocol



Steps 4.1-4.3



Step 4.4



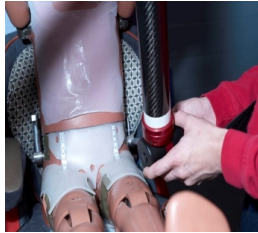
Step 4.5



Step 5.2



Steps 5.3-5.6



Step 5.8



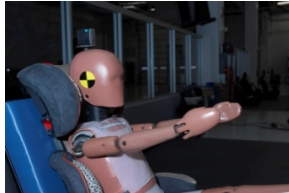
Step 5.8



Step 5.9



Step 5.9



Step 5.10



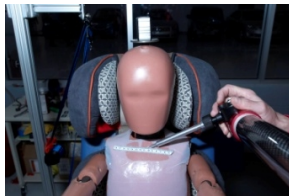
Steps 5.11-5.13



Step 5.12



Step 5.14



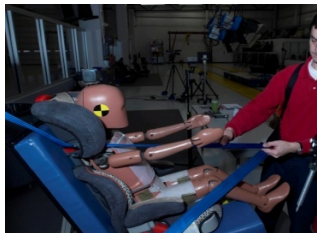
Step 5.15



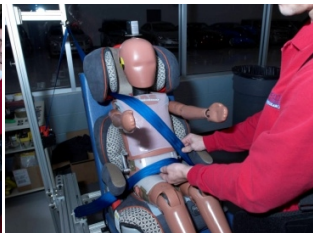
Step 5.15



Step 5.15



Step 6.1



Step 6.3-6.8



Step 6.9



Step 6.10



Step 6.13



Step 6.14



Step 6.14



Head angle



Lap belt hand measurement



Shoulder belt hand measurement



Pelvis recovery point 1



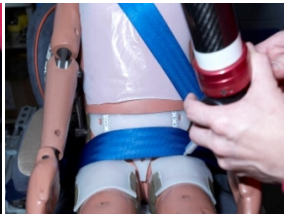
Pelvis recovery point 2



Pelvis recovery point 3



Left upper edge of lap belt at lateral location of ASIS



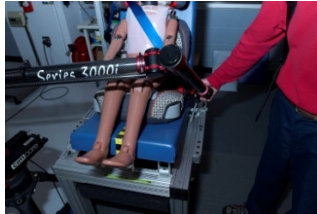
Left lower edge of lap belt at lateral location of ASIS



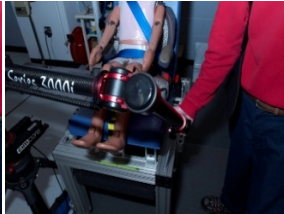
Right upper edge of lap belt at lateral location of ASIS



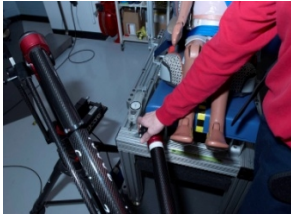
Right lower edge of lap belt at lateral location of ASIS



Fixture recovery point 1



Fixture recovery point 2



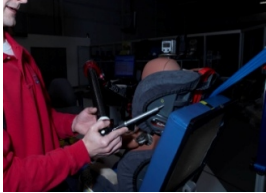
Fixture recovery point 3



Front left reference point #1 on booster pan



Rear left reference point #2 on booster pan



Top left reference point #3 on booster seat back



Left head target sticker (center of gravity)



Neck bracket plane rear and forward- most point



ATD chest reference point



Inboard edge of shoulder belt where it crosses the ATD chest reference line



Outboard edge of shoulder belt where it crosses the ATD chest reference line



Upper edge of shoulder belt where it crosses the ATD centerline



Lower edge of shoulder belt where it crosses the ATD centerline



Left hip offset tool top



Left hip offset tool front



Left ASIS ATD



Buckle reference point



Lower inboard anchorage point (X & Z)



Test fixture reference point



Pubic Synchysis (PS-ATD)



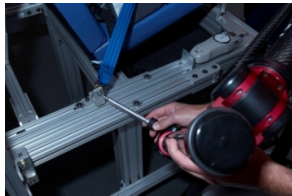
D-ring (center of bolt face)



Right ASIS-ATD



Right hip offset tool front



Lower outboard anchorage point (X & Z)



## Procedure for Measuring the Pelvis-Lap Shield Contour

- Remove the ¼" X 1" bolts at the thighs that hold the knee to the femur load cell
- Remove the knees and legs
- Prepare two 1 ½" X 8" strips of 1/8" silicone rubber (lap shield material)
- Attach silicone strips on surface of pelvis at the lateral location of the ASIS with double sided tape, making sure that the silicone strips follow the entire pelvis contour
- Place a Teflon sheet on the test fixture seat cushion
- Place the ATD on the booster test fixture, and ensure that dummy is symmetrically positioned
- The arms can be used to help stabilize the ATD
- Adjust the thighs, if necessary, so they are symmetric and properly rotated
- Apply 40# of force to the pelvis and torso
- Using necessary shimming material under the front of the thighs, position the upper surface of the thighs at 18°, with respect to horizontal
- The pelvis angle (measured on the H-point tool upper bar) should be approximately 28°
- Set up the CMM device in the pelvis reference frame
- Digitize the pelvis-lap shield contour with same Y values as the ASIS (left and right sides)

