

**Guidelines for Using the UMTRI
ATD Positioning Procedure for
ATD and Seat Positioning (Version I)**

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**INSURANCE INSTITUTE
FOR HIGHWAY SAFETY**

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Insurance Institute for Highway Safety

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Introduction

These guidelines provide a simplified method of applying the University of Michigan Transportation Research Institute (UMTRI) anthropometric test device (ATD) positioning procedure that will be used by the Insurance Institute for Highway Safety for positioning the driver ATD in side impact crash tests. This procedure is based on the original ATD positioning procedure by Reed et al. (2001) but differs slightly in the following forms:

Additional steps to the procedure improve repeatability and reproducibility. Several of these steps include positioning tolerances that are used during the initial H-point measurement as well as the final positioning of the ATD.

In the original procedure, mathematical formulae were provided to determine the UMTRI H-point position and final seat position. This procedure simplifies the process by using an Excel spreadsheet to automatically calculate the UMTRI H-point and seat position.

The January 2003 revision of this procedure differs from the last version (July 2002) in that the ATD torso recline angle specification now has positioning priority over the pelvic angle specification in cases when both requirements cannot be met.

Electronic Spreadsheets

To determine the UMTRI H-point position for the driver ATD and the seat adjustments needed to support the ATD properly in the UMTRI position, it will be necessary to download an Excel workbook template (*ATD_positioning_template.xls*) from the Institute's website, http://www.highwaysafety.org/vehicle_ratings/tech_info.htm. The workbook contains the calculations needed to determine the UMTRI position; calculations are presented in the Appendix. For the workbook to function properly, macros must be enabled. Upon opening the workbook, a form is opened that prompts the user for the following: ATD size for which the UMTRI position is being calculated; vehicle model year, make, and model; and basic seat information.

The Excel workbook template contains five worksheets and one chart, which are referred to throughout the procedure. The following describes the purpose of the worksheets and chart.

Seat Information – This worksheet is used to indicate the size of ATD for which the UMTRI position will be determined. It also is used to document, for future reference, the type of seat in the vehicle being measured. This is important because many vehicles available with both manual and electric seats often do not have similar adjustment ranges (horizontally and vertically), which can result in different UMTRI seating positions. The only user inputs required are in the cells labeled as “Manually Entered Data.”

CMM Data – This worksheet is used to enter the data obtained with a coordinate measurement machine (CMM). CMM data should only be entered in cells labeled as “CMM Data.” Instructions on taking the measurements are provided in the procedure.

Seat Range Calculations – This worksheet requires no user input. It uses data entered in the *CMM Data* worksheet to establish a relationship between the seat reference points and the H-point. It then uses the travel path of these points to establish an H-point travel path.

UMTRI Calculations – This worksheet uses data from the *CMM Data* and *Seat Range Calculations* worksheets to calculate the UMTRI H-point position.

Final H-Point and Seat Position – This worksheet shows the calculated UMTRI H-point position and the seat fore-aft and vertical positions required to obtain the correct H-point position. It also contains several cells that aid the user in positioning the ATD torso recline angle.

Seat Chart – This worksheet provides a graphical representation of the seat and H-point travel path, along with the UMTRI H-point location.

For the calculations to work properly, the data entered into the worksheets must adhere to the following coordinate system: X is positive toward the rear of the vehicle, Z is positive in the upward direction.

Positioning Procedure

With the Excel workbook template open, complete the information in the user form, then click on the *Continue* button. Confirm that the information in the *Seat Information* worksheet is correct, then continue with the positioning procedure

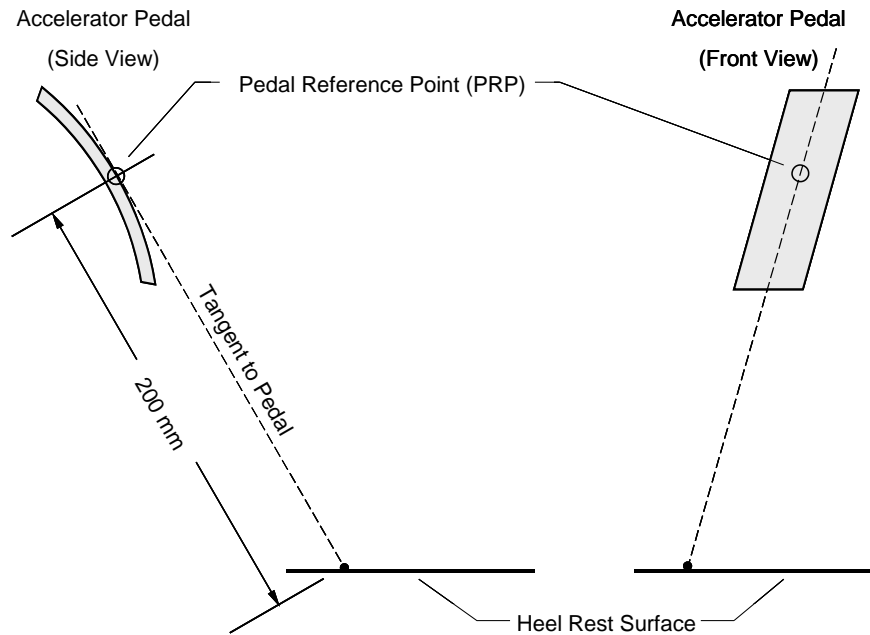
1. Establish the Pedal Reference Point

The pedal reference point (PRP) is a point on the accelerator pedal from which fore-aft dimensions are measured in the UMTRI calculations. The PRP is defined in side view using the midline contour of the accelerator pedal (Figure 1). The PRP lies on the surface of the pedal at the lateral midline and is 200 mm from the heel rest surface (floor mat). The heel rest surface is the horizontal plane on the floor mat passing through the H-point manikin (or ATD) heel point when the foot is on the pedal. The PRP can be located as follows:

- 1.1. If the vehicle has an accelerator pedal with fore-aft adjustment, adjust the pedal to its forwardmost position.
- 1.2. Place masking tape or some other markable material on the accelerator pedal surface. Mark a line defining the lateral center of the pedal. If the pedal is inclined in the plane perpendicular to the surface (e.g., if the top of the pedal is inboard of the bottom of the pedal), make the line pass through the lateral center of the pedal at each vertical level. The PRP is used for fore-aft reference dimensions only, so the lateral position of the pedal

centerline is important only as it affects the fore-aft position of the PRP. Using this line, the PRP is located using one of the following methods:

Figure 1
Pedal Reference Point Definition



- 1.2.1. If a CAD system is not available, the point may be located physically using a straightedge ruler to find the PRP (Figure 1); this method is recommended because it is significantly less time consuming than the alternative measurement method described in step 1.2.2. Continue to step 1.3.
- 1.2.2. Use a CMM to record points on the line. If the pedal is flat, only two points defining the top and bottom of the line are required. A stream of points should be taken for a curved pedal. Transfer the data to CAD, referencing the points to the vertical position of heel rest surface. Continue to step 1.3.
- 1.3. Record the PRP using one of the following methods:
 - 1.3.1. For a flat accelerator pedal, construct a line in side view (XZ plane) tangent to the accelerator pedal, i.e., at the angle of the undepressed accelerator pedal. The PRP is the point on this line that is 200 mm from the heel rest surface. For an extremely low or high pedal, the PRP may not lie on the pedal surface. Note that the tangent line generally will not pass through the measured manikin (or ATD) heel location.
 - 1.3.2. For a curved accelerator pedal, construct a line in side view (XZ plane) tangent to the accelerator pedal such that the distance from the contact point on the pedal to the heel rest surface along the tangent line is 200 mm. The contact point when this condition is met is

the PRP. Note that the tangent line generally will not pass through the measured manikin (or ATD) heel location.

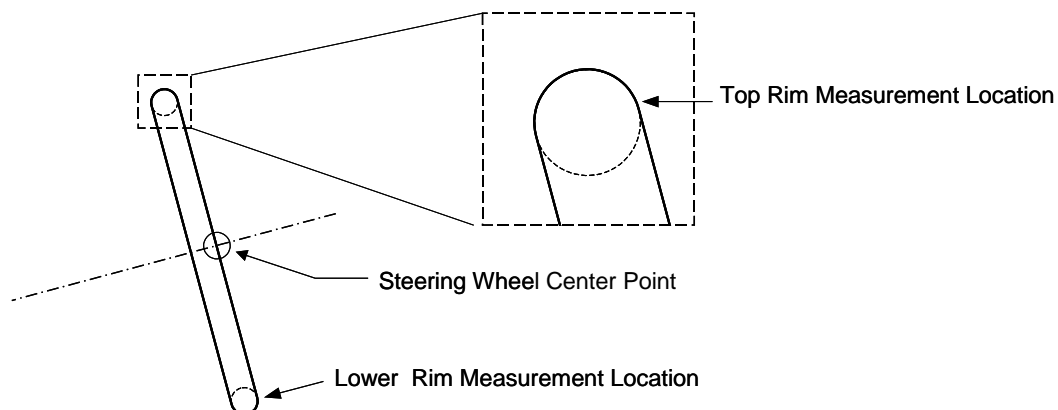
- 1.4. Enter the coordinates for the PRP and the heel rest surface into the appropriate cells of the *CMM Data* worksheet.

2. Establish the Steering Wheel Center Point

- 2.1. The location of the steering wheel center point is determined with the steering wheel at the center of its tilt adjustment range. If there is no setting detent at the mid position, lower the steering wheel to the detent just below the mid position.
- 2.2. If the steering column has a telescope, adjustment should be positioned as follows:
 - 2.2.1. For the 5th percentile female ATD, adjust the steering column to its full-forward position (untelescoped).
 - 2.2.2. For 50th and 95th percentile male ATDs, adjust the steering column to the middle of its telescoping range.
- 2.3. The steering wheel center point is defined as the intersection between the pivot axis of the steering wheel and the plane tangent to the driver side of the steering wheel rim. To locate this point:
 - 2.3.1. Measure the locations of points on the steering wheel rim at the top and bottom of the wheel with the wheel in the neutral position (Figure 2).
 - 2.3.2. Turn the steering wheel 180 degrees and record the positions again.

The steering wheel center point will automatically be calculated from the spatial average of the points recorded in steps 2.3.1 and 2.3.2.

Figure 2
Steering Wheel Center Point Calculated
from Measured Point Locations on Wheel Rim



3. Define Seat Travel Range

- 3.1. The objective of this step is to define the full range of available seat position adjustments. For manual seats the full-forward locking position is considered notch 1.
 - 3.1.1. Use the seat controls to place the seat in the full-down, full-rear position. Record the locations of two seat-frame reference points. Ideally, these points will be bolt heads or some other well-defined reference points, one near the front (seat reference point 1) and one near the rear of the seat frame (seat reference point 2). It is useful to move the seat on all its adjustment axes while selecting these points to ensure they are fixed with respect to the seat cushion; however, they should not be on the cushion itself.
 - 3.1.2. With the seat in its full-down position, use the adjuster to move the seat to its full-forward position. Record the reference point locations.
 - 3.1.3. With the seat in its full-forward position, use the height adjuster to raise the seat to its full-up position. Some seats allow further forward adjustment when the seat is in the full-up position. If possible, use the adjuster to move the seat farther forward. Record the reference point locations.
 - 3.1.4. With the seat in its full-up position, move the seat to its full-rear position. Record the reference point locations.
- 3.2. Enter the data points recorded in step 3.1 into the appropriate cells of the *CMM Data* worksheet. For seats without vertical adjustment, copy the full-down coordinates into the full-up locations for both seat reference points.

4. Conduct Initial H-Point Measurement

- 4.1. The H-point measurement should be conducted with the seat in the middle of the fore-aft seat adjustment range. If an adjustment position does not exist midway between the forwardmost and rearmost positions, the closest adjustment to the rear of the midpoint is used. If the seat is vertically adjustable, it should be placed in its full-down position. If the seat pan cushion moves independently of the seat back and frame, it should be placed in its lowest and rearmost position. If the front and back of the seat pan cushion adjust independently, adjust both to their lowest positions.
- 4.2. Determine the initial H-point location according to the current procedure outlined in SAE J826, using the 50th percentile male thigh and leg segment lengths. The seat back angle should be set to 23 degrees (as measured by the manikin torso angle) or to that specified by the manufacturer. Initially set the seat back at an angle that corresponds to a 23-degree manikin torso angle (as measured by the SAE J826 H-Point manikin) or to that specified by the manufacturer.
- 4.3. Use a CMM to record the initial H-point location along with the two reference points described above (Step 3.1.1).

- 4.4. Enter the coordinates for the H-point and seat reference points 1 and 2 into the appropriate cells of the *CMM Data* worksheet (cells L16-N18).
- 4.5. If the seat has a manual fore-aft adjustment and an even number of adjustment positions, adjust the seat forward one position and use a CMM to record the coordinates of seat reference points 1 and 2 and enter them into appropriate cells of the *CMM Data* worksheet. Confirm that no errors are reported within the *CMM Data* worksheet (cells L14-N15).

If the “Midpoint Discrepancy” message is displayed, the midtrack position calculated using the entire track range does not match the midtrack position (to within ± 2 mm) obtained by averaging the measures of seat reference point 2 obtained in steps 4.2 and 4.5. This is due to either a miscount of the initial number of seat locking positions or an incorrect initial adjustment of the seat. This can be confirmed by comparing the amount of seat fore-aft travel per adjustment indicated in the *Seat Information* worksheet (labeled as “Movement per Notch”) to the actual amount of fore-aft travel measured when the seat was moved between steps 4.2 and 4.5. If the seat was in the wrong position during the initial H-point measurement, adjust the seat to the correct position and repeat steps 4.1 through 4.5.

- 4.6. Additional measurement: Record the position of the H-point relative to another point on the vehicle. Typically the front, middle edge of the door striker is used. This measurement is not necessary for the calculation of the UMTRI seat position, but is used for reference in positioning of the test manikin in the vehicle.

5. Position the Seat for Testing

Using the data entered into the *CMM Data* worksheet, the *UMTRI Calculations* worksheet determines the ATD’s H-point location with respect to the PRP (X-axis origin) and heel rest surface (Z-axis origin), as well as the original coordinate system. The *UMTRI Calculations* worksheet also shows the amount of seat movement required (from true midtrack) to achieve the UMTRI position. The *Final H-Point and Seat Position* worksheet shows the final coordinates for the H-point and seat reference points 1 and 2. The final seat positioning proceeds as follows:

- 5.1. Seats with electric adjustment.
 - 5.1.1. Adjust the fore-aft position until the X-axis coordinate of seat reference point 2 matches its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet.
 - 5.1.2. Adjust the seat vertically (if applicable) until the Z-axis coordinate of seat reference point 2 matches its calculated UMTRI position in the *Final H-Point and Seat Position* worksheet. If the seat controls adjust the front and rear seat heights independently, they should be adjusted so that both seat reference points 1 and 2 match their calculated UMTRI positions.
 - 5.1.3. Using a CMM, record the position of seat reference point 2. If the measurement does not match the UMTRI position from the *Final H-Point and Seat Position* worksheet, repeat steps 5.1.1 and 5.1.2 until seat reference points 1 and 2 are within ± 2 mm of their calculated X- and Z-axis locations.

- 5.1.4. Using a CMM, record the final positions of seat reference points 1 and 2 and enter them into the appropriate cells of the *Final H-Point and Seat Position* worksheet.
- 5.2. Seats with manual adjustment.
 - 5.2.1. Adjust the fore-aft position of the seat to a locking position that places the X-axis coordinate of seat reference point 2 closest to its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet.
 - 5.2.2. Adjust the seat vertically (if applicable) until the Z-axis coordinate of seat reference point 2 matches its calculated UMTRI position shown in the *Final H-Point and Seat Position* worksheet. If the seat controls adjust the front and rear seat heights independently, they should be adjusted to the position that places both seat reference points (1 and 2) closest to their calculated UMTRI positions shown in the *Final H-Point and Seat Position* worksheet.

6. Final Positioning of ATD in Seat

- 6.1. Initially set the seat back at an angle that corresponds to a 23-degree manikin torso angle (as measured by the SAE J826 H-Point manikin) or to that specified by the manufacturer.
- 6.2. Place the ATD into the seat.
 - 6.2.1. For bucket seats, center the ATD on the seat cushion so that its midsagittal plane is vertical and coincides with the vertical longitudinal plane through the center of the seat cushion.
 - 6.2.2. For bench seats, position the midsagittal plane of the ATD vertical and parallel to the vehicle's longitudinal centerline and aligned with the center of the steering wheel rim.
- 6.3. Place the lower legs at approximately 120 degrees to the thighs. If the contact occurs between the back of the ATD's calves and the front of the seat cushion, the ATD should be moved forward until there is no contact at the 120 degree angle.
- 6.4. Place the legs at 120 degrees to the thighs. Push rearward on the ATD's knees to force the pelvis into the seat so there is no gap between the pelvis and the seat back or until contact occurs between the back of the ATD's calves and the front of the seat cushion.
- 6.5. Driver leg and foot positioning.
 - 6.5.1. Rest the ATD's thighs against the seat cushion and set the ATD's knees as follows:
 - 6.5.1.1. For 5th percentile female ATDs, set the minimum initial transverse distance between the longitudinal centerline of the ATD's knees at 160-170 mm (6.3-6.7 in.), with the thighs and lower legs of the ATD in vertical planes.
 - 6.5.1.2. For 50th and 95th percentile male ATDs, set the minimum initial transverse distance between the outside flanges of the knees at 270 mm, with the thighs and lower legs of the ATD in vertical planes.

6.5.2. For the right foot position, if the vehicle has an accelerator pedal with fore-aft adjustment, the pedal should be adjusted to its forwardmost position.

6.5.3. Rest the right foot of the ATD on the undepressed accelerator pedal, with the rearmost point of the heel on the floorpan in the plane of the pedal. If the foot cannot be placed on the accelerator pedal, set it initially perpendicular to the lower leg and then place it as far forward as possible in the direction of the pedal centerline, with the rearmost point of the heel resting on the floorpan. If the ball of the foot does not contact the pedal, change the angle of the foot relative to the lower leg such that the toe of the foot contacts (or is in the position closest to contacting) the undepressed accelerator pedal. The angle between the foot and the lower leg should not be less than 90 degrees. If the vehicle has an accelerator pedal with fore-aft adjustment and the right foot does not contact the pedal, the pedal should be adjusted rearward until the sole of the right foot overlaps the pedal surface by at least 20 mm.

6.5.4. Left foot position.

6.5.4.1. Left foot positioning guidelines for vehicles with a footrest: Position the ATD's left foot on the footrest unless:

more than 30 mm of the medial sole of the ATD's shoe measured at the location of the ball of the foot is not directly over the footrest, or

the ATD's leg/foot will not stay unaided in a position with the foot on the footrest and the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

If neither condition above can be met, then position the left foot on the most outboard flat surface of the toepan that is inboard of the footrest unless:

the toepan is too far forward to rest the bottom of the foot on it, or

the foot is under the brake pedal, or

the ATD's leg/foot will not stay unaided in a position with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

If neither positioning method above can be achieved, then position the ATD's left foot flat on the horizontal part of the floor, with the toes at the corner between the floor and toepan or as far forward as possible while keeping the left knee at the same height as the right knee and with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

6.5.4.2. Left foot positioning guidelines for vehicles without a footrest: Position the ATD's left foot on the most outboard flat surface of the toepan while maintaining the knee-to-knee distance specified in step 6.5.1 unless:

the toepan is too far forward to rest the bottom of the foot on it, or

the foot is under the brake pedal, or

the ATD's leg/foot will not stay unaided in a position with the leg in a vertical plane with a minimum knee-to-knee distance specified in 6.5.1.

If the positioning method above cannot be achieved, then position the ATD's left foot flat on the horizontal part of the floor, with the toes at the corner between the floor and toepan or as far forward as possible while keeping the left knee at the same height as the right knee and with the leg in a vertical plane with the knee-to-knee distance specified in step 6.5.1.

- 6.6. Fully recline the seat back.
- 6.7. Hold the ATD's thighs down and push rearward on the upper torso to maximize the ATD's pelvic angle.
- 6.8. While holding the thighs in place, rotate the ATD torso forward until the torso recline angle (the angle of a side view line from the ATD H-point to the head's center of gravity) is set to 12 ± 1 degrees. The H-point and head center of gravity coordinates can be entered into the appropriate cells in the *Final H-Point and Seat Position* worksheet, where the torso recline angle is automatically calculated. While supporting the ATD, rotate the seat back forward until the ATD torso is supported in the 12 degree torso recline position.
- 6.9. Gently rock the upper torso relative to the lower torso laterally in a side-to-side motion three times through a ± 5 degree arc (approximately 50 mm side to side) to reduce friction between the ATD and the seat.
- 6.10. Reposition feet if necessary.
- 6.11. Check foot position. If the right foot does not reach the accelerator pedal or if the heel does not touch the ground, adjust the seat in the following manner:
 - 6.11.1. Adjust the seat forward at increments of one locking position (manual seats) or 10 mm (power seats) until the sole of the right foot contacts a point the pedal surface that is at least 20 mm from the bottom of the pedal, as measured along the plane of the bottom of the foot. This is done with the ATD's right foot and lower leg in the forwardmost stretched position.
 - 6.11.2. If the heel of the foot is not resting on the heel rest surface (floormat), lower the seat vertically at 5-mm increments until contact is made. If the seat has independent front and rear height adjustments, they must both be adjusted equally to ensure the seat pan angle does not change. If the seat is in its lowest position and the foot still cannot contact the heel rest surface, no further adjustment of the seat or ATD should be attempted.
- 6.12. Measure the ATD's pelvic angle. The angle should be set to 20 ± 2.5 degrees for 5th percentile female ATDs and 22.5 ± 2.5 degrees for 50th and 95th percentile male ATDs.
 - 6.12.1. If the ATD's pelvic angle is within the specified range, continue to step 6.15. If the ATD's pelvic angle is above or below the specified range, the torso recline angle can be adjusted up to ± 1 degree from the 12 degree position in order increase or decrease the

pelvic angle. If after adjusting the torso recline angle the pelvic angle is still not within the specified range, no further adjustment of the ATD should be attempted.

- 6.13. Measure the head transverse instrumentation platform angle. The angle should be level to within ± 0.5 degrees. Adjust the lower neck nodding joint to level the head. If it is not possible to achieve the head level within ± 0.5 degrees, minimize the angle.
- 6.14. Measure the ATD's torso recline angle (the angle of a side view line from the ATD H-point to the head's center of gravity). The angle should be set to 12 ± 1 degrees. If the torso recline angle is within the specified range, proceed to step 6.15.
 - 6.14.1. If the measured torso recline angle is below the specified range, recline the seat back one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls). Hold the ATD's thighs down and push rearward on the upper torso to increase the ATD's torso recline angle. Measure the torso recline angle. Repeat this step until the torso recline angle is within the specified range. Return to step 6.13.
 - 6.14.2. If the measured torso recline angle is above the specified range, hold the ATD's thighs and rotate the torso forward until the torso recline angle is within the specified range. If the ATD's torso is not supported, adjust the seat back forward at increments of one adjustment position (for seats with manual seat back controls) or 2 degrees (for seats with electric seat back controls) until the torso is fully supported in the new position. Measure the torso recline angle. Repeat this step until the torso recline angle is within the specified range. Return to step 6.13.

Note: If the torso recline angle, head transverse instrumentation platform angle, and pelvic angle requirements cannot all be met, priority should be given to the torso recline angle, followed by the head transverse instrumentation platform angle.

- 6.15. Using a CMM, record the final positions of the ATD H-point and seat reference points 1 and 2 and enter them into the appropriate cells of the *Final H-Point and Seat Position* worksheet.
- 6.16. Position ATD arms and hands.
 - 6.16.1. For ATDs with full arms (e.g., Hybrid III), place hands on the 9 and 3 o'clock positions of the steering wheel. If the steering wheel rim has a telescoping adjustment range and the ATD's hands cannot reach the steering wheel, adjust the steering column rearward (if applicable) until the hands reach the steering wheel rim.
 - 6.16.2. For ATDs with half arms (BioSID, EuroSID-1, ES-2, and SID-IIIs), adjust the upper arm to the stop position 45 degrees forward of the neutral (down) position.

References

Reed, M.P.; Manary, M.A.; Flannagan, C.A.C.; Schneider, L.W.; and Arbelaez, R.A. 2001. Improved ATD positioning procedure. SAE Technical Paper Series 2001-01-0118. Warrendale, PA: Society of Automotive Engineers.

Appendix

Calculations for Determining UMTRI Position

The following calculations are used by the Excel workbook template (*ATD_positioning_template.xls*) to determine the UMTRI H-point. When using these calculations to independently verify the UMTRI position, the H-point and vehicle measurements must be conducted as described in the procedures above. The measurement locations used for the UMTRI calculations are illustrated in Figure A1.

Coordinate system orientation: X+ toward rear of vehicle, Z+ upwards.

1. Calculate the seat track rise $r = \Delta Z / \Delta X$:

$$r = \frac{HPtFZ - HPtRZ}{HPtRX - HPtFX}$$

where

HPtRZ is the vertical coordinate of the rear of the mid-height H-point travel path with respect to the heel rest surface,

HPtRX is the horizontal coordinate of the rear of the mid-height H-point travel path with respect to PRP,

HPtFZ is the vertical coordinate of the front of the mid-height H-point travel path with respect to the heel rest surface, and

HPtFX is the horizontal coordinate of the front of the mid-height H-point travel path with respect to PRP.

The seat track rise r should be zero or positive, indicating the increase in H-point height for each unit of forward movement of the seat along the mid-height H-point travel path. The H-point travel path is based on the relative position of the H-point with respect to the two seat reference points, with the seat in the midtrack and full-down position.

2. Calculate seat H-point location for testing:

The fore-aft H-point location (X coordinate) aft of the PRP to be used for ATD testing is given by

$$HPtX(\text{mm aft of PRP}) = -15.0 + 0.433S + 0.41W - \frac{0.24}{1 - 0.3943r} (HPtRZ + r(HPtRX - 1054))$$

where

S is the ATD reference stature (see below), and

W is the fore-aft distance between the PRP and steering wheel center point.

S is set to:

1511 mm for the 5th percentile adult female ATD,

1753 mm for the 50th percentile adult male, and

1870 mm for the 95th percentile adult male.

For seats with vertical adjustment, the vertical position of the seat H-point location used for testing is given by

$$HPtZ(mm) = HPtRZ + r (HPtRX - HPtX)$$

i.e., the location along the mid-height H-point travel path that lies *HPtX* mm rearward of PRP.

Figure A1
H-point Travel Range and Other Measurement
Locations Used in UMTRI Positioning Procedure

