SAE International™

SURFACE VEHICLE STANDARD

SAE J4002

REV. AUG2005

Issued 2002-06
Revised 2005-08

Superseding J4002 FEB2004

(R) H-Point Machine (HPM-II) Specifications and Procedure for H-Point Determination—Auditing Vehicle Seats

TABLE OF CONTENTS

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE 100 Leading Our World In Motion

Introduction

The tools and procedures for H-point determination given in this standard are based on the new SAE H-Point Machine (HPM-II).

H-point devices are used during vehicle design and development to establish interior reference points and dimensions for occupant packaging, and to validate the location of these key reference points and dimensions on physical properties during audits.

H-point devices are also used for the design and validation of seats. However, in these instances, the reference points and dimensions are defined relative to the seat structure and/or surface, rather than the vehicle's interior. The procedures for positioning the H-point devices in seats are abridged, and do not require the use of the shoe tool or leg segments.

For convenience and simplicity, many terms associated with H-point devices use human body parts in their name. However, they should not be construed as measures that indicate occupant accommodation, human capabilities, or comfort. H-point devices do not represent the size or posture of any category of occupant.

a. Key Differences from SAE J826

Compared to the H-point machine described in SAE J826, the changes made have resulted in improved repeatability, greater ease of use, and additional features and measurement capabilities. All efforts were made to achieve these improvements while minimizing their impact on the location of reference points and measurements. Several of the changes are discussed below.

1. Separate Components

For the HPM-II, the legs (upper and lower), shoe, cushion pan and back pan are all separate pieces. This greatly improves the ease of installation.

2. 'Legless' Manikin

The new tools allow the H-point location to be defined without having to attach the legs. This is a major advantage of the HPM-II. The new procedure is based on installing the HPM-II without legs. Use of legs is optional.

3. Shoe Tool

Several improvements were made to the shoe tool and how it is positioned in the vehicle, including:

- changing the location of the ball of foot to 200 mm from heel of shoe,
- establishing a new pedal reference point (PRP), and
- defining a more complete procedure for positioning the shoe.

4. Cushion Angle

The cushion angle can now be measured independently of thigh angle, and at the same time the other measurements are made. Previously, cushion angle was measured off the thigh line, and required a separate installation of the HPM.

5. Lumbar Support

The articulation of the back pan assembly allows the HPM-II to be better seated in contoured seats. It also provides a new measurement called lumbar support prominence (LSP). This measurement provides an indication of the amount the seatback is contoured to provide support for the lumbar spine. The contour of the new back pan assembly is most similar to the original H-point machine when the HPM-II is in a neutral posture (LSP equals zero).

b. Time period for coexistence of SAE J826 and SAE J4002

SAE J4002 and SAE J826 shall co-exist for a transition period of at least 10 years, preferably no longer, from the first publication date of SAE J4002. Following this transition period SAE J826 will be withdrawn. During the transition period, it remains up to the vehicle designers to decide which HPM to use. Regulatory bodies and other parties that need to know shall be informed regarding which HPM was used.

1. Scope

This Standard provides the specifications and procedures for using the H-point machine (HPM[1]) to audit vehicle seating positions. The HPM is a physical tool used to establish key reference points and measurements in a vehicle (see Figure 1 and Appendix A). The H-point design tool (HPD) is a simplified CAD[2] version of the HPM, which can be used in conjunction with the HPM to take the optional measurements specified in this document, or used independently during product design (see Appendix D).

These H-point devices provide a method for reliable layout and measurement of occupant seating compartments and/or seats. This document specifies the procedures for using the H-point machine (HPM) to audit (verify) key reference points and measurements in a vehicle.

The devices are intended for application at designated seating positions. They are not to be construed as tools that measure or indicate occupant capabilities or comfort. They are not intended for use in defining or assessing temporary seating, such as folding jump seats.

1.1 Rationale

With this revision, the 2004 version of SAE J4002 has been subdivided into three separate standards in order to specify in more detail the uses of the HPM II and HPD in auditing vehicles (J4002:2005), benchmarking vehicles (J4003), and in designing vehicle interior packages (J4004).

---

[1] All references to H-point machine or HPM in this standard refer to the new SAE H-point machine (HPM-II), unless otherwise noted.

[2] CAD is an acronym for computer-aided design. In a general sense, it has come to encompass any software system/approach to automotive design and development, and is often used to refer to CAE (computer-assisted engineering) and CAM (computer-assisted manufacturing) software systems as well.

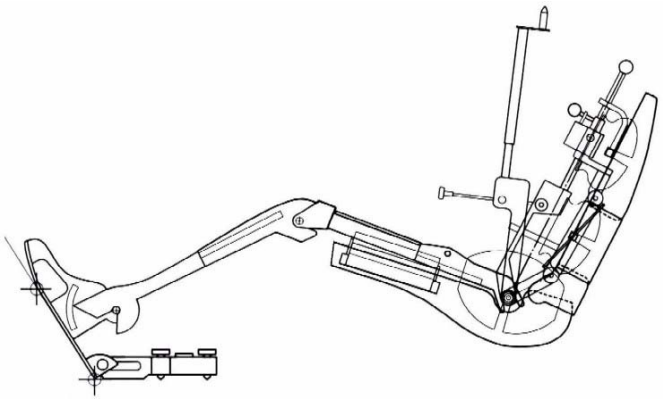


FIGURE 1—SIDE VIEW OF HPM

2. Normative References

This document contains provisions which reference the following documents. At the time of publication, the indicated editions of these references were valid. Since all publications are subject to revision or deletion, users of this document are encouraged to refer to the most recent published editions of these referenced documents. Information obtained using the following publications is needed for application of the procedures described in this document.

SAE J1100 (2005)—Motor Vehicle Dimensions
SAE J182—Motor Vehicle Fiducial Marks

3. Definitions

For the purposes of this Standard, the following definitions apply. Several of the reference points established with an H-point device are required for the subsequent positioning of other design devices, such as head contours, eyellipses, and reach curves. The most important reference points established by an H-point device are the H-point, the H-point travel path, the SgRP (seating reference point), the AHP (accelerator heel point), and the PRP (pedal reference point).

3.1 H-point

Point at the pivot center of the back pan and cushion pan assemblies, located on the lateral centerline of the H-point device (HPM or HPD).

NOTE 1—The H-point is also the intersection of the cushion line and the torso (back) line. When an H-point device is properly positioned within a vehicle – either in CAD or in an actual physical property – the location of the H-point relative to the vehicle is used as a vehicle reference point. If the seat is moved, the location of the H-point within the vehicle is changed. Therefore, adjustable seats will have more than one H-point location, while fixed seats will have only one H-point location.

NOTE 2—H-points are often referred to as hip points or hip pivot points. However, they do not accurately represent the location of the human hip joint.

3.2 H-point Travel Path

All possible locations of the H-point provided by the full range of seat adjustments (horizontal, vertical or tilt) for a given designated seating position.

3.3 SgRP (Seating Reference Point), R-point, Design H-point

Manufacturer's intended location for a design H-point, which is specifically designated as R-point or SgRP, and which:

a. is the fundamental reference point used to establish occupant accommodation tools and dimensions;
b. simulates the position of the pivot center of the human torso and thigh;
c. has coordinates established with respect to the designed vehicle structure;
d. establishes the rearmost normal design driving or riding H-point of each designated seating position, which accounts for all modes of adjustment: horizontal, vertical and tilt that are available for the seat, but does not include seat travel used for purposes other than normal driving and riding

3.4 AHP (Accelerator Heel Point)

Point located at the intersection of the heel of shoe and the depressed floor covering, with the ball of foot contacting the lateral centerline of the undepressed accelerator pedal, and the bottom of shoe on the pedal plane.

3.5 PRP (Pedal Reference Point)

Point on the accelerator pedal lateral centerline where the ball of foot contacts the pedal, with the heel of shoe at AHP and bottom of shoe on the pedal plane.

3.6 FRP (Floor Reference Point, Rear Passenger)

Point located at the intersection of the heel of shoe and the depressed floor covering, with the HPM shoe and/or lower leg segment resting against the seat immediately in front, and the bottom of foot positioned flat on the depressed floor covering.

4. Measurement Procedure for the Three-dimensional H-point Machine

A complete description of the three-dimensional H-point machine is given in Appendix A. Specifications and tolerances are given in Appendix B. A field checking procedure for the HPM is given in Appendix C.

4.1 Summary of Installation Procedure

TABLE 1—SUMMARY OF INSTALLATION PROCEDURE

Driver Position	2nd and 3rd Row Passenger Positions
Prepare the physical property. If possible, calibrate the CMM equipment to vehicle grid coordinates.	
Position seat to design intent location and attitude.	Position the test seat and (if the HPM legs will be installed) the seat in front of the test seat to design intent location and attitude.
Install shoe fixture and shoe tool, if measuring leg and shoe dimensions. Record shoe-based measurements. See 5.1.	Install shoe tool, if measuring leg and shoe dimensions. Record shoe-based measurements. See 6.1.
Install and load the cushion pan, and back pan. If measuring head room, install head room fixture before loading the pans. See 7.1. Determine H-point, torso (back) angle, cushion angle, and LSP. See 4.8.	
Attach thigh and lower leg segments, if measuring leg-based dimensions. See 5.1.	Attach thigh and lower leg segments, if measuring leg-based dimensions. See 6.1.
Determine optional measurements. See 5.2 and 7.1.	Determine optional measurements. See 6.2 and 7.1.

4.1.1 Measured Versus Design Values

When verifying or auditing a particular designated vehicle seating position, measurements taken with the three-dimensional HPM are normally compared to the design values indicated by the vehicle manufacturer. If any measured value is sufficiently close to the manufacturer's design value, the vehicle/seat is considered to meet the manufacturer's design intent for that measurement. The vehicle manufacturer or a regulatory agency may provide specifications for the term "sufficiently close". Two HPM measurements of particular interest are H-point (SgRP) and torso (back) angle.

4.2 Prepare Vehicle and Seat

4.2.1 Vehicle

Dimensions are measured relative to the vehicle three-dimensional reference system by setting up the vehicle relative to the fiducial marks (see SAE J182) as specified by the manufacturer. The property (e.g., vehicle) shall be levelled prior to any HPM installation or measurement. Once the property is levelled, care should be taken to not lean on it, rock it, or in some other way knock it off level.

If the accelerator pedal is needed for the measurements, the accelerator pedal shall be held in an undepressed position by some means. For example, use blocks or clamp the accelerator cable to prevent the pedal from moving. If the pedal freely rotates about a pivot, independent of pedal travel, fix or block the pedal at the middle of the free rotation range. If the pedal rotates, but is held at a given angle with a spring, block the pedal at the given angle to maintain its position. If the accelerator pedal has fore/aft adjustment, the pedal shall be positioned as specified by the manufacturer. If no specification is provided, the pedal shall be adjusted to its most forward position in the vehicle.

4.2.2 SEAT

The vehicle shall be preconditioned at the manufacturer's discretion, at a temperature of 20 °C ± 10 °C to ensure that the seat material reaches room temperature. If the seat to be checked has never been sat upon, a 70 to 80 kg person or device shall sit on the seat to flex the cushion and back.

The following considerations will help ensure that stable, reliable measurements are made across seat types. Prior to the installation of the HPM, seats should remain unloaded for 30 minutes at the manufacturer's request. This is to allow the seat and seat materials (e.g., foam) to recover from compression.

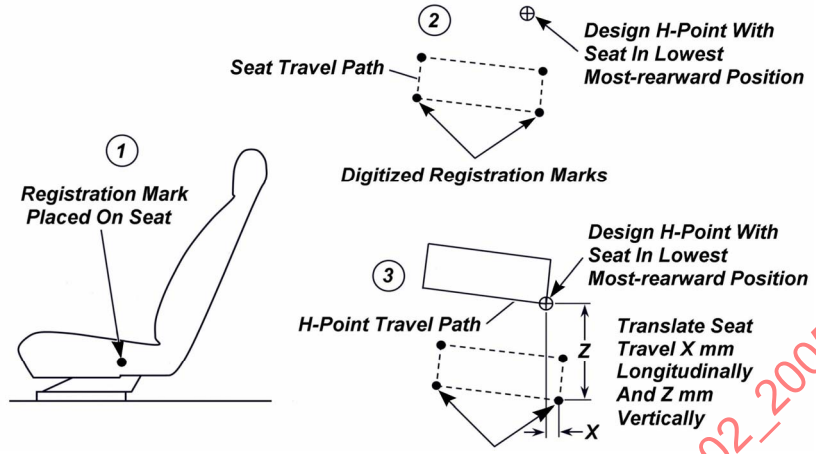
At the request of the manufacturer muslin cloth should be placed over the seat prior to installing the HPM. The muslin cloth may be a single piece fitting across both seat cushion and seat back, or two pieces, one for the cushion and one for the seat back. This ensures a constant friction surface across seat fabrics. See B.11.

When using the H-Point Machine (HPM), interactions can occur between adjacent seating positions (i.e. having an HPM installed at the center occupant position can change the results obtained for the outboard occupant position). Therefore, only one machine should be installed in a particular row of seats during each test.

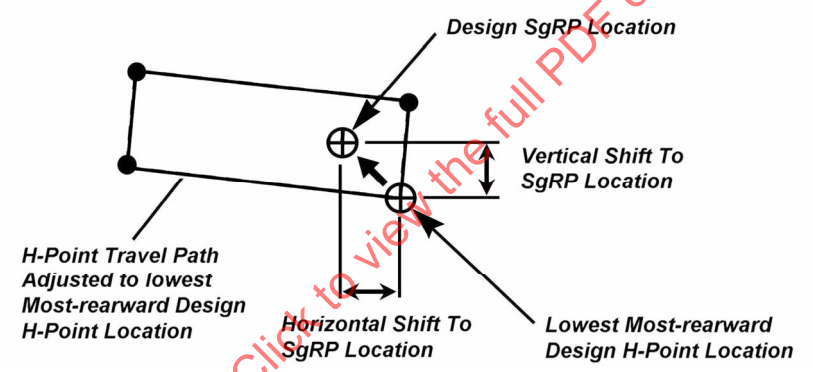
4.3 Determine the H-point Travel Path (Optional)

If verification of the H-point travel path is desired, the seat's travel path must be digitized, and then translated to the H-point travel path. First, adjust the seat cushion to the middle of the cushion angle adjustment range. Next, place one or more registration marks on the side of the seat. The registration mark(s) can be located anywhere along the side of the seat that can be easily accessed by the CMM equipment. Finally, digitize the location of the registration mark(s) with the seat in each of four positions: lowest most-rearward, highest most-rearward, highest most-forward, lowest most-forward. By connecting these four points, the seat's travel path can be seen more readily. See Figure 2A, steps 1 and 2.

NOTE—For seats without vertical adjustment, only two points need to be taken, most forward and most rearward, provided the seat track follows a linear path. If the seat track travel path is curved, additional points (between foremost and rearmost) need to be taken.



(a) Translate seat travel path to H-point travel path



(b) Move seat to SgRP location

FIGURE 2—LOCATING SGRP FROM THE SEAT TRAVEL PATH

4.4 Adjust Seat to Design Intent

4.4.1 Move Seat to Design Intent Position

All adjustable features of the seat shall be set to manufacturer's design intent attitude or position before installing the HPM.

For seats with an independent vertical adjustment or suspension, the vertical position shall be rigidly fixed in a position specified by the manufacturer.

The seat registration mark is helpful in positioning the seat at design intent relative to one of the seat's extreme locations (usually the rearmost, lowest position) determined in 4.3. Normally the design intent position specified by the vehicle manufacturer is the seating reference point (SgRP). Figures 2A and 2B illustrate a typical way to translate seat travel to H-point travel, and then to SgRP. After an adjustable seat is positioned at design intent, digitize the seat cushion registration mark(s).

4.4.2 TORSO (BACK) ANGLE AND CUSHION ANGLE

The location of the H-point is influenced by a number of factors, including how the seat cushion and seat back are adjusted. Therefore, for accurate results, the seat shall be adjusted to the design intent torso (back) angle and cushion angle before installing the HPM.

Seat torso (back) and cushion angle adjustment procedures for auditing differ depending on whether or not variance in seat build is of interest.

4.4.2.1 If the purpose of the audit is to evaluate both the seat build and the vehicle build, then the seat structure shall be adjusted to the design attitude.[3] If the seat and seat assembly do not match their design intent values, this will affect the measured torso (back) and cushion angles, and could result in a displacement of the H-point. The vehicle manufacturer (or seat supplier) will need to provide information regarding the location and attitude of the discernable seat structure (e.g., the seat frame), other hard points (e.g., seat controls, pivot points, head restraint rods, etc), or the amount of adjustment required to attain the desired seat attitude.

4.4.2.2 If the purpose of the audit is to evaluate vehicle build independent of seat construction, then the seat shall be positioned to the design intent torso (back) angle and cushion angle using either the method in 4.4.2.2.1 or 4.4.2.2.2. (Since both torso (back) and cushion angles measure how the seat impacts the HPM, the HPM needs to be installed in order to set the seat to the design intent values of these angles).

4.4.2.2.1 Method 1: Install the HPM twice. The first installation allows the seat to be positioned at the design intent values of torso (back) and cushion angle. Then, remove the HPM, wait 30 minutes to allow the seat materials to recover, and install the HPM a second time for the audit.

4.4.2.2.2 Method 2: Monitor and adjust cushion angle and torso (back) angle during the installation and loading of the HPM according to Table 2 and Table 3.

As the HPM is loaded, torso (back) angle will increase. Therefore, as a guide, the initial (unloaded) torso (back) angle reading should be approximately 2 degrees less than the desired final torso (back) angle reading after loading. For example, an initial setting of approximately 20 degrees should result in a final reading of 22 degrees.

Check the initial torso (back) angle using an inclinometer placed on the torso angle land of the back pan inclinometer land (Figure 3). Adjust the seat recliner as necessary to achieve a reading of approximately 2 degrees less than design intent torso (back) angle.

[3] Note that the seat can also be verified independent of the vehicle.

TABLE 2—ADJUSTING TORSO (BACK) AND CUSHION ANGLES DURING HPM LOADING

	Driver Position	2nd or 3rd Row Passenger Positions
Torso (Back) Angle A40	Initially set the torso (back) angle to approximately 2 degrees more vertical than design intent. Monitor and adjust if needed during HPM loading to achieve design intent.	If the seat recliner is adjustable, initially set the torso (back) angle to approximately 2 degrees more vertical than design intent. Monitor and adjust if needed during HPM loading to achieve design intent.
Cushion Angle A27	If the seat cushion is adjustable, initially set the cushion angle to be slightly greater than design intent value. Monitor and readjust as necessary during HPM installation to achieve the design intent cushion angle as the final reading.	

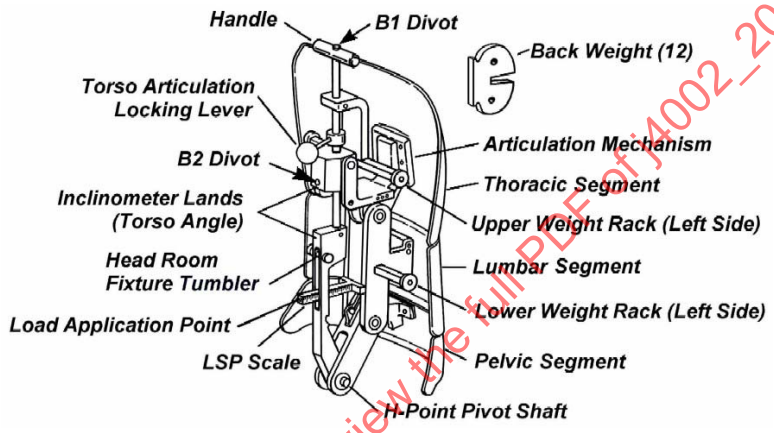


FIGURE 3—BACK PAN

4.4.3 SEAT IN FRONT OF TEST SEAT

If leg positions, leg room, foot room, and knee clearance are planned to be measured, the seat in front of the test seat should be positioned to its SgRP or R-point and design intent torso (back) angle.

4.5 Install HPM Cushion and Back Pan Assembly

4.5.1 INSTALL THE CUSHION PAN

Place the cushion pan (Figure 4) on the seat with the back of the pan resting lightly against the seat back. Visually center the cushion pan laterally in the seat.

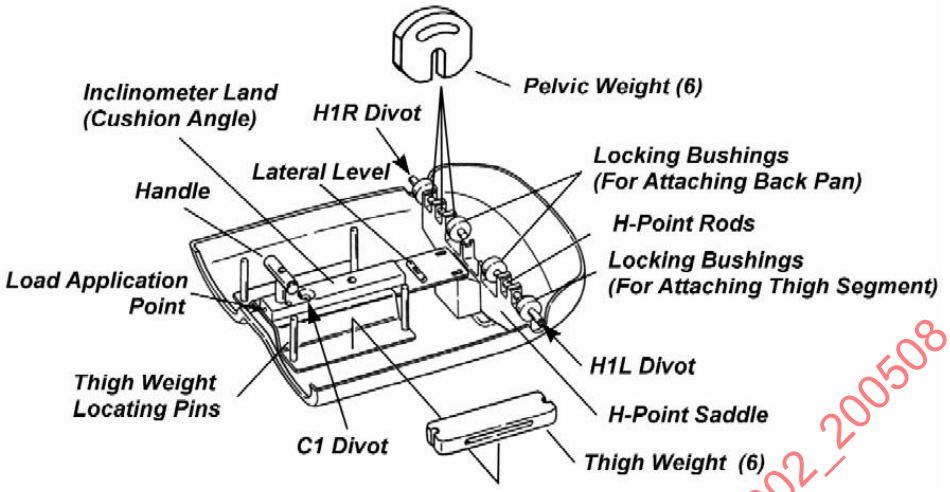


FIGURE 4—CUSHION PAN

4.5.2 INSTALL THE BACK PAN

To protect the shells of the cushion and back pans, the back pan should be locked in a slouched position before installing it. Articulate the back pan into a slouched position (LSP < 0) and lock.

Place the H-point pivot shaft, located at the base of the back pan, on the H-point saddle of the cushion pan (see Figures 3 and 4). The upper portions of the back pan should not contact the seat back. Secure by sliding the brass locking bushings inwards over the H-point shaft.

Unlock the torso articulation. Put one hand firmly on the cushion pan T-handle to maintain the position of the cushion pan. Put the other hand on the back pan T- handle and gently rotate the back pan assembly against the seat back to allow the back pan assembly to conform to the seat back contour. Ensure that the top and bottom corners at each side of the lumbar segment remain outside the thoracic and pelvic segments. Also ensure that the muslin cloth is not caught between the back segments.

NOTE 1—The cushion and back pan can be connected and installed as a single unit if preferred. Follow the same steps as above, centering the cushion pan lightly against the seat back with the back pan rotated forward and locked in the slouched position.

NOTE 2—If measuring head room, install the head room fixture now (see 7.1).

4.5.3 LEVEL THE HPM

Referring to the bubble level on the cushion pan, dither and adjust the HPM to level laterally on the seat. Make sure the HPM is in firm contact with the seat back.

4.6 Load the HPM

Installing weights on the HPM is referred to as 'loading'. The HPM shall be loaded with the torso articulation mechanism unlocked. Weights shall be installed from the H-point outward and from the H-point upward to prevent the HPM from toppling out of the seat. Prior to each round of weights being loaded, an 89 N force shall be applied twice by 'punching' the appropriate load application site with the spring-loaded probe. After each 'punch' the operator shall immediately release any applied force once the punch probe reaches its spring loading. This procedure ensures the HPM remains fully nested into the seat during the loading.

The HPM shall be checked for level during the loading process. The sequence of actions for loading the HPM, summarized in Table 3, shall be followed.

TABLE 3—LOADING THE HPM

Round	Apply 89 N	Load 2 Weights	THEN Load 2 Weights	Check for:
1	Punch twice (cushion)	2 Pelvic - innermost positions	2 Thigh	Level
2	Punch twice (cushion)	2 Pelvic - next innermost positions	2 Thigh	Level
3	Punch twice (cushion)	2 bevelled Pelvic - outermost positions	2 Thigh	Level
4	Punch twice (back)	2 Lower rack - innermost positions	2 Upper rack - innermost positions	Level
5	Punch twice (back)	2 Lower rack - next innermost position	2 Upper rack - next innermost positions	Level
6	Punch twice (back)	2 Lower rack - outermost positions	2 Upper rack - outermost positions	Level
7	Lock Torso Articulation			

4.6.1 Load the Cushion Pan

There are two types of weights for loading the cushion pan; pelvic weights, which are positioned in slots along the H-point axis, and thigh weights that are held in place by the pins in the thigh area.

Punch the HPM twice at the cushion pan load application site. Install two pelvic weights in the innermost pelvic weight slots (one to either side of the H-point). Install two thigh weights (one to either side). Check for level.

Repeat these steps (punch twice, load two pelvic weights, load two thigh weights, and level) two more times to complete the loading of the cushion pan.

4.6.2 Load the Back Pan

There are two areas for loading weights on the back pan assembly, the lower and upper racks. However, the same type of weight is used in both areas.

NOTE—When auditing the vehicle but not the seat build, adjust the seat cushion or seat back recliner if necessary during the loading to obtain a final cushion and torso (back) angle that equals design intent (see 4.4.2.2). The adjustments should be made after checking the cushion or back pan for level in each round shown in Table 3.

Punch the HPM twice at the back pan load application site. Install two weights on the lower racks – one on either side of centerline. Push the weights toward the centerline as far as possible. Install two weights on the upper racks, one on either side of centerline, and push towards the centerline. Check for level.

Repeat these steps (punch twice, load two weights on the lower rack, load two weights on the upper rack, and level) two more times.

After the back pan is fully loaded and level, lock the torso articulation mechanism.

4.7 Soak Time

After installation, the HPM can continue to 'settle' into a seat, depending on the type of seat being used. Therefore, the installer should wait 5 minutes after completing the HPM installation before recording data.

4.8 Record Measurements—Digitize HPM Points

The HPM allows the H-point location, torso (back) angle, lumbar support prominence and cushion angle to be defined without having to attach the legs.

4.8.1 H-POINT

The H-point is located at the centerline of the HPM. Therefore, this point cannot be directly digitized. Rather, divot points H1L and H1R are provided for digitizing at either end of the H-point rods (see Figure 4). Both H1L and H1R should be digitized. The H-point is midway between these two points. If H1R (or H1L) is difficult to digitize, divots B1, B2 and C1 may be used to establish the HPM centerplane in CAD to determine the H-point.

The digitized H-point, which represents the measured SgRP or R-point, shall be compared to the design SgRP or R-point to assess the accuracy of the seat build.

4.8.2 TORSO (BACK) ANGLE AND CUSHION ANGLE

Record the following measurements using an inclinometer and the appropriate land: use the head room fixture land or back assembly land for the measurement of the torso (back) angle. Use the cushion pan inclinometer land for the measurement of the cushion angle. As an alternative, the torso (back) angle can be calculated from divot points H1L, H1R and B1, and the cushion angle from divot points H1L, H1R and C1.

4.8.3 LUMBAR SUPPORT PROMINENCE

The HPM provides a scale on the back pan assembly for a direct read-out of the lumbar support prominence (Figure A9).

5. Optional Measurements for Driver Seat

5.1 Leg and Shoe Installations

If the user plans to measure shoe and leg dimensions, the shoe fixture and shoe tool should be installed before the HPM cushion and back pans are installed. The shoe tool is used to establish the pedal reference point (PRP) and the accelerator heel point (AHP) for the driver.

5.1.1 Mark Accelerator pedal Centerline

Before installing the shoe tool in the driver compartment, place masking tape down the longitudinal center of the accelerator pedal, and draw a line along the accelerator centerline.

5.1.2 Install the Shoe Fixture

The shoe fixture is used to hold the shoe level and in place on the pedal (Figure A4). Position the forward edge of the shoe fixture approximately 100 to 150 mm rearward of the accelerator pedal such that the fork that will hold the shoe tool is in line with the accelerator centerline. The fixture shall be square to the pedal and level. Adjust the screws on the shoe fixture until it is level.

5.1.3 Install the Shoe Tool

Place the shoe in the fixture, and slide the shoe forward. The shoe shall be positioned so that the heel is on the floor and the ball of foot (BOF) contacts the pedal face at centerline. For flat pedals, the bottom of the shoe will be flush with the face of the pedal.

Check to make sure the shoe tool is square to the pedal. Adjust the fixture and shoe if necessary. Tighten the shoe locking screw to hold the shoe in place.

5.1.3.1 Interference

Occasionally, some aspect of the vehicle's structure – such as the tunnel, rocker, center console, etc. – prevents the positioning of the shoe tool and fixture as described in 5.1.3. If the interference prevents the shoe tool from being properly positioned at the accelerator centerline, the shoe and fixture shall be shifted laterally until the interference is cleared. The amount of the lateral offset should be recorded. The PRP is still defined at the centerline of the accelerator pedal, even though the BOF will not be at the centerline. The AHP is defined at the location of the heel of shoe after the shoe tool is moved to clear the interference (see Figure 5).

In some cases the shoe tool may fit properly, but the shoe fixture cannot. The tool and fixture will still need to be moved to clear the interference, but the AHP location is defined as if the shoe were aligned at the pedal centerline. In other words, the AHP coordinates are defined as if the shoe had remained positioned on the pedal centerline with no interference. This translation is most easily done in CAD.

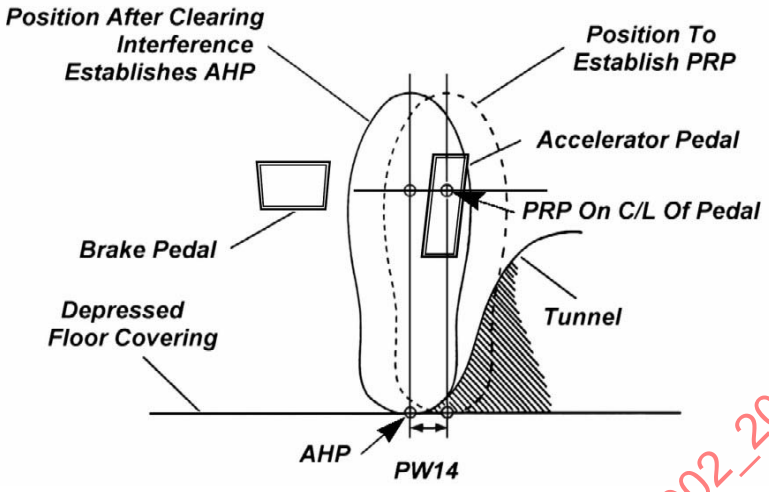


FIGURE 5—AHP TO PRP LATERAL OFFSET

5.1.4 INSTALL LEG SEGMENTS

When taking the measurements in 5.2 and 6.2 for the purpose of reporting these dimensions to outside organizations, set the leg segments at the SgRP leg lengths, i.e. pin the thigh length to 456 mm and the lower leg to 459 mm. Manufacturers may use non-SgRP leg lengths for other purposes.

Install the thigh segment by placing the forks on the H-point rods. Slide the locking bushings inward and rotate until the pins lock into place. Install the lower leg at the ankle pivot without moving the shoe. Join the thigh and lower leg segments, raising the thigh segment if necessary. Use the bushing on the knee pivot rod to secure the lower leg in place.

5.2 Record Measurements

The shoe measurements (5.2.1, 5.2.2, 5.2.3, and 5.2.4) should be recorded immediately after installation of the shoe tool (see Figure 6).

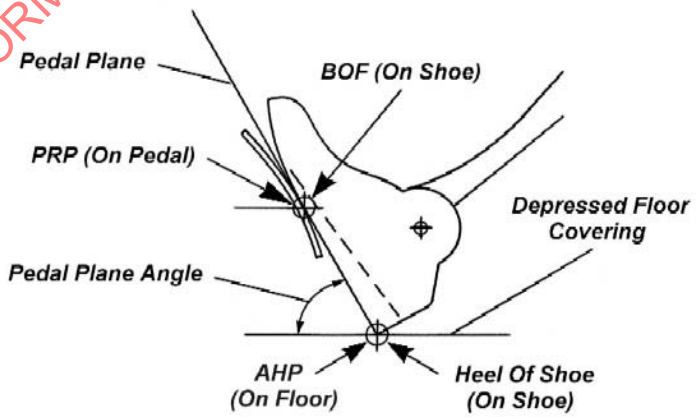


FIGURE 6—SHOE REFERENCE POINTS

5.2.1 PEDAL PLANE ANGLE

The PPA is measured directly by placing the inclinometer on the rearward-facing surface of the shoe 'sole'. Alternatively the Pedal Plane Angle can be calculated from the z-coordinates of divot points S3 and S2.

$$\text{PPA} = \text{Pedal Plane Angle} = \arcsin\left[(S3_z - S2_z) / 94\right] \quad \text{(Eq. 1)}$$

5.2.2 PEDAL REFERENCE POINT

The PRP lays at the intersection of the accelerator centerline and the BOF (or BOF lateral scale). This point can be digitized directly, or it can be calculated using the followings equations.

$$PRP_x = S3_x - 25\cos(PPA) - 5\sin(PPA) \quad \text{(Eq. 2)}$$

$$PRP_z = S3_z + 25\sin(PPA) - 5\cos(PPA) \quad \text{(Eq. 3)}$$

5.2.3 ACCELERATOR HEEL POINT

The point contacted by the heel of shoe on the depressed floor covering is the AHP. The AHP cannot be directly digitized. It will be calculated using the shoe divot points (S1, S2 and S3), and the equations below.

$$AHP_x = S3_x + 175\cos(PPA) - 5\sin(PPA) \quad \text{(Eq. 4)}$$

$$AHP_z = S3_z - 175\sin(PPA) - 5\cos(PPA) \quad \text{(Eq. 5)}$$

AHP_Y and PRP_Y are defined at the shoe centerline, and can also be determined from the divot point locations. The S1, S2, and S3 divot points are offset 10 mm to either side of the shoe centerline. The direction of the 10 mm correction to an S_Y location will depend on which side of the shoe was digitized (see Figure 7).

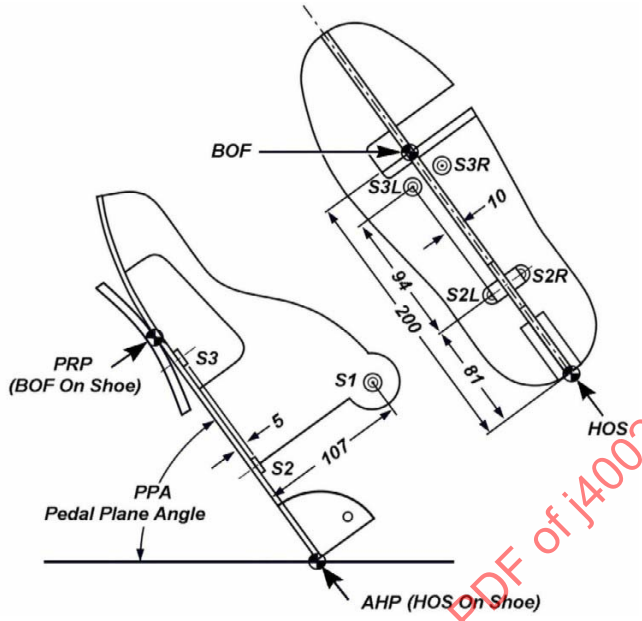


FIGURE 7—SHOE DIVOT POINTS

5.2.4 AHP TO PRP LATERAL OFFSET

The AHP to PRP lateral offset can be read off the AHP to PRP lateral offset scale (see Figure 5). This offset is used to correct the y-coordinate of the PRP and AHP, if necessary.

5.2.5 KNEE ANGLE AND ANKLE ANGLE

Both can be read directly on the scales provided.

5.2.6 THIGH ANGLE AND HIP ANGLE

The thigh angle is measured using an inclinometer and the inclinometer land provided on upper leg segment (Figure A3).

The hip angle can be calculated from the torso (back) and thigh angles as follows:

$$\text{Hip Angle} = 90 \text{ degrees} - \text{thigh angle} + \text{torso (back) angle} \quad \text{(Eq. 6)}$$

6. Optional Measurements for 2nd or Succeeding Row Passenger Seats

6.1 Leg and Shoe Installation

If the user plans to measure shoe and leg dimensions, the shoe tool should be installed before the HPM cushion and back pans are installed. The shoe tool is used to establish the floor reference point (FRP) for passengers.

The shoe installation differs from the procedure described for driver's seats, but the leg and thigh installations are the same. The shoe fixture is not needed for passenger seat positions.

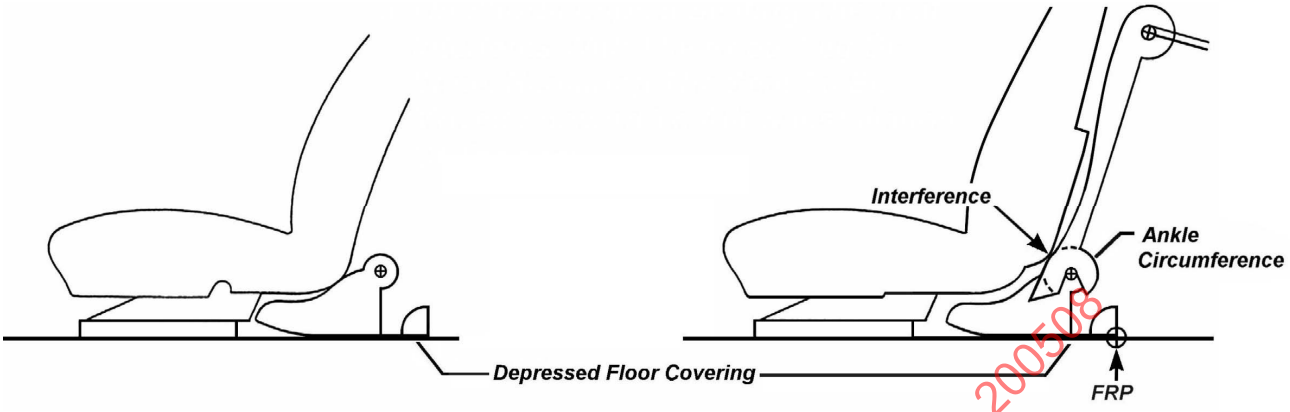
6.1.1 INSTALL THE SHOE TOOL

Place the shoe tool on the floor and slide it forward, beneath the seat in front, until it reaches an obstruction. The shoe can be placed anywhere within ±127 mm of occupant centerline, and should be positioned such that its movement forward is optimized (see Figure 8a).

If the shoe cannot be fitted on the floor between the seats, measurement of knee clearance, leg clearance, and leg room is best done in CAD. If a physical installation of the HPM shoe and legs is desired, move the preceding seat forward along its seat adjustment path until the shoe just fits between the seats (Figure 8c). Move the shoe laterally within ±127 mm of occupant centerline, keeping the rear of the shoe against the trim under the test seat, to find the location that requires the least amount of preceding seat movement. Record the seat movement. This movement shall be subtracted from the leg room measured in 6.2.3 (see Figures 8c and 9).

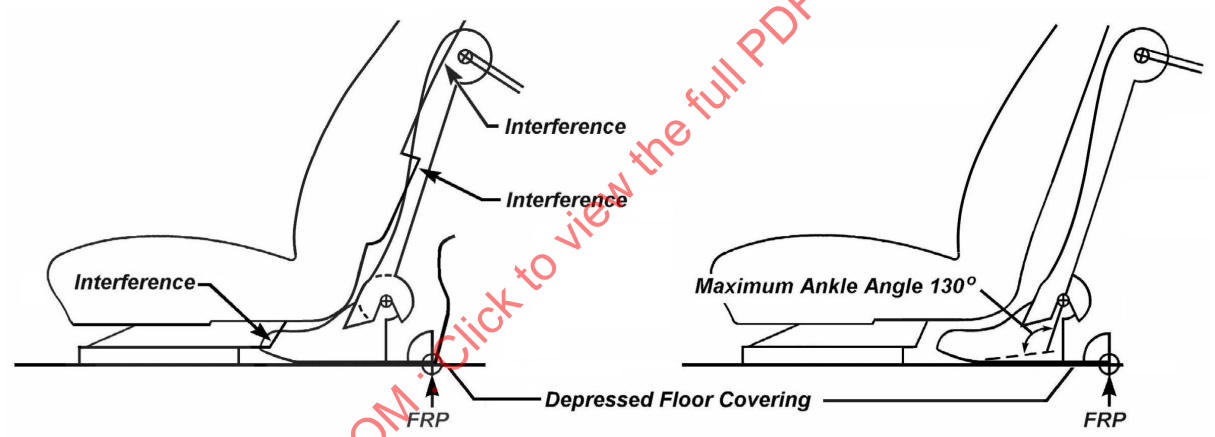
If the shoe cannot be fitted and the preceding seat does not have fore/aft adjustment, then measurement of knee clearance, leg clearance, and leg room must be done in CAD. Move the seat horizontally forward in CAD to determine the amount to be subtracted from leg room.

NOTE—The HPD shoe, along with the lower leg and thigh, can be installed in CAD, if the preceding seat back, trim under the test seat, and the floor were digitized.



(a) Shoe is first positioned as far forward as possible

(b) Shoe may need to be moved rearward to eliminate ankle interference with lower seat back trim



(c) Short-coupled seating: the seat interferes with the knee, leg, or shoe, requiring the seat be moved forward to allow installation of the leg/shoe

(d) Long-coupled seating: the shoe must be moved rearward so the lower leg reaches the shoe with an ankle angle no more than 130 degrees

FIGURE 8—SHOE AND LEG INSTALLATION FOR REAR PASSENGER SEATS

6.1.2 INSTALL LEG SEGMENTS

In some vehicles, the thigh–lower leg–ankle segments cannot be attached without first repositioning the shoe tool or moving the preceding seat forward (see Figure 8, 6.1.2.1, and 6.1.2.2).

6.1.2.1 Reposition the Shoe Tool (if necessary)

There are two conditions under which the shoe tool will need to be moved rearward:

- Interference between the preceding seat back or seat trim and the ankle circumference of the lower leg segment or shoe tool (Figure 8b).
- In vehicles with long-coupled seating, the lower leg segment may not reach the shoe tool, or, if it does reach, the ankle angle exceeds 130 degrees (Figure 8d).

In either of these events, the shoe tool shall be repositioned before FRP or floor plane angle can be defined.

6.1.2.1.1 Interference

Temporarily attach only the lower leg to the shoe to determine if there is interference in the area of the ankle pivot circumference on the lower leg (Figure 8b). If there is interference at the ankle circumference, move the shoe rearward to just clear the interference. Interference above the ankle pivot circumference is not considered for positioning the shoe but will be considered when determining knee or leg interferences with short-coupled seating. Use this shoe position to define the FRP, floor plane angle, and all other dimensions.

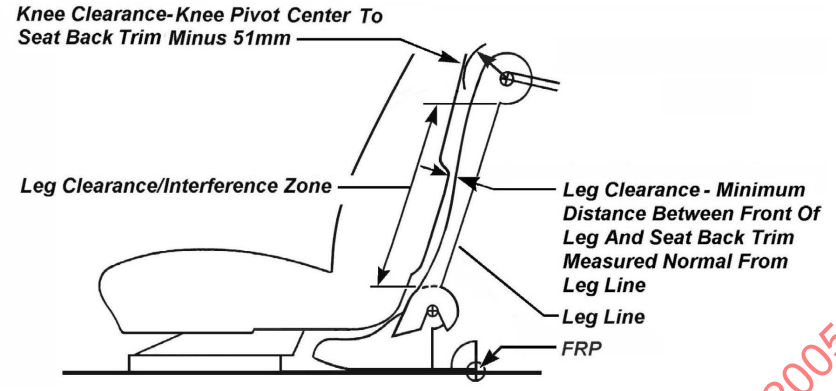
If there is interference above the ankle circumference, proceed to 6.1.2.2. Otherwise, attach the thigh and lower leg segments now (see 5.1.4).

6.1.2.1.2 Long-coupled Seating

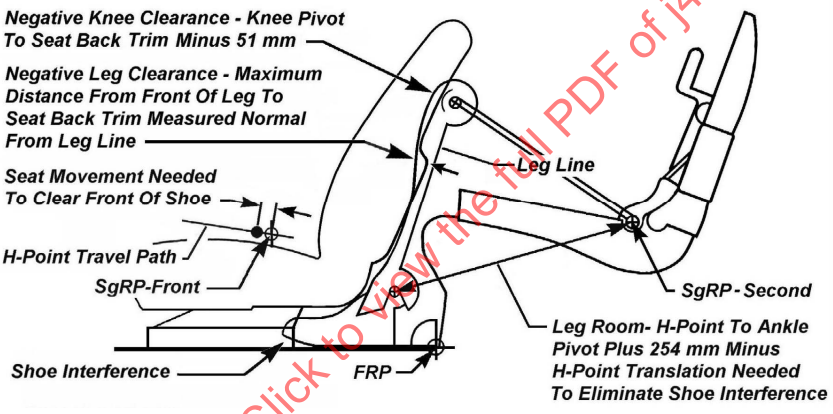
Prior to moving the shoe rearward, record the ankle pivot point (S1 divot) so that leg room can be correctly calculated. Use this shoe position to establish the floor reference point, floor plane angle, and all other dimensions except leg room. Move the shoe rearward until the cushion pan-thigh-lower leg assembly can be attached to the shoe tool at the ankle pivot point, with an ankle angle of 130 degrees.

6.1.2.2 Short-coupled Seating

In vehicles with short-coupled seating, the knee or the lower leg segment interferes with the seat back of the seat directly ahead (Figure 9b). In this case mark the SgRP location of the preceding seat. Move the preceding seat forward to allow the lower leg and thigh to be installed. Do not move the shoe.



(a) Leg and knee clearances



(b) Shoe, leg, and knee interferences

FIGURE 9—KNEE CLEARANCE, LEG CLEARANCE, AND LEG ROOM FOR SHORT-COUPLED SEATING

6.2 Record Measurements for Rear Passengers

For knee angle, thigh angle, hip angle, and ankle angle proceed in the same way as for the driver seat (see 5.2.5 and 5.2.6).

6.2.1 Floor Reference Point (FRP)

The floor reference point is defined as the intersection of the heel of shoe and the depressed floor covering. The shoe divot points can be digitized, and the FRP calculated by using the AHP equations in 5.2.3. Other divot points can be digitized if desired.

6.2.2 FLOOR PLANE ANGLE

The floor plane angle is measured directly by placing the inclinometer on the rearward-facing surface of the shoe 'sole'. Alternatively the floor plane angle can be calculated from the coordinates of the divot points $S3_z$ and $S2_z$ by using PPA equation in 5.2.1.

6.2.3 KNEE CLEARANCE AND LEG ROOM

Knee clearance is the minimum distance between the knee pivot point (K1 divot) and the preceding seat back, minus 51 mm. The measurement is taken within 127 mm to either side of the occupant centerline. This measurement is best done in CAD from a scan of the preceding seat back in the vicinity of the K1 divot point and lower leg of the HPM. Knee clearance will be a negative value if the knee interferes with the preceding seat back.

If there is interference below the knee and above the ankle circumference, use the leg clearance dimension (L58) in SAE J1100 to determine the amount of interference. For short-coupled seating, measurement of knee and leg interferences shall be done in CAD.

Leg room is the distance along a line from the ankle pivot center (S1 divot point) to the SgRP, plus 254 mm, measured within 127 mm to either side of the occupant centerline, with the heel of shoe at the FRP (AHP for driver). The knee clearance and leg room measurements are shown in Figure 9 for a short-coupled vehicle.

7. Additional Optional Measurements

7.1 Effective Head Room

If the user plans to measure head room, the head room fixture should be installed immediately after the HPM cushion and back pans are installed.

7.1.1 INSTALL THE HEAD ROOM FIXTURE

Slide the forks at the end of the head room fixture into the grooves on the brass locking bushings of the cushion pan. With the adjuster screw fully out, snap the end of the screw into the rotating tumbler on the back pan (see Figures 4 and 10). Ensure the fixture is fully against the stop on the back pan. If the user plans to take head room measurements, the head room fixture should be installed after the cushion and back pans but before the HPM is loaded.

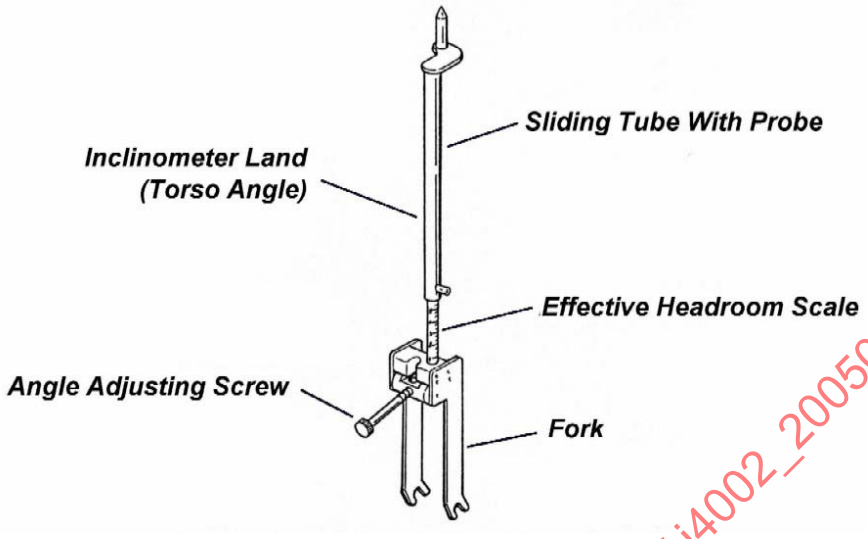


FIGURE 10—HEAD ROOM FIXTURE

7.1.2 MEASURE EFFECTIVE HEAD ROOM

Effective head room can be measured using the scale inside the head room fixture. First, turn the adjuster screw until the torso (back) angle is at 8 degrees rearward of vertical (use the inclinometer on the head room fixture land). Then pull up the probe in the head room fixture so that it lightly contacts the headliner. Read the measurement from the scale on the head room probe.

8. Remove the HPM

To aid in removing the HPM, seats may be moved, unless a subsequent HPM installation will be made in the succeeding row.

Remove lower leg segment, if installed.

Remove thigh segment if installed.

Weights are removed from the HPM in the reverse order that they were installed. Unload the HPM following the removal order of Table 4.

TABLE 4—UNLOADING THE HPM

Round	Remove 2 Weights from:	THEN Remove 2 Weights from:
1	Outermost Upper Rack	Outermost Lower Rack
2	Next outermost Upper Rack	Next outermost Lower Rack
3	Innermost Upper Rack	Innermost Lower Rack
4	Thigh	Outermost PELVIC
5	Thigh	Next outermost PELVIC
6	Thigh	Innermost PELVIC

Remove head room fixture, if installed.

Remove cushion and back pans: Unlock the torso articulation mechanism, position the back pan in a slouched posture, and re-lock the mechanism. Slide the brass locking bushings outward and remove the back pan. Remove the cushion pan. Alternatively the cushion and back pan can be removed as a single unit.

Remove shoe tool and shoe fixture, if installed.

9. Notes

9.1 Marginal Indicia

The change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE HUMAN ACCOMMODATION AND DESIGN DEVICES COMMITTEE

APPENDIX A
(NORMATIVE)

DESCRIPTION OF THE THREE-DIMENSIONAL H-POINT MACHINE (HPM)

A.1 Availability

The HPM is available from SAE, 400 Commonwealth Drive, Warrendale, PA, 15096-0001.

This section provides descriptions of the parts and some basic dimensions. Complete dimensional information can be found in Appendix B.

A.2 Major Components

For the new HPM, the legs (upper and lower), shoe, cushion pan and back pan assembly are all separate pieces (see Figure A1).

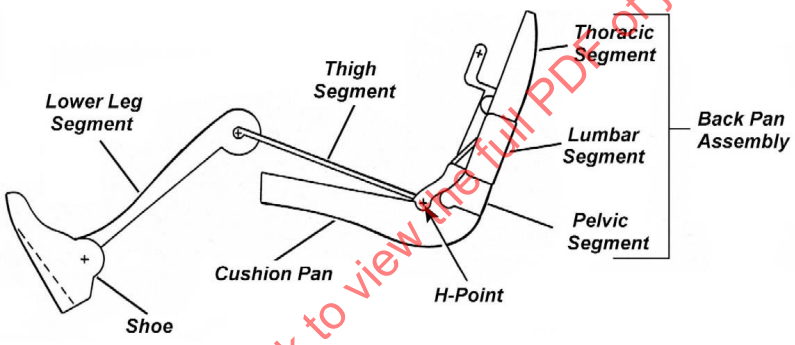


FIGURE A1—MAJOR NEW HPM COMPONENTS

A.2.1 Back Pan Assembly

The back pan assembly consists of the back pan with its thoracic, lumbar, and pelvic segments. It contains the following parts (see Figure 3):

- Handle
- Torso articulation locking lever
- H-point pivot shaft (sits on H-point saddle)
- Load application point (receptacle for spring loaded probe)
- Torso (back) angle inclinometer land
- Upper weight rack
- Lower weight rack

A.2.2 Cushion Pan

The cushion pan assembly contains (see Figure 4):

- Cushion pan
- Handle
- H-point saddle with pelvic weight locations
- H-point rods
- Locking bushings for attaching back pan
- Locking bushings for attaching thigh segment
- Load application point for spring probe
- Lateral level
- Thigh weight platform and locating pins

A.2.3 Lower Leg Segment

The lower leg segment includes (see Figure A2):

- Knee pivot slot
- Leg length scale
- Leg length locking pin
- Leg length locking screws
- Knee angle scale
- Lower leg angle inclinometer land

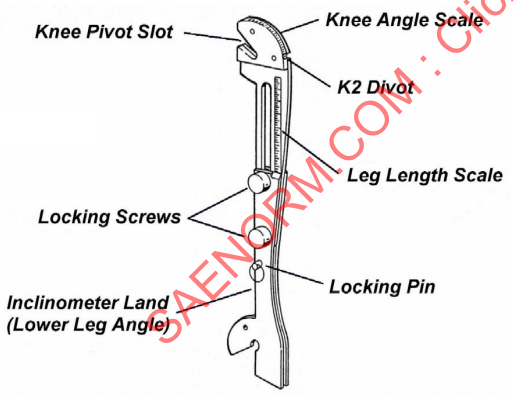


FIGURE A2—LOWER LEG SEGMENT

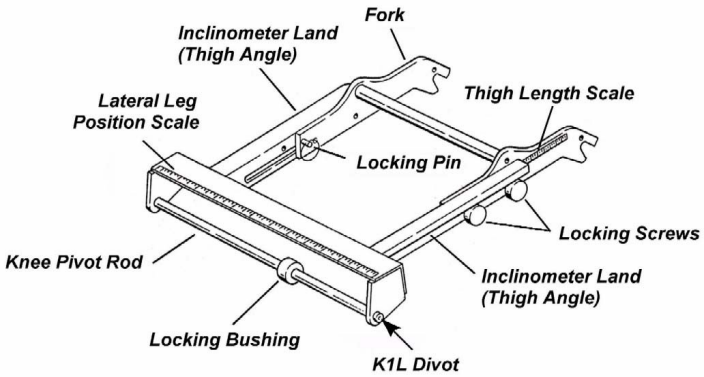


FIGURE A3—THIGH SEGMENT

A.2.4 Thigh Segment

The thigh segment consists of (see Figure A3):

- Locking bushing (for attaching lower leg)
- Knee pivot rod
- Thigh length scales
- Thigh length locking pins
- Thigh length locking screws
- Fork (for attaching to H-point rod)
- Lateral leg position scale
- Thigh angle inclinometer land

A.2.4.1 Length of Thigh and Lower Leg Segments

The length of the leg segments can be adjusted. However, for measurements related to the SgRP (or R-point), the SgRP leg length values must be used (see Table A1).

TABLE A1—LEG SEGMENT LENGTHS

Leg Segment	SgRP	Mid-Size Male
Thigh (knee pivot to H-point)	456 mm	432 mm
Lower Leg (knee pivot to ankle pivot)	459 mm	417.5 mm

A.2.5 Shoe Tool and Shoe Fixture

The ball of foot (BOF), heel of shoe (HOS), and bottom of shoe are found on the shoe tool, and are key reference points or surfaces for using the H-point machine. Other parts of the shoe tool include (see Figure A4):

- Locking screw
- Ankle angle scale
- AHP to PRP lateral offset scale
- Pedal plane angle inclinometer land

The shoe fixture is used to hold the shoe tool in place on the accelerator (see Figure A4).

- 2 levelling screws
- Bubble level
- Fork for attaching the shoe tool

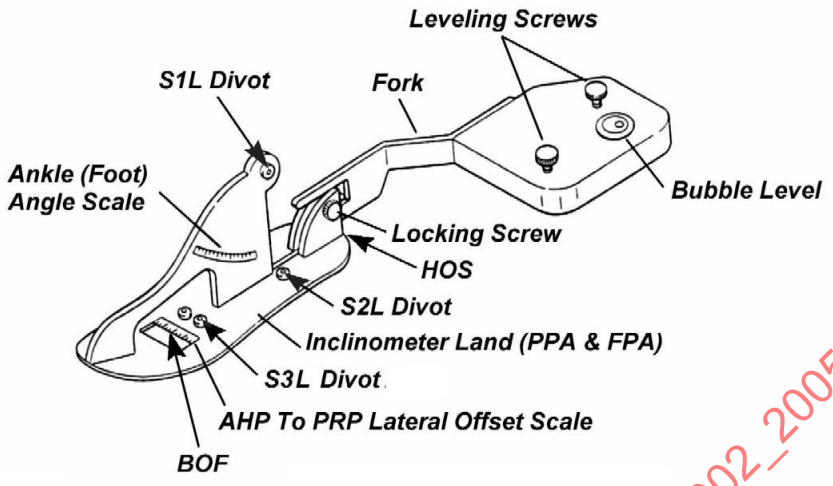


FIGURE A4—SHOE AND SHOE FIXTURE

A.2.6 Spring Loaded Probe

The probe is used to deliver 89 N (20 lb) of force at the appropriate load application points.

A.2.6.1 LOAD APPLICATION SITES

There are two sites for applying force using the spring loaded probe; one on the cushion pan and one on the back pan (see Figures 3 and 4).

A.2.7 Inclinometer (Electronic Level)

An inclinometer is provided for determining various posture angles when using the HPM, including torso (back) angle, thigh angle, cushion angle, and pedal plane angle. Specific sites for placing the inclinometer – referred to as lands – are provided on the appropriate components.

A.2.7.1 INCLINOMETER LANDS

There are six locations provided for positioning the inclinometer; lower leg, thigh, head room fixture, shoe tool, back pan, and cushion pan.

A.2.8 Weights

The HPM comes with 3 types of weights: pelvic, thigh, and back. The total number of weights is 24: 6 pelvic, 6 thigh, and 12 back. Two of the pelvic weights have bevelled edges. See Appendix B for a full specification.

A.2.9 Head Room Fixture

A separate fixture is provided for measuring effective head room. The fixture consists of (see Figure 10):

- Fork (for attaching to the HPM)
- An adjusting screw for setting the angle of the fixture
- A land for measuring the angle of the fixture
- A sliding tube with probe
- Effective head room scale

A.3 Reference Points and Angles

A.3.1 Pivot Locations

The HPM can be articulated about six pivot locations: ankle pivot, knee pivot, H-point (where cushion and back pan are joined), lumbar-pelvic pivot, thoracic-lumbar pivot, and sliding thoracic pivot (see Figure A5). In the HPM, the pivot point centers lie within the pivot mechanism.

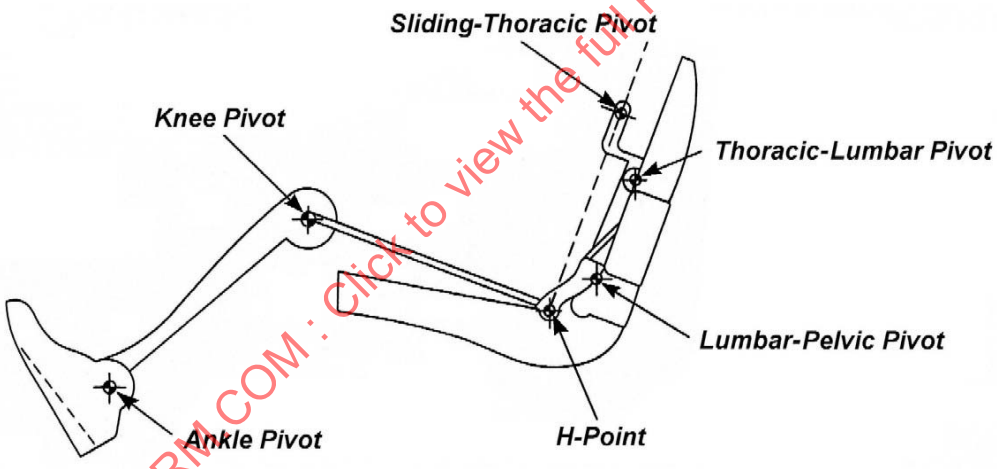


FIGURE A5—PIVOT POINTS

A.3.2 Support Points

There are nine support points; 5 are located on the outer surface of the cushion pan and 4 are on the back pan assembly (see Figure A6). The support points are provided to facilitate seat design. Additional information can be found in Appendix B.

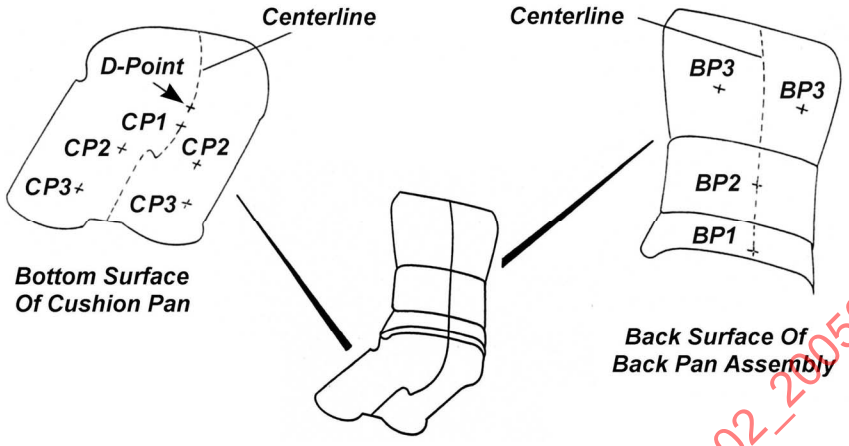


FIGURE A6—SUPPORT POINTS

A.3.3 Divot Points

Fourteen divot points are provided on the HPM for use with CMM[4] equipment (see Figure A7). On the HPM, divot points are located in the center of the small gold colored disks on the mechanism. Specific locations of the divot points can be found in Appendix B. The primary purpose of the divot points is to allow for the calculation of key reference points.

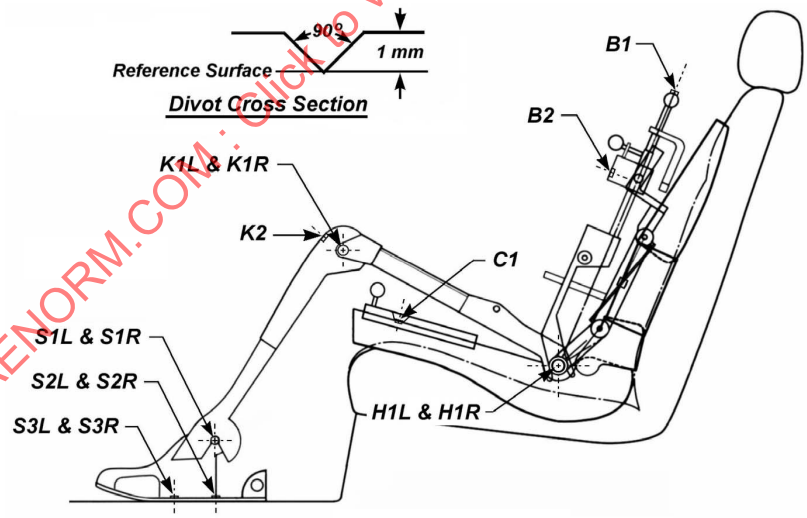


FIGURE A7—DIVOT POINTS ON THE HPM

[4] A CMM (Coordinate Measuring Machine) is a computer assisted three-dimensional system for the measurement and digitizing of physical properties. Typically, data from a CMM can be captured as individual points or streams of data. The 3D information provided includes the X,Y,Z coordinates of the points. This information can then be read into the appropriate CAD environment.

For example, the coordinates of H1L and H1R are required to calculate the H-point location. The coordinates of S1, S2, and S3 are required to calculate the location of the accelerator heel point (or floor reference point). Divot points can also be used to calculate with additional precision anything that can be measured directly from the HPM (e.g., torso (back) angle, cushion angle, knee angle, lumbar support prominence, etc.). See Table A2.

TABLE A2—DIVOT POINT OVERVIEW

Divot Type	Summary of Use
Back Pan Divot Points (B1, B2) and Cushion Pan Divot Points (C1, H1R, H1L)	The B1 point can be used with the H1 points to define the torso (back) angle. This can then be compared to B2 for a measure of lumbar support. The C1 point can be used with the H1 points to define the cushion angle. Additionally, B1 and B2 can be used together with C1 to define the centerline of the HPM.
H-Point Divot Points (H1R & H1L)	The H1 points are used to define the H-point location. The measured H-point is located at the intersection of centerline of the HPM, the torso (back) line and the cushion line. The H1 locations are averaged to define the x, y, z coordinates of the H-point. (Alternatively, B1, B2, and C1 can be used to define the H-point y coordinate.)
Shoe Divot Points (S1R, S1L, S2R, S2L, S3R & S3L)	Shoe divot points are used to define the AHP (accelerator heel point). They can also be used to define the PRP (pedal reference point), the pedal plane angle, and the floor plane angle.
Knee Divot Points (K1L, K1R, & K2)	Knee divot points can be used to locate the knee pivot point center. By using this in combination with the S1 and H1 points, knee angle can be determined.

A.3.4 Key Reference Points and Lines

For the HPM, the key reference points and reference lines need to be calculated using divot points. Table A3 summarizes the HPM locations.

TABLE A3—KEY REFERENCE POINTS AND LINES

Reference Point or Line	Summary of Location
H-Point	The intersection of the cushion line and torso (back) line corresponds to the pivot center of the cushion pan and back pan. This point is within the mechanism, and must be calculated using the divot points H1L and H1R. For additional accuracy, the divot points B1, B2, and C1 can be used to define the lateral centerline of the HPM.
D-Point	Located on the bottom of the cushion pan, at the lateral centerline, 25.5 mm (15 degrees) rearward of the H-point (when cushion angle equals 0). This point is identified by a divot point on the surface of the cushion pan. However, when the HPM is installed, this point cannot be reached and so must be calculated relative to the H-point.
Heel of Shoe	The heel point is found at the bottom of the back of the shoe, at the lateral centerline. It is used to define the accelerator heel point (AHP) for the driver, and the floor reference point (FRP) for passengers. The heel point cannot be reached when the HPM is installed. The location must be calculated using S1, S2, and S3 divot points.
Ball of Foot (BOF)	The ball of foot (BOF) is located on the bottom of the shoe, at the lateral centerline, 200 mm from the heel point. It is used to define the pedal reference point (PRP) for the driver. A notch is provided along the lateral offset opening on the shoe. A more precise location can be calculated using S1, S2, and S3 divot points.
Torso (back) line	A line from the H-point through the sliding thoracic pivot (B1 divot point).
Cushion Line	A line from the H-point through the C1 divot point.
Thigh Line	A line from the H-point through the knee pivot K1.
Leg Line	A line from the knee pivot K1 through the ankle pivot S1.

Bottom of Shoe	A line from the heel of shoe through the BOF. The angle of this line from horizontal defines the pedal plane angle (driver) or floor plane angle (passengers).
Bare Foot Flesh Line	A line originating from a point 286.9 mm from the heel of shoe, on the bottom of shoe line, at a 6.5 degree angle. This line is provided on the HPD, but not on the HPM.

A.3.5 Posture Angles and LSP

The HPM can be used to determine posture angles. Several angles are summarized in Table A4. The methods for taking the measurements refer to reference lines, divots, and lands. Torso (back) and cushion angles, as well as lumbar support prominence, can be measured without installing the legs. Other angles in Table A4 require installation of the legs and shoe tool (see Figures A7 and A8).

TABLE A4—POSTURE ANGLES AND LSP

SAE J1100 Code	Posture angle	Location and measurement
A40	Torso (Back) Angle	The angle of the torso (back) line from vertical defines the torso (back) angle. The torso (back) angle can be measured by H1 and B1 divots, or by placing the inclinometer on torso angle land on the back pan assembly, or by the torso angle land on the head room fixture with the fixture mounted flush to the back pan assembly.
A27	Cushion Angle	The angle of the cushion line from horizontal defines the cushion angle. The cushion angle can be measured using H1 and C1 divots, or by placing the inclinometer on the cushion angle land on the cushion pan assembly.
A57	Thigh Angle	The angle of the thigh line from horizontal defines the thigh angle. Thigh angle can be measured by using knee pivot K1 and the H-point (H1 divot), or by placing the inclinometer on the thigh angle land on the thigh assembly. Cushion and thigh angles are independent.
A42	Hip Angle	The angle between the torso (back) and thigh lines defines the hip angle. After the thigh and torso (back) angles are measured, the hip angle can be calculated: Hip angle = 90 degrees + torso (back) angle – thigh angle.
A44	Knee Angle	The angle formed by the intersection of the thigh line and the leg line defines the knee angle. A direct read-out scale is provided on the leg segment. The angle can also be calculated using divot points S1, K1, and H1.
A46	Ankle Angle	The angle between the lower leg and the bare foot flesh line forms the ankle angle. A direct read-out scale is provided on the shoe assembly.
A47, A48	Pedal Plane Angle or Floor Plane Angle.	The angle from horizontal to the bottom of the shoe forms the Pedal Plane Angle or Floor Plane Angle. The angle can be determined by using divot points S3 and S2, or by placing an inclinometer on the pedal plane and on the shoe.
L81	Lumbar Support Prominence (LSP)	LSP is defined as: LSP = 57mm – X where X is the distance between the lumbar-pelvic pivot to the torso (back) line, measured normal to the torso (back) line. In a neutral posture – when LSP equals zero – the distance between the lumbar-pelvic pivot and the torso (back) line is 57 mm. As LSP increases, the lumbar segment of the back pan assembly is pushed forward, the pelvic and thoracic segments are tipped, and the lumbar-pelvic pivot moves closer to the torso (back) line (see Figure A9). For measurement a direct read-out scale is provided on the back pan assembly.

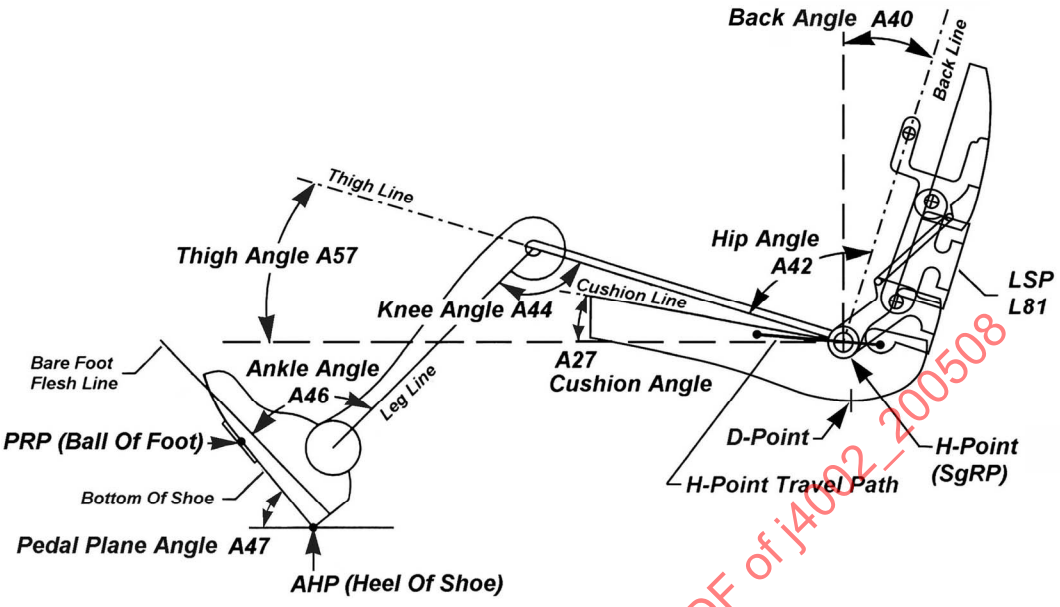


FIGURE A8—REFERENCE POINTS, REFERENCE LINES, AND POSTURE ANGLES

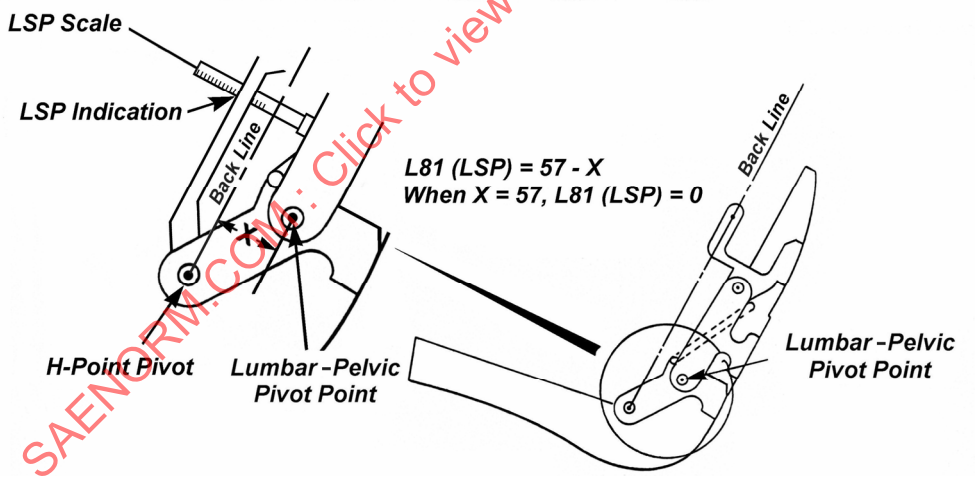


FIGURE A9—LUMBAR SUPPORT PROMINENCE (LSP)

APPENDIX B
(INFORMATIVE)

HPM SPECIFICATION AND TOLERANCES

B.1 Tolerances

The following comments apply to all tolerances given in the tables of this Appendix.

HPM tolerances reflect an acceptable dimensional variation that would not affect the overall performance measurements of the H-point machine. If conditions of use, wear, or damage result in measurements that exceed the specified tolerance values, the HPM should be recalibrated.

The build tolerances of the HPM as produced by the HPM manufacturer are well below the tolerances specified in these tables.

B.2 Reference Posture for Specifications

Unless otherwise specified, all dimensions in this section are given in true vertical or true horizontal, with the device postured using the settings in Table B1 (see Figure B1).

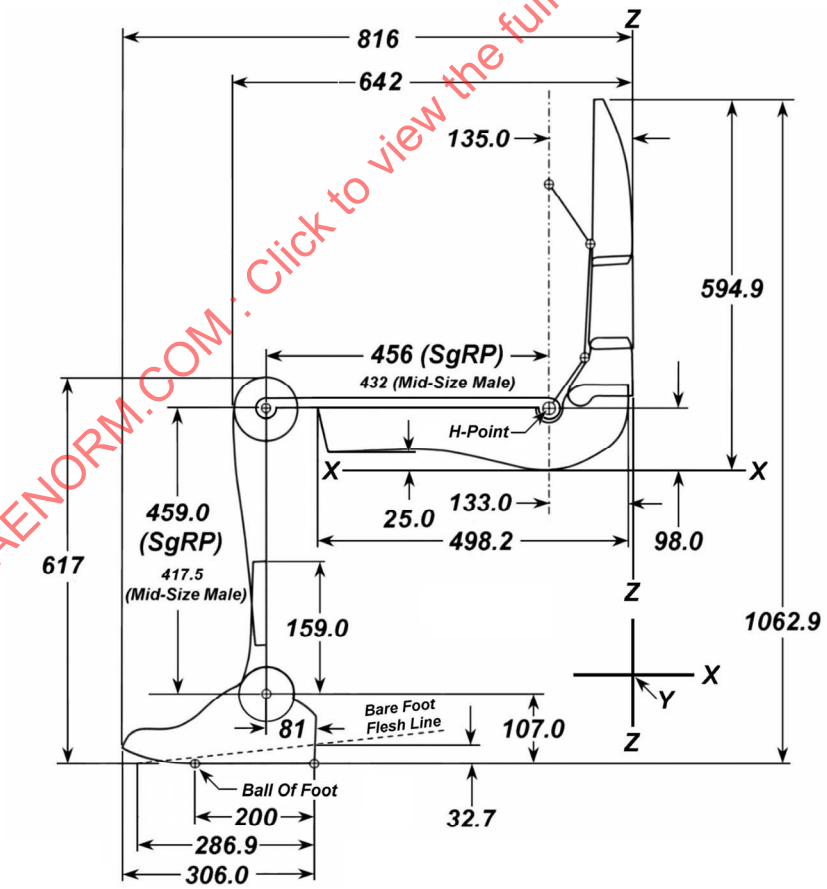


FIGURE B1—HPM LENGTHS AND HEIGHTS, SIDE VIEW

TABLE B1—POSTURE OF DEVICE FOR SPECIFICATIONS

Torso (back) angle	0	degrees
LSP	0	mm
Cushion Angle	0	degrees
Thigh Angle	0	degrees
Knee Angle	90	degrees
Ankle Angle *	96.5	degrees
Thigh Length	456	mm (SgRP)
Lower Leg Length	459	mm (SgRP)

* The bottom of the shoe is flat on the XY plane. However, since ankle angle is measured from the bare foot flesh line, and not the bottom of shoe, the ankle angle will be 96.5 degrees, not 90 degrees.

B.3 Shoe Tool Dimensions

See Table B2.

TABLE B2—SHOE TOOL DIMENSIONS

Dimension	Value
Overall length of shoe	306 mm
BOF to HOS distance	200 mm
Ankle pivot	107 mm above HOS 81 mm forward of HOS
Bare foot flesh line	6.5 degrees above the bottom of shoe. Originates 286.9 mm forward of HOS.
Relative to BOF	9.9 mm above
Relative to HOS	32.7 mm above

B.4 Lengths

See Table B3 and Figure B1.

TABLE B3—LENGTHS (IN MM)

Description	Value	HPM Tolerance
Overall (rearmost to foremost)	816.0	± 4.0
Overall, not counting shoe	642.0	± 4.0
Cushion Pan	498.2	± 4.0
Shoe	306.0	± 2.0
Heel of Shoe to Ball of Foot	200.0	± 2.0
Heel of Shoe to Ankle Pivot	81.0	± 2.0
Heel of Shoe to Origin of Bare Foot Flesh Line	286.9	N/A
H-Point to Knee Pivot	456.0	± 2.0
H-Point to Knee Pivot, w/ mid-size male leg lengths	432.0	± 2.0
H-Point to back of cushion pan	133.0	± 2.0
H-Point to back of back pan	135.0	± 2.0

B.5 Widths

See Table B4.

TABLE B4—WIDTHS (IN MM)

Description	Value	HPM Tolerance
Cushion Pan, Max. (358 mm forward of H-Point)	405.8	± 4.0
Cushion Pan, at H-Point	383.3	± 4.0
Cushion Pan, at D-Point	371.0	± 4.0
Cushion Pan, at CP2 support points	401.0	± 4.0
Cushion Pan, at CP3 support points	405.1	± 4.0
Back Pan, Max. (442 mm above H-Point)	384.6	± 4.0
Pelvic Segment, at BP1 support point	373.7	± 4.0
Lumbar Segment, at BP2 support point	326.0	± 4.0
Thoracic Segment, at BP3 support point	360.3	± 4.0
Shoe, Max. (at ball of foot)	110.0	± 2.0

B.6 Heights

See Table B5 and Figure B1.

TABLE B5—HEIGHTS (IN MM)

Description	Value	HPM Tolerance
Overall	1062.9	± 4.0
Seated Height (bottom of cushion pan to top of device)	594.9	± 4.0
Cushion Pan, Max.	132.3	± 4.0
Pelvic Segment, Max.	94.9	± 4.0
Lumbar Segment, Max.	150.3	± 4.0
Thoracic Segment, Max.	255.6	± 4.0
Lumbar-Pelvic Pivot to Bottom of Cushion Pan	180.8	± 4.0
Thoracic-Lumbar Pivot to Bottom of Cushion Pan	363.5	± 4.0
H-Point to Bottom of Cushion Pan	98.0	± 2.0
Heel of Shoe to Ankle Pivot	107.0	± 2.0
Heel of Shoe to Bare Foot Flesh Line	32.7	N/A
Ball of Foot to Bare Foot Flesh Line	9.9	N/A
Knee Pivot Point to Ankle Pivot Point	459.0	± 2.0
Knee Pivot Point to Ankle Pivot Point, mid-size male	417.5	± 2.0
Knee Pivot Point to 'Cross-Over' of Lower Leg Pieces	300.0	± 1.0
Ankle Pivot Point to 'Cross-Over' of Lower Leg Pieces	159.0	± 1.0
Top of Knee to Bottom of Shoe	617.0	± 2.0
Sole of Shoe	3.2	± 1.0

B.7 Radii

The radius of the knee is 51 mm. The radius of the ankle on the shoe tool is 19.1 mm. The radius of the ankle curve at the lower end of the lower leg is 44.5 mm.

B.8 Weight, HPM Only

See Table B6.

TABLE B6—WEIGHTS (IN KG)

Description	Value per Unit	Tolerance per Unit	Quantity
HPM w/o Weights	19.31	± 0.35	1
Cushion Pan	8.41	± 0.15	1
Back Pan	5.94	± 0.10	1
Head room Fixture	1.43	± 0.03	1
Upper Leg	2.11	± 0.03	1
Lower Leg	0.88	± 0.02	1
Shoe	0.54	± 0.02	1
HPM w/ Weights (fully loaded)	72.69	± 1.20	1
Pelvic Weight, plain	3.2	± 0.05	4
Pelvic Weight, bevelled	3.13	± 0.05	2
Thigh Weight	2.14	± 0.03	6
Back Weight	1.79	± 0.03	12

B.9 Support Points

Support points are located on the outer surface of the cushion pan (CP) and back pan (BP) contours. See Table B7 and Figure A6.

TABLE B7—SUPPORT POINT LOCATIONS (IN MM)

		Distance from H-Point		
Point	Quantity	X [a]	Y	Z [b]
D-Point	1	25.5	0.0	-95.2
CP1	1	0.0	0.0	-98.0
CP2	2	-125.0	+/- 80.0	-78.2
CP3	2	-250.0	+/-110.0	-69.2
BP1	1	135.1	0.0	35.0
BP2	1	135.1	0.0	175.0
BP3	2	122.7	+/- 90.0	350.0
HPM Tolerance	All Support Points	± 4.0	± 4.0	± 4.0

[a] Positive X values are rearward, negative values are forward of H-Point.
[b] Positive Z values are above, negative values are below H-Point.

B.10 Divot Point Locations

See Table B8.

TABLE B8—DIVOT POINT LOCATIONS

Divot	Location	HPM Description	HPM Tolerances
B1	550 mm above the H-Point on the torso (back) line	Located in the screw hole on the top of the back pan T-handle.	± 2.0
B2	330 mm above the H-Point 35 mm forward of the torso (back) line (and H-Point).	Located along the back pan centerline, in front of the sliding thorax pivot.	± 2.0
H1L H1R	200 mm to the left (H1L) or the right (H1R) of the measured H-Point.	Located at the ends of the rod where the back pan and cushion pan are joined.	± 1.0
C1	275 mm forward of the H-Point on the cushion line.	Located along the cushion pan centerline, in a hole on top of the push block.	± 2.0
K1L K1R	239 mm to the left (K1L) or right (K1R) of centerline, on the knee pivot axis.	Used to define the K-Point location. The K1L and K1R provide the x, z coordinates, while K2 provides the y coordinate.	± 2.0
K2	50 mm forward of the knee pivot center (K-Point)		± 1.0
S1L S1R	(x) 81 mm forward of heel of shoe, (y) +/- 10 mm to either side of the shoe centerline, (z) 107 mm above bottom of shoe.	Located on either side of the ankle pivot. (S1L is 10 mm to the left; S1R is 10 mm to the right.)	± 2.0 x ± 0.5 y ± 0.5 z
S2L S2R	(x) 81 mm forward of the heel of shoe, (y) +/- 10 mm to either side of the shoe centerline, (z) 5 mm above bottom of shoe.	Located on top of the sole of the shoe below the ankle pivot. (S2L is 10 mm to the left; S2R is 10 mm to the right.)	± 2.0 x ± 0.5 y ± 0.5 z
S3L S3R	(x) 175 mm forward of the heel of shoe, (y) +/- 10 mm to either side of the shoe centerline, (z) 5 mm above bottom of shoe.	Located on top of the sole of the shoe, near the ball of foot. (S3L is 10 mm to the left; S3R is 10 mm to the right.)	± 2.0 x ± 0.5 y ± 0.5 z

B.11 Muslin Cloth

The muslin shall be plain cotton, knitted or non-woven fabric having 18.9 threads per cm² and weighing 0.228 kg/m². The cloth should be large enough to prevent the HPM from contacting the seat.

The muslin cloth is available from SAE.

B.12 Check That HPM is Within Tolerance Specifications

The HPM should be periodically checked to verify it is dimensionally accurate and functioning properly. It should be checked immediately if it appears to be functioning incorrectly, if it appears out of alignment, or if any misuse occurs. Some examples of misuse include:

- The HPM is dropped.
- The HPM is improperly loaded or assembled – or is improperly unloaded or unassembled – during use.
- The HPM is improperly moved or shipped. The HPM should be stored unassembled, with each piece protected and secured to prevent damage. It is recommended that the weights be stored separately.

A procedure for checking key elements of the HPM is given in Appendix C. The HPM should be repaired and rechecked whenever the tolerance specifications given in Appendix C cannot be met.

APPENDIX C
(INFORMATIVE)

HPM FIELD CHECKING PROCEDURE

C.1 Purpose

This procedure can be used for checking the accuracy of the H-Point Machine (HPM) to determine if repairs are needed.

C.2 Equipment Required for Checking

C.2.1 User Provided Equipment

The user shall provide the following equipment:

- Flat, level surface (or surface plate) approximately 750 mm wide and 1000 mm long
- Two 90-degree angle blocks at least 200 mm wide, one approximately 150 mm high and a second approximately 100 mm high
- 2 small C-clamps, one with 100 mm throat and one with 25 mm throat
- CMM equipment for taking the measurements
- HPM inclinometer

C.2.2 Checking Fixtures

Checking fixtures are available from SAE. Checking fixtures are described in the following sub-clauses and shown in Figure C1. Tolerances for surfaces on the fixtures and shims that affect the checking measurements are ±0.05 mm.

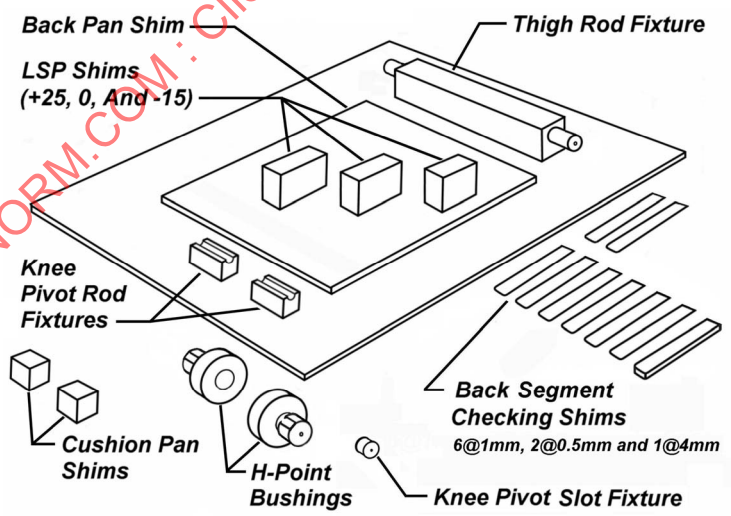


FIGURE C1—CHECKING FIXTURES AND SHIMS

C.2.2.1 CUSHION PAN SHIMS

two 25x25x25 mm gage blocks used for levelling cushion pan.

C.2.2.2 LSP SHIMS

gage blocks of a specified length (73.04, 99.67, and 46.84 mm) that fit between the two inclinometer lands on the back pan articulation rod. The three shims are used to position the back pan articulation mechanism at LSP scale readings of 0, +25, and -15.

C.2.2.3 BACK PAN SHIM

rectangular shim used to support the back pan 4 mm above the flat level surface. The shim is approximately 250 mm wide and 400 mm long.

C.2.2.4 BACK SEGMENT CHECKING SHIMS

two 0.5 mm thick shims, six 1 mm thick shims, and one 4 mm thick shim used to check pelvic segment clearance to the level surface and back pan gap between lumbar and thoracic segments. The shims are 25 mm wide and approximately 65 mm long.

C.2.2.5 H-POINT BUSHINGS

two bushings that fit on each side of the back pan H-point pivot shaft (12 mm diameter holes) to provide a divot point for measuring H-point location and slots for inserting the head room probe H-point forks.

C.2.2.6 THIGH ROD FIXTURE

fixture for providing H-point divots and supporting the H-point center (H1L and H1R) on the forks of the thigh segment at a height of 30 mm above the level surface. The diameter of the H-point rods extending from each side of the fixture is 12 mm.

C.2.2.7 KNEE PIVOT ROD FIXTURES

fixtures that support the knee pivot rod divots, K1L and K1R, 30 mm above the level surface. The diameter of the slot in the fixtures is 12.7 mm.

C.2.2.8 KNEE PIVOT SLOT FIXTURE

fixture that provides divot points for the knee pivot center (K1) on the leg segment knee pivot fork. The diameter of the knee pivot slot on the fixture is 12.7 mm.

C.2.3 Measurement Equipment

C.2.3.1 CMM

Points used to determine distance measurements shown in Table C1 and clause C.5 should be taken with a CMM. Angular measurements on the inclinometer lands are taken with both the inclinometer and a CMM. When CMM equipment is used to check angle measurements on the inclinometer lands, the digitized points taken on the lands should be separated by the length of the inclinometer (or greater) as shown in Figure C3.

The xyz axis orientations to be used for recording CMM data are shown in Figures C4, C6, C7, C8 and C9. This provides a direction convention for both linear and angular measurements. Establish and maintain this axis orientation on the flat level surface used to position the HPM components. A positive angle is clockwise as viewed from the left side of the components. This angle convention is consistent with positive cushion angle and torso (back) angle definitions.

C.2.3.2 ELECTRONIC LEVEL (HPM INCLINOMETER)

Prior to checking the HPM place the inclinometer parallel to the X axis on the flat level surface used for testing and set the inclinometer reading to zero using the alt zero button. It is desirable to re-zero the inclinometer prior to each measurement taken. Use the information provided by the inclinometer manufacturer to check accuracy of the inclinometer. The inclinometer should be regularly checked and certified per manufacturer specifications.

C.3 HPM Measurement Locations

Most measurements specified in the checking procedures are taken to the HPM divot points and inclinometer lands shown in Figures C2 and C3. Divot points K2, S2, S3 and inclinometer lands on the bottom of the shoe are not used in the calibration procedure.

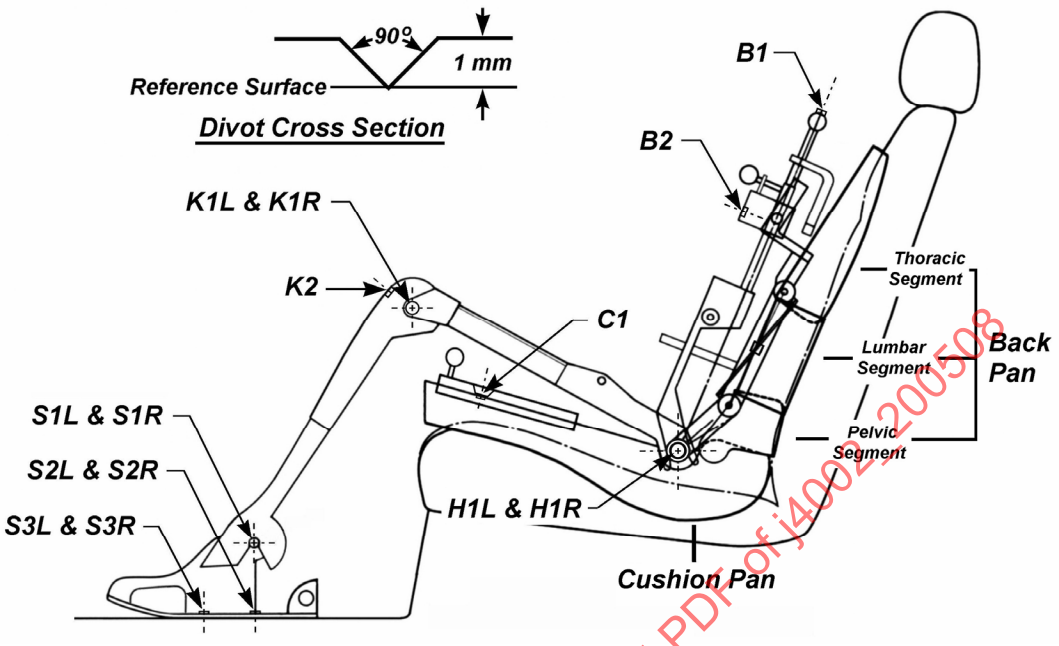


FIGURE C2—HPM REFERENCE POINTS (DIVOT POINTS)

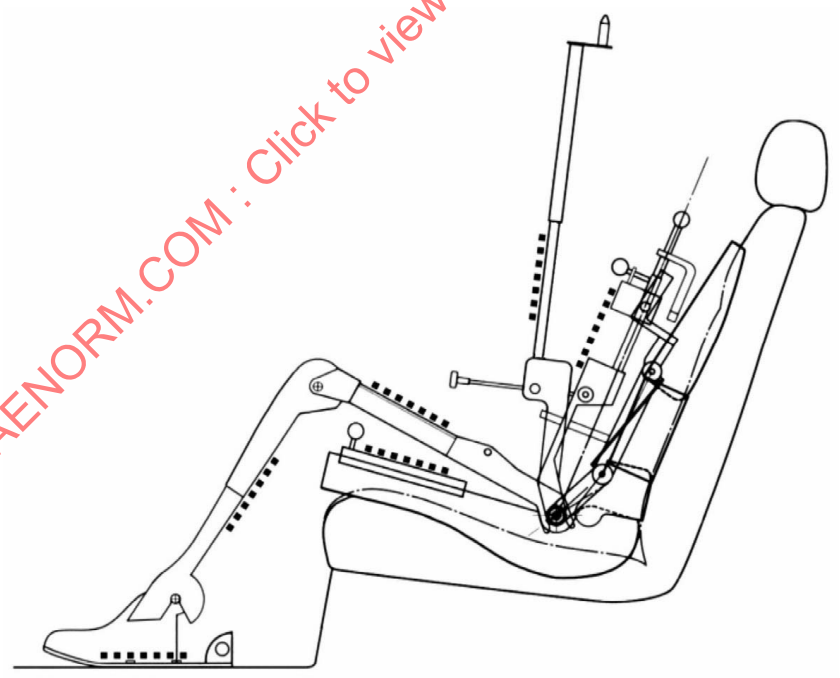


FIGURE C3—HPM REFERENCE SURFACES (INCLINOMETER LANDS)

C.4 Summary of Measurements and Tolerances

Measurements and tolerances used to check the HPM are summarized in Table C1. If the tolerance specifications cannot be achieved for any measurement, the HPM should be repaired and rechecked.

TABLE C1—HPM CHECKING DIMENSIONS AND TOLERANCES

Section	Description	Measurement	Tolerance
	Cushion Pan		
C.5.1.1.1	Cushion angle on inclinometer land using inclinometer	0 degrees	±1 degree
C.5.1.1.1	Cushion angle on inclinometer land using CMM	0 degrees	±1 degree
C.5.1.1.2	Cushion angle (using C1, H1L, and H1R divot points)	0 degrees	±1 degree
C.5.1.1.3	Differences in cushion angle measurements (inclinometer/divots)	0 degrees	1 degree
C.5.1.1.3	Differences in cushion angle measurements (CMM/divots)	0 degrees	1 degree
C.5.1.2	Bubble level reading	Between marks	
C.5.1.2	H1L and H1R heights from level surface	98 mm	±2 mm
C.5.1.2	Difference between H1L and H1R heights	0 mm	2 mm
C.5.1.3	C1 divot point to H-point	275 mm	±2 mm
C.5.1.3	C1 divot point above the level surface	98 mm	±2 mm
C.5.1.4	H-point to back of cushion pan	133 mm	±2 mm
C.5.1.5	Cushion pan alignment (difference between C1 to H1L and C1 to H1R)	0 mm	2 mm
	Back Pan		
C.5.2.1	LSP at –15 (on LSP scale)	-15	±1 unit
C.5.2.2	LSP at +25 (on LSP scale)	+25	±1 unit
C.5.2.3	LSP at zero (on LSP scale)	0	±1 unit
C.5.3.1	Lumbar or thoracic segment offset from level surface	0 mm	1 mm
C.5.3.1	Segment that is offset (lumbar or thoracic)		
C.5.3.2	Pelvic segment offset from level surface	4 mm	±2 mm
C.5.3.3.1	Torso (back) angle on inclinometer land using inclinometer	0 degrees	±1 degree
C.5.3.3.1	Torso (back) angle on inclinometer land using CMM	0 degrees	±1 degree
C.5.3.3.2	Torso (back) angle (using B1 and H-point bushing divot points)	0 degrees	±1 degree
C.5.3.3.3	Differences in torso (back) angle (inclinometer/divots)	0 degrees	1 degree
C.5.3.3.3	Differences in torso (back) angle (CMM/divots)	0 degrees	1 degree
C.5.3.4	H-point bushing divot on back pan (each side) from level surface	139 mm	±2 mm
C.5.3.4	Difference in H-point bushing divot height at each side	0 mm	2 mm
C.5.3.5	B1 divot point height above the level surface	139 mm	±2 mm
C.5.3.5	B1 divot point to H-point	550 mm	±2 mm
C.5.3.6	B2 divot point to H-point	330 mm	±2 mm
	Head room Probe		
C.5.4.1	Torso (back) angle on head room probe using inclinometer	0 degrees	±1 degree
C.5.4.1	Torso (back) angle on head room probe using CMM	0 degrees	±1 degree
C.5.4.1.1	Difference in torso (back) angle measures using head room probe (inclinometer/CMM)	0 degrees	1 degree
C.5.4.1.2	All differences in torso (back) angle measurements (including C.5.3.3.1, C.5.3.3.2, and C.5.3.3.3) – six difference measures	0 degrees	1 degree
C.5.4.2	Distance from tip of head room probe to H-point line (1000 mm reading on head room scale)	898 mm	±1 mm
C.5.4.3	Distance in top view from tip of head room probe, perpendicular to a line extended from the mid H-point through the B1 divot	0 mm	4 mm
	Thigh		
C.5.5.1	Thigh angle on thigh angle land (inclinometer and CMM)– left side	0 degrees	±1 degree
C.5.5.1	Thigh angle on thigh angle land (inclinometer and CMM)– right side	0 degrees	±1 degree
C.5.5.2	Thigh segment flatness (maximum angle difference between sides)	0 degrees	1 degree
C.5.5.3	K1L on the thigh segment to divot on the thigh rod fixture, measured parallel to X axis (thigh length left side)	456 mm	±2 mm