SURFACE VEHICLE RECOMMENDED PRACTICE

J4004™ AUG2024

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Superseded by J3099 and J4002

Positioning the H-Point Design Tool—Seating Reference Point and Seat Track Length

RATIONALE

This document has been cancelled because it has been superseded by SAE J3099 and SAE J4002.

CANCELLATION NOTICE

This technical report has been declared "CANCELLED" as of August 2024 and has been superseded by SAE J3099 and SAE J4002. By this action, this document will remain listed in the respective index, if applicable. Cancelled technical reports are available from SAE.

FOREWORD

This document describes how to position and posture the H-point design tool (HPD), and how to establish the seating reference point (SgRP) and other key reference points that are used in the design and specification of both driver and passenger seat positions. Use of the HPD in conjunction with the H-point machine (HPM-II) for benchmarking vehicle occupant packages is described in SAE J4003.

Prediction of where drivers select seat positions on the seat adjuster path is important for many aspects of vehicle design related to comfort and safety. Vehicle designers use driver seat position models to determine the length and location of adjustable seat tracks to insure that drivers of varying size can comfortably reach and operate vehicle hand and foot controls.

This document provides a new method for determining driver seat track length and for positioning the seat track in the vehicle package. It is based on studies and statistical models developed at the University of Michigan Transportation Research Institute. The new method for positioning driver seat tracks in the vehicle is based on H30 and two new variables, L6 and the presence or absence of a clutch pedal. The seat track length is independent of vehicle seat or package variables. It is based on accommodating with high statistical confidence the range of statures represented by an equal number of U.S. male and female drivers. Background details of the new method are given in Appendix A. Historical information about the prior procedure is given in Appendix E.

SAE J4004 will in the future fully replace SAE J1517:1990 for Class A vehicles. Until 2017 the ball-of-foot and accelerator heel point determined according to SAE J1517 may be used in lieu of the BOFRP cited in this document. However, SAE J4004 should be used to determine the seat track length and the accommodation levels for the U.S. driving population.

TABLE OF CONTENTS

1. SCOPE

This SAE Recommended Practice describes how to position and posture the H-point design tool (HPD) described in Appendix B, and how to establish the seating reference point (SgRP), design H-point travel path, and other key reference points that are used in the design and specification of both driver and passenger seat positions.

This practice also provides a method for determining the length of the seat track for a driver seat that adjusts fore/aft. The seat track length is based on a desired level of driver accommodation, assuming a U.S. population containing an equal number of male and female drivers. The procedure can be used to establish driver seat track accommodation for new vehicle designs or to evaluate accommodation in existing vehicles.

A general method for determining driver seat track length for any driver population (male and female stature distribution) at any selected accommodation percentile and gender mix is given in Appendix A.

Application of this document is limited to Class A Vehicles (Passenger Cars, Multipurpose Passenger Vehicles, and Light Trucks) as defined in SAE J1100.

2. REFERENCES

2.1 Applicable Publications

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 Practice.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J4002 H-Point Machine (HPM-II) Specifications and Procedure for H-Point Determination—Auditing Vehicle Seats

SAE J1100 Motor Vehicle Dimensions

2.2 Related Publications

The following publications were discussed or used to develop the seating accommodation procedures and are not required for application of this document.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J826 Devices for Use in Defining and Measuring Vehicle Seating Accommodation

SAE J1516 Accommodation Tool Reference Point

SAE J1517 Driver Selected Seat Position

SAE J4003 H-Point Machine (HPM-II)—Procedure for H-Point Determination—Benchmarking Vehicle Seats

2.2.2 Philippart, N.L., Roe, R.W., Arnold, A.J., and Kuechenmeister, T.J. (1984). *Driver selected seat position model.* SAE Technical Paper 840508. SAE International, Warrendale, PA.

2.2.3 Flannagan, C.C., Schneider, L.W., and Manary, M.A. (1996). *Development of a Seating Accommodation Model.* SAE Technical Paper 960479. SAE International, Warrendale, PA.

2.2.4 Abraham, S., Johnson, C.L., and Najjar, M.F. (1979). Weight and height of adults 18-74 years of age. *Vital and Health Statistics.* Series 11, No. 211.

2.2.5 U. S. National Heath and Nutrition Examination Survey (NHANES III): Height for males and females 20 years and older: United States, 1988-1994.

2.2.6 Flannagan, C. C., Schneider, L.W., and Manary, M.A., and Reed, M. P. (1998). *An Improved seating Accommodation Model with Application to Different User Populations.* SAE Technical Paper 980651. SAE International, Warrendale, PA.

3. DEFINITIONS

3.1 SAE J1100 Definitions

Accelerator Heel Point (AHP)
Ball of Foot (BOF)
Ball of Foot Reference Point (BOFRP)
Floor Reference Point (FRP)
Heel of Shoe (HOS)
H-point
H-Point Travel Path
Pedal Contact Point (PCP)
Seating Reference Point (SgRP)
A27 – Cushion Angle
A47 – Shoe Plane Angle (SPA)
H30 – Seat Height
L6 – BOFRP to Steering Wheel Center
PW86 – AHP to BOFRP Lateral Offset
TH21 – Rearmost Lowest to Rearmost Highest H-Point Height – Driver

BOFRP and AHP are reference points in the shoe plane that are coincident with the BOF and HOS points on the HPD shoe, when the HPD shoe is on the accelerator pedal. BOF and BOFRP are not coincident when there is an interference condition (4.2.2.1). When BOF and HOS are on the floor, HOS defines the FRP. The terms “shoe tool” and “shoe” are both used to describe the HPD shoe. (See Figures 1, 5 and 10.)

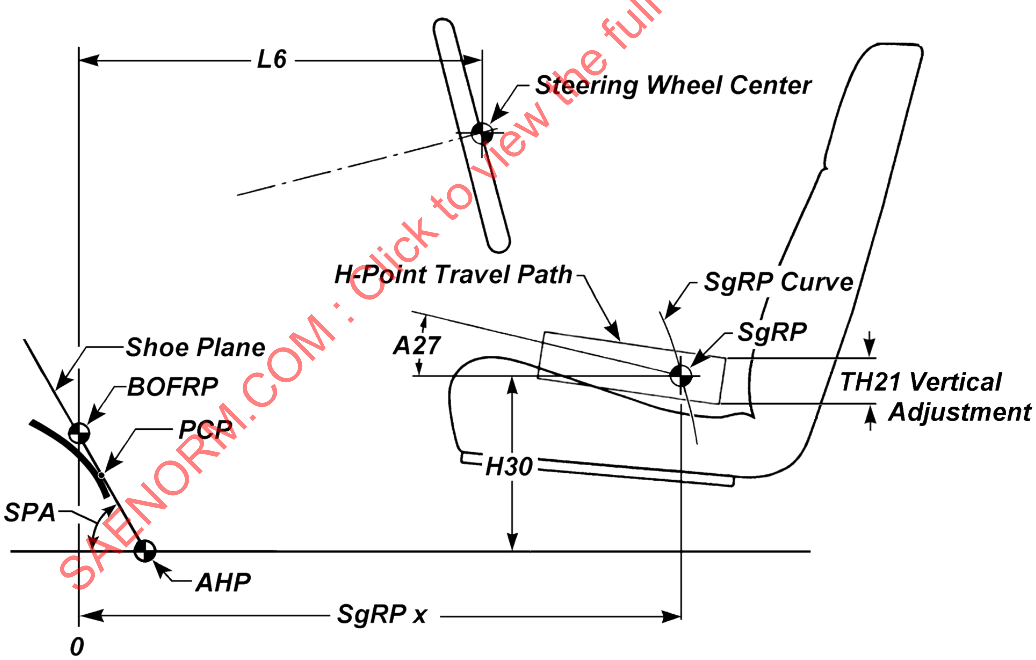

FIGURE 1 - SEATING PACKAGE DESCRIPTION SHOWING PACKAGE FACTORS USED TO CALCULATE DRIVER SEAT POSITIONS

3.2 SAE J4004 Definitions

3.2.1 Driver Seat Position Accommodation

Percent of a 50/50 male/female driver population whose preferred fore/aft seat track position is within the seat track travel path.

3.2.2 Driver Seat Position Accommodation Point

Point on design H-point travel path that provides a specified level of driver seat position accommodation for a given driver population and vehicle package.

4. DETERMINING THE DRIVER SEATING REFERENCE POINT AND POSITIONING THE HPD

This procedure is used to position the H-point design tool (HPD, Figure 2) in the correct location for the driver, and to establish the driver Seating Reference Point (SgRP-Front), Ball of Foot Reference Point (BOFRP), Accelerator Heel Point (AHP) and driver Shoe Plane Angle (SPA). Specifications and tolerances for the HPD are given in Appendix B. Note that shoe plane and SPA replaces pedal plane and pedal plane angle terminology used in SAE J1516.

Design procedures in this document can be used with both the HPM and HPM-II CAD tools. The SAE J826 HPM has a non-articulated torso that does not provide a measure of Lumbar Support Prominence (LSP). The SAE J826 manikin shoe has a standard bottom-of-shoe profile with a heel pocket, and an optional flat shoe bottom without the heel pocket. Procedures in this document use the flat bottom-of-shoe profile.

4.1 Overview of Design Procedures

The HPD is used during design to establish key reference points within the vehicle for each occupant seating position, including the SgRP and heel points (AHP for the driver and FRPs for passengers). These points are then used to configure and measure many aspects of the vehicle interior compartment.

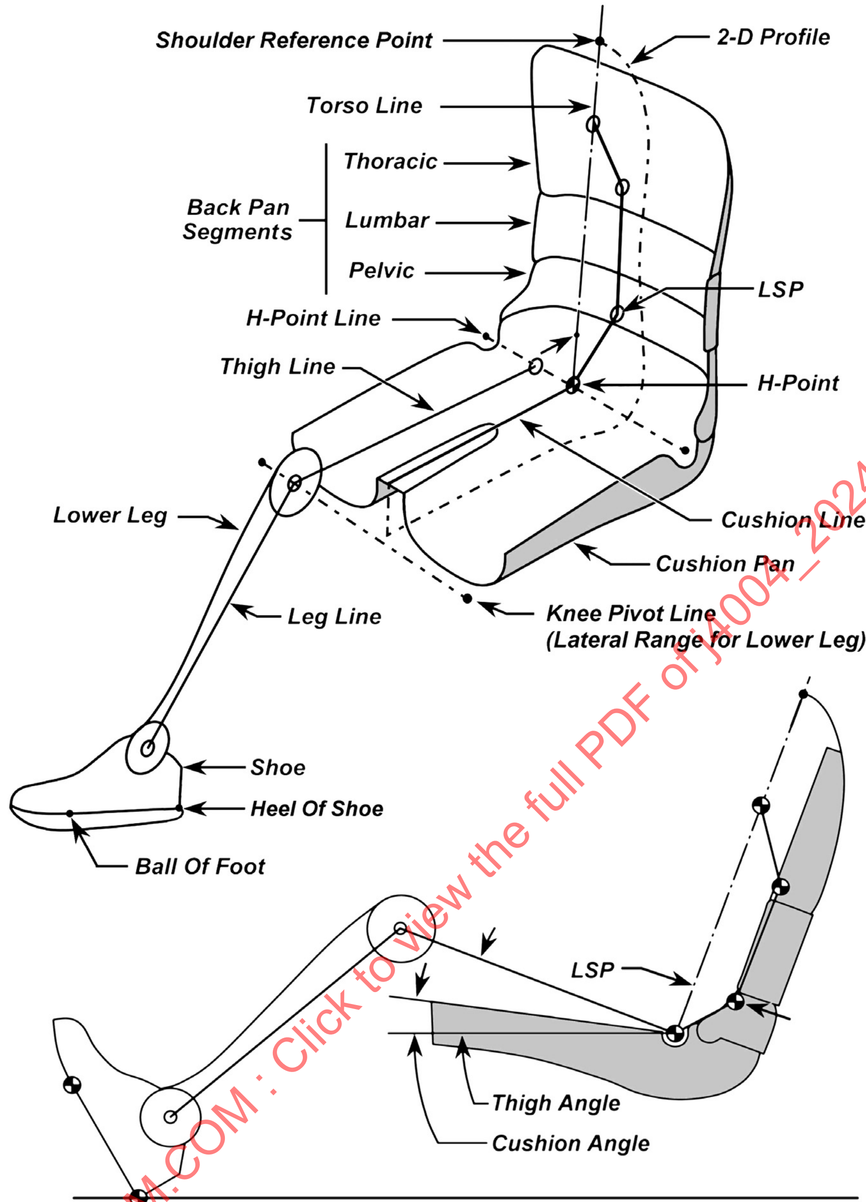

FIGURE 2 - H-POINT DESIGN TOOL (HPD) - ELEMENTS ARE COMMON WITH H-POINT MACHINE (HPM-II) EXCEPT FOR PARTS OF THE 2-D PROFILE

The SgRP is a specific and unique H-point location for each designated seating position. (Although adjustable seats will have many H-point locations within their H-point travel path, only one H-point location is defined as the SgRP for any designated occupant seating position.) The most critical SgRP is the one defined for the driver (SgRP-Front). It is used to position many other design tools (e.g., head clearance contours, eyellipses), to define a number of key vehicle dimensions (e.g., legroom, shoulder room, etc.), and is cited in several national and international regulations and standards.

The shoulder reference point is unique to the 2-D profile and is located on the torso line. It represents a point below which the shoulder of most vehicle occupants would be found. This point was established by an SAE committee in 1966 to be above the 99^{th} percentile shoulder height of the adult male seated population based on a 1959 Air Force male survey.

Other reference points established by this procedure (AHP and BOFRP), relate directly to the design position of the accelerator pedal. Manufacturers may provide pedal adjustments in a vehicle so that drivers can change the undepressed position of the pedals from their nominal design position. SAE J4004 does not provide methods for designing the travel adjustment path of these adjustable pedals.

4.2 Driver Designated Seating Position Design Procedure

4.2.1 Determine the Initial Target Values

Determine the initial target values for the dimensions listed in Table 1. (See SAE J1100 for definitions.) Some of these values may be modified during the procedure, resulting in different final values.

TABLE 1 - VALUES FOR INITIAL POSITIONING OF THE HPD FOR DRIVER

Dimension	Code	Final Values
Seat Height	$H30_{(Target)}$	The final value of H30 will be defined during this procedure.
Depressed Floor Covering Height		Undepressed floor covering height at AHP minus 5 mm or an amount specified by the manufacturer.
Occupant Centerline	$W20_{(Target)}$	If the seat track has an outboard/inboard angle, then the final value of W20 may be different than the target value (depending on the fore-aft location of SgRP).
Torso Angle	A40	Set at manufacturer design intent. A40 is a seat characteristic. It is neither calculated nor modified by this procedure. Rather, it is used to define the orientation of the back pan assembly.
Lumbar Support Prominence (LSP)	L81	L81 is a seat characteristic. It is neither calculated nor modified by this procedure. Rather, it is used to posture the back pan articulation, specifying the distance (X) of the lumbar-pelvic pivot (L/P pivot) to the torso line, measured normal to the back line. (See Figure 3.) LSP=57-X mm
Ankle Angle	A46-1	87 deg (standardized for this procedure)
Cushion Angle	A27	A27 is a seat characteristic. It is neither calculated nor modified by this procedure. It is used to position the attitude of the cushion pan assembly.

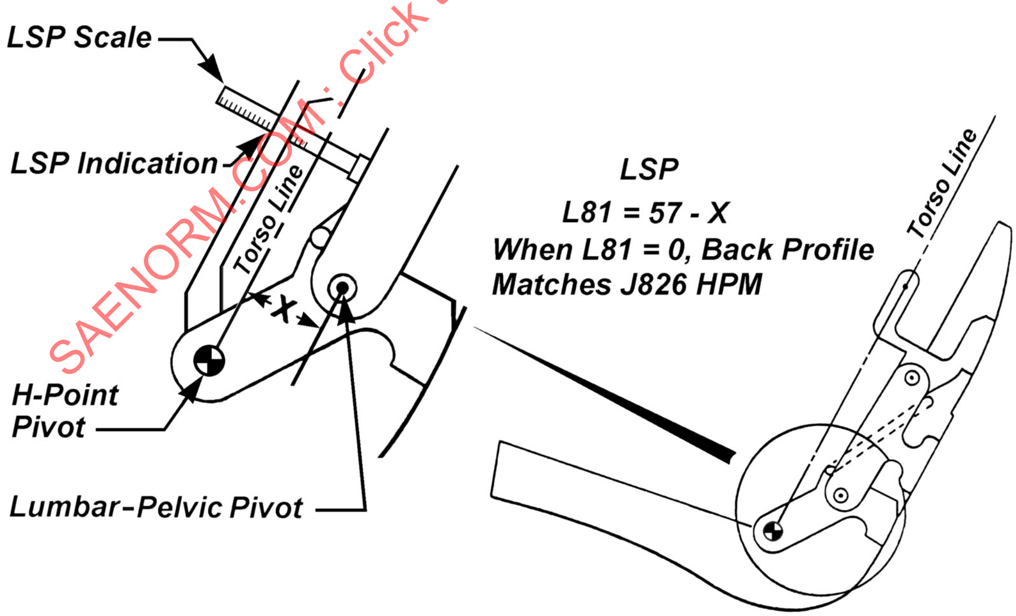

FIGURE 3 - LUMBAR SUPPORT PROMINENCE (LSP)

4.2.2 Define Shoe Tool Location and Attitude

The driver SPA defines the attitude of the shoe tool as a function of the seat height established by the manufacturer. The SPA is calculated by using Equation 1 in 4.2.2.1.1. The location of the shoe tool can be established either before or after a pedal is designed. If the pedal has not yet been designed, refer to Appendix D for information derived from driver studies that can help in designing the side view orientation of the accelerator pedal. The shoe plane along with reference points on the shoe tool are shown in Figure 4. The angle of the shoe plane from horizontal is the SPA.

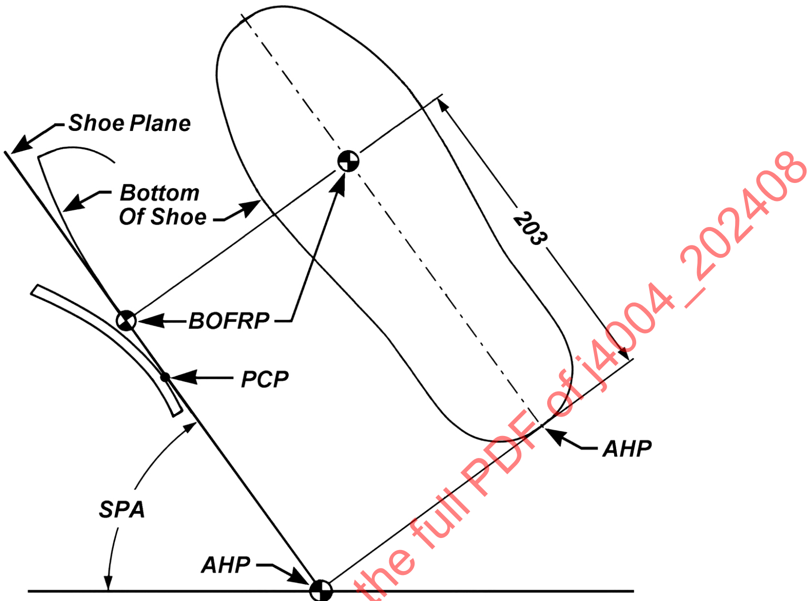

FIGURE 4A - DRIVER SHOE PLANE CAD TOOL

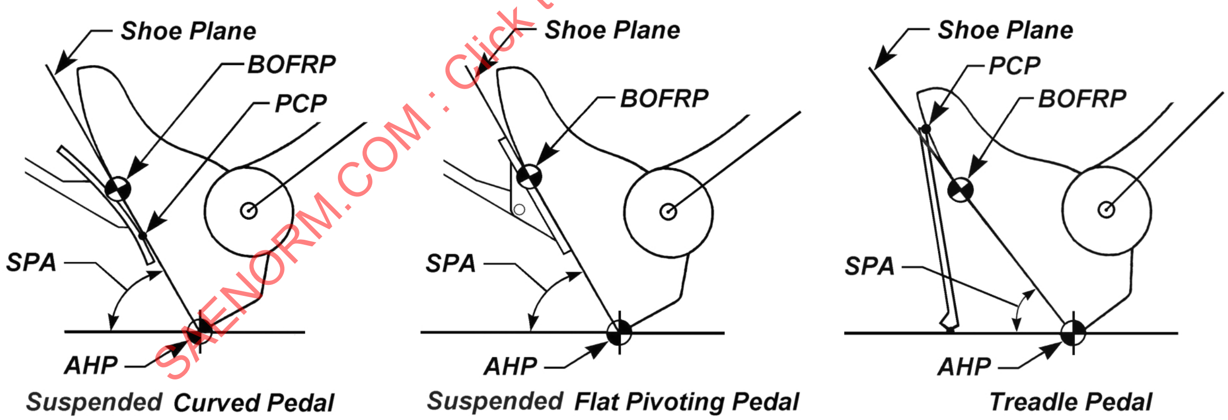

FIGURE 4B - SHOE REFERENCE POINTS SHOWING CURVED, FLAT PIVOTING, AND TREADLE PEDALS RESPECTIVELY

4.2.2.1 Define Driver SPA and Position the Shoe Plane

The shoe plane and SPA are defined at the lateral centerline of the undepressed accelerator pedal. The SPA is measured from horizontal in side view, with the pedal in design position and the shoe in contact with the lateral centerline of the pedal pad. When the shoe contacts the pedal pad at a single point, that point is called the Pedal Contact Point (PCP). Where there is continuous contact, e.g. with a suspended, flat pivoting pedal, there is not a specific PCP. In rear view, the shoe tool will be square to grid (the shoe is not yawed even if the pedal pad has a yaw angle). If the pedal pad has a roll angle, the shoe should not be rolled to align to the pad, so a portion of the pedal pad on either side of the lateral centerline may penetrate the shoe plane.

NOTE: When either the HPM or HPM-II physical measurement tools are used to locate the AHP and BOFRP in an actual vehicle or seating buck the shoe might not contact the accelerator pedal at the pedal centerline due to pedal pad orientation (roll or yaw). This discrepancy will be small and therefore can be ignored. If scan data is obtained on a vehicle it will be possible to adjust the shoe position in CAD to bring it into point contact at the pedal pad centerline.

If the accelerator pedal has already been designed, determine driver shoe plane location by using the existing accelerator pedal geometry per 4.2.2.1.2.

4.2.2.1.1 Driver SPA Equation: Accelerator Pedal Design

The SPA equation defines the side view orientation of the shoe (SPA) as a function of seat height (H30):

$$SPA = 2.522(10^{-7})(H30^{3}) - 3.961(10^{-4})(H30^{2}) + 4.644(10^{-2})(H30) + 73.374 \text{ degrees from horizontal} \quad \text{(Eq. 1)}$$

Design the pedal such that once the driver shoe plane location and angle are established, the lateral centerline of the pedal surface contacts but does not protrude through the driver shoe plane and the Heel of Shoe (HOS) contacts the depressed floor covering. If Seat Height (H30) is changed the driver SPA and shoe plane location will change.

NOTE: Equation 1 is the result of a fitting a cubic curve to the data resulting from the geometric relationship between SPA and Seat Height for an 87 deg. ankle angle when the H-point of the 2-D template is moved along the SgRP locator equation. Equation 1 is a replacement for the “theta” equation in SAE J1516. It provides a better fit to the kinematics of the template linkage.

4.2.2.1.2 Driver Shoe Plane Location Derived from Existing Accelerator Pedal Geometry

1. Suspended pedal with a non pivoting curved pad – Position the driver shoe plane CAD tool shown in Figure 4B so that the bottom of the shoe contacts the lateral centerline of the pedal surface with the heel on the depressed floor covering.

2. Suspended pedal with a flat pivoting pedal pad – Position the driver shoe plane CAD tool shown in Figure 4B so that the bottom of the shoe contacts the lateral centerline of the pedal pad surface with the heel on the depressed floor covering, allowing the pedal pad to pivot tangent to the bottom of the shoe.

3. Treadle (pivot at floor) pedal - Position driver shoe plane CAD tool shown in Figure 4B so that the bottom of the shoe contacts the lateral centerline of the pedal pad surface with the heel on the depressed floor covering (same as for # 2. just above) Three types of contact can occur with a treadle pedal: at the heel of shoe with the pedal at a flatter angle than the bottom of shoe, tangent to the bottom of the shoe or contact at the upper portion of the shoe with the heel of shoe rearward of the bottom of the pedal.

4.2.2.1.3 Carryover Pedal Design

A third method is provided to give manufacturers the option of retaining the SPA, AHP, and BOF from the carryover design. In this case the 2-D H-point template should be used in lieu of the HPD as the design tool (see SAE J826 and SAE J1517). Users can either keep the shoe of the 2-D template that has a heel pocket or use the flat shoe from the HPD (See SAE J826 and Appendix C.). This is the least preferred method and will be eliminated in 2017. For most of these carryover designs the SPA was determined by the theta equation given in SAE J1516.

Manufacturers may retain driver shoe plane (pedal plane) and SgRP locations in carryover designs for vehicles entering production before 2011.

For this method the BOF shall also be the BOFRP.

4.2.2.2 Determine Coordinates for Shoe Reference Points

The X and Z location of the BOFRP are the same as for the BOF.

4.2.2.2.1 BOFRP and AHP Lateral Location

The Y coordinate location for the BOFRP is determined by aligning the BOF of the shoe with the lateral centerline of the pedal. With a curved pedal pad the BOFRP may not be on the surface of the pedal pad.

The AHP Y coordinate will be the same as the BOFRP unless there is interference from a center console, the contour of the tunnel, etc., that prevents the heel of shoe from assuming that position. When there is interference, translate the AHP to the left until the shoe clears the interference (Figure 5). The lateral offset between AHP and BOFRP should be recorded. (PW86). The lateral offset does not influence the positioning of the H-point. It is measured for tracking purposes only.

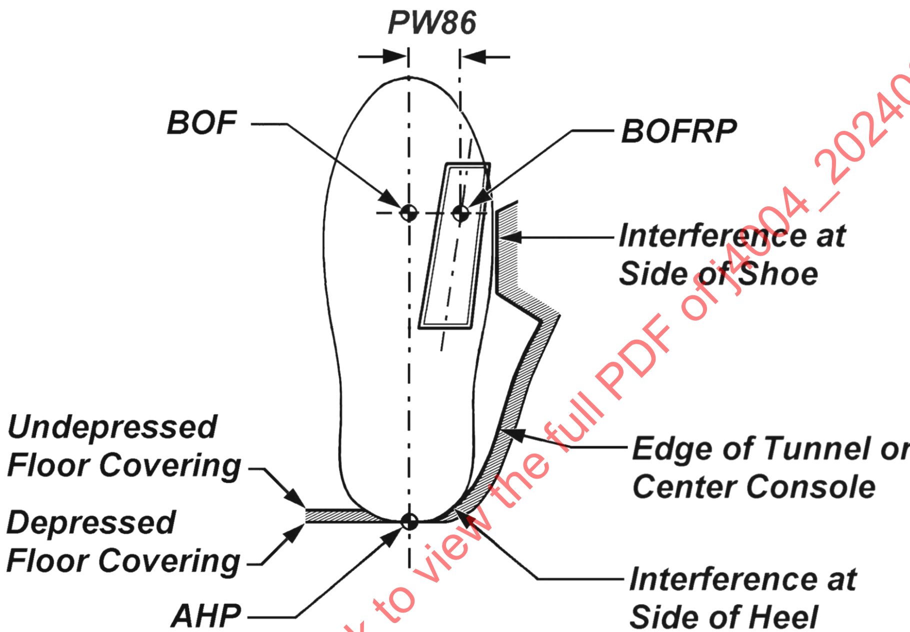

FIGURE 5 - LATERAL OFFSET OF SHOE ON PEDAL IN SHOE PLANE (PW86)

After the shoe plane, the SPA, and the shoe tool are properly positioned, the dimensions listed in Table 2 can be determined.

TABLE 2 - BALL OF FOOT AND PEDAL REFERENCE POINTS AND DIMENSIONS
(SEE SAE J1100 FOR DEFINITIONS)

Code	Name	Comment
A47	Shoe Plane Angle	
L1	BOFRP X Coordinate	Used for positioning SgRP curve
W1	BOFRP Y Coordinate	
H1	BOFRP Z Coordinate	
L8	AHP X Coordinate	
W8	AHP Y Coordinate	W8=W1 unless there is an interference condition
H8	AHP Z Coordinate	Used to measure H30 (vertical distance between AHP and SgRP)
PW86	AHP to BOFRP Lateral Offset	

4.2.3 Position the SgRP Curve and Design H-point Travel Path

4.2.3.1 SgRP Curve (Figure 6)

The SgRP curve is positioned aft of the BOFRP using the following equation from SAE J1517:

$$SgRP_X = 913.7 + 0.672316(H30) - 0.0019553(H30)^2 = \text{Distance (in mm) rearward of BOFRP} \quad \text{(Eq. 2)}$$

The method for positioning the design H-point travel path through the SgRP is given in Section 5.

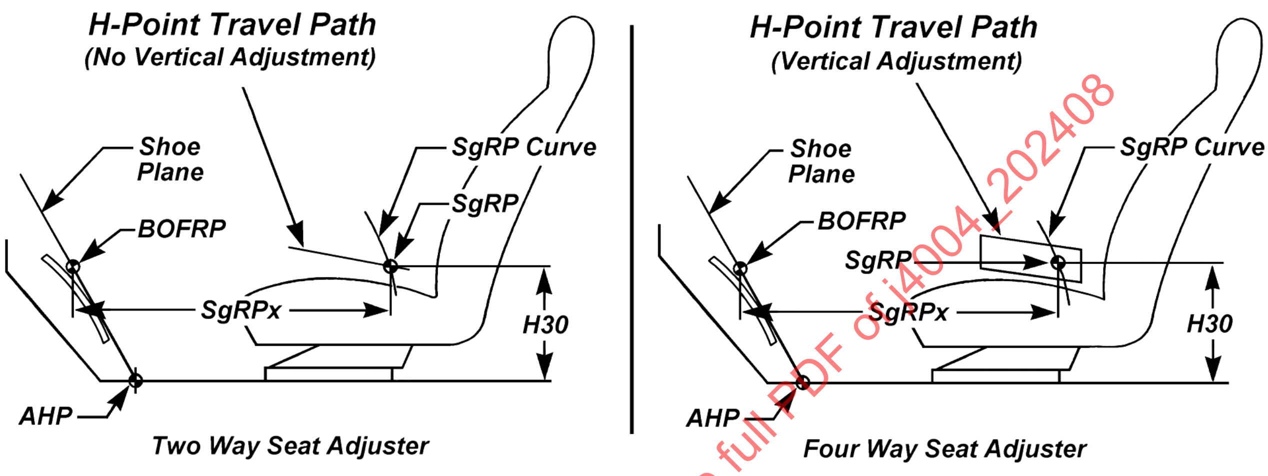

FIGURE 6 - H-POINT TRAVEL PATHS, 2-WAY AND 4-WAY SEAT ADJUSTER

4.2.4 Determine SgRP, Measure H30, Verify W20

The vertical position of the SgRP along the SgRP curve is at the discretion of the manufacturer. For vertically adjustable seats, a recommended procedure for determining the SgRP is given in 4.2.4.3.

The vertical distance measured between the AHP and the SgRP is the design H30.

Depending on the x,z location of SgRP, W20 may be somewhat different than the initial $W20_{Target}$ value. This can happen when the track travel is not parallel to the longitudinal axis of the vehicle (i.e. the track travel is angled in plan view).

4.2.4.1 Fixed Seats

Since fixed seats have only one H-point location, this H-point is the SgRP. No further calculations are necessary.

1. Measure H30.
2. Verify W20.

4.2.4.2 Fore-aft Adjustable Seats without Independent Height Adjustment

For seats without independent height adjustment, the H-point travel path can be described as a line (or curve). SgRP is the location where the SgRP curve intersects the design H-point travel path. (See Figure 6.)

1. Measure H30.
2. Verify W20.

4.2.4.3 Seats with Independent H-Point Fore-Aft and Height Adjustment

For seats with vertical and fore/aft adjustments, there are many points within the H-point travel path that lie on the SgRP curve. (See Figure 6.) The manufacturer has discretion in selecting which of the H-points along the SgRP curve is the SgRP. However, it is strongly recommended that the vertical location of the SgRP be established as follows:

– 20 mm above the full down H-point travel path, when the vertical adjustment range is at least 40 mm
– At the middle of the vertical adjustment range, when that range is less than 40 mm

4.2.4.3.1 Preferred Method

1. Determine the height of the design H-point travel path as described in 4.2.4.3.
2. Locate SgRP at the intersection of the SgRP curve and the design H-point travel path. (See Figure 7.)
3. Measure H30.
4. Verify W20.

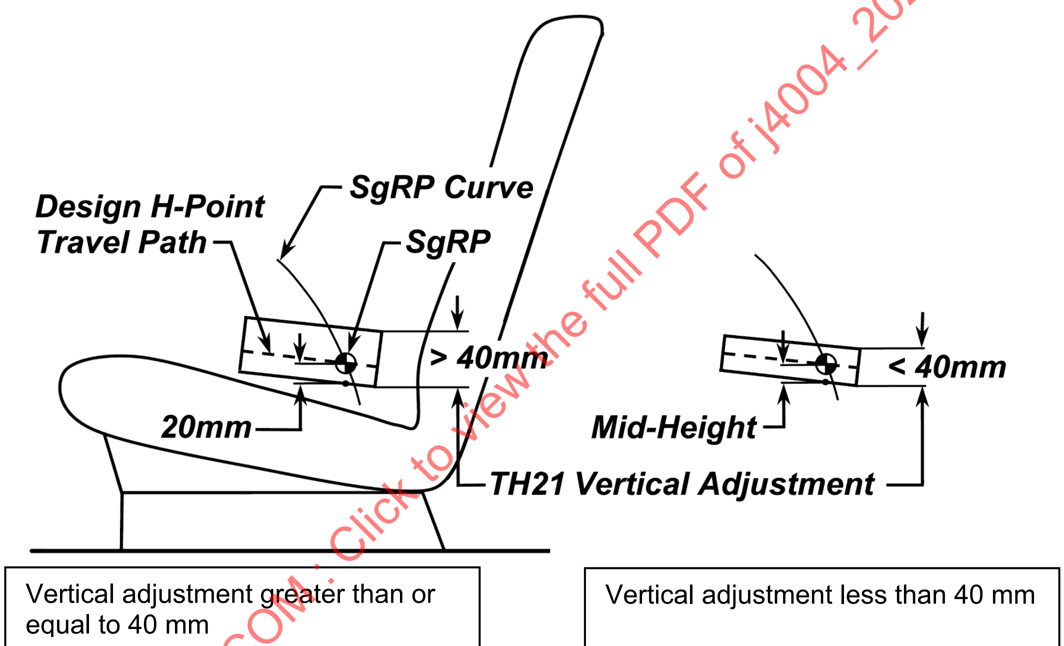

FIGURE 7 - PREFERRED SGRP LOCATION IN A SEAT TRACK TRAVEL PATH WITH VERTICAL ADJUSTMENT

4.2.4.3.2 Alternative Method

1. Locate SgRP anywhere along the SgRP curve within the design H-point travel path.
2. Measure H30.
3. Verify W20.

4.2.4.4 Short Seat Track Travel

If the design H-point travel path is not long enough to include the SgRP determined by Equation 2, then the SgRP shall be defined and positioned at the rearmost point of the design H-point travel.

4.2.5 Optional SPA Recalculation

If pedal geometry was not available, and Equation 1 was used to define the SPA, the actual H30 determined in the previous steps may be different than the $H30_{Target}$ value. In this event, SPA may be recalculated. If SPA is recalculated, the locations of AHP and BOFRP will also change and need to be re-established. This will result in a different location for the SgRP curve, and a new H30. Steps 4.2.1 through 4.2.4 must be repeated.

4.2.6 Position HPD Cushion and Back Pan

Set the HPD H-point at SgRP with torso angle at design intent, while maintaining the desired target values for cushion angle and lumbar support prominence (Figure 8). SAE J4004 does not provide methods for establishing design cushion angle, torso angle, or LSP. These dimensions are determined by the manufacturer.

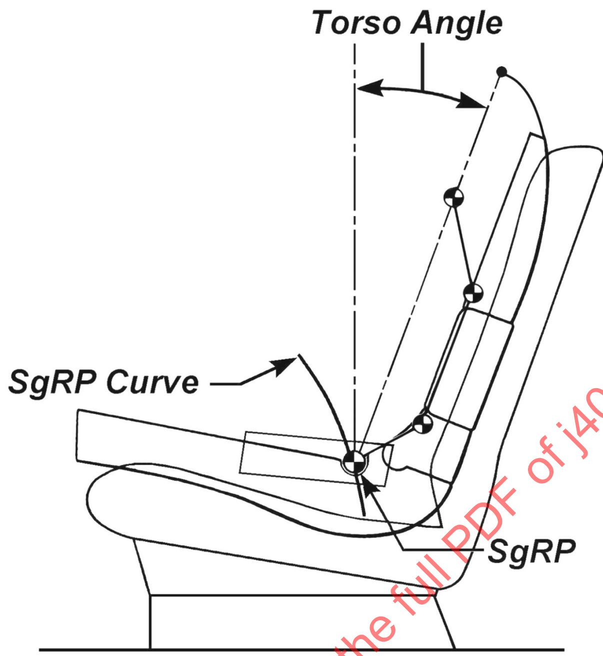

FIGURE 8 - DESIGN TORSO ANGLE OF HPD IS SET BY MANUFACTURER

4.2.7 Position HPD Shoe, Thigh, and Lower Legs

Position the shoe tool so the flat area of the shoe contacts the lateral centerline of the pedal surface, with the BOF aligned to the lateral centerline of the accelerator pedal in the shoe plane, and the heel of shoe contacting the depressed floor covering. The accelerator heel point (AHP) is the point on the depressed floor covering that is contacted by the heel of shoe.

Use the SgRP leg lengths of 456 mm for thigh and 459 mm for lower leg. Position the legs without moving the shoe while keeping the H-point on the SgRP. The thigh rotates about the H-point y-axis connecting the H1L and H1R divot points, and the lower leg rotates about the ankle in order to accomplish this. The Y coordinate of the leg is aligned to the AHP y. Lateral splay of the leg is not permitted.

5. DRIVER SEAT TRACK ACCOMMODATION FOR A U.S. DRIVER POPULATION

5.1 Determine H-point Reference X Position

The X distance of the H-point reference position aft of the BOFRP is

$$\text{H-point reference position, } X_{ref} = 718 - 0.24(H30) + 0.41(L6) - 18.2t \quad \text{(Eq. 3)}$$

where,

H30 is the vertical distance from the SgRP on the design H-point travel path to the AHP
L6 is the BOFRP-to-steering wheel center, and
t is the transmission type (1 if clutch pedal and 0 if no clutch pedal).

The Y and Z coordinates, W20 and H30, of the H-point reference position are determined by the manufacturer.

5.2 Determine Seat Track Length

The seat track length determines the length of the design H-point travel path. The seat track length and front/rear of the H-point travel path relative to the X-reference point are given in Table 3 for five levels of driver accommodation. A minimum seat track length of 240 mm, which accommodates 95% of the driving population, is recommended. The end points of the H-point travel path provide a symmetrical disaccommodation, i.e. the same percentage of the driving population is excluded at the front and the rear of the seat track travel.

TABLE 3 - SEAT TRACK LENGTH (mm)

Desired Accommodation (%)	Front of H-point travel path from H-point X-reference (mm)	Rear of H-point travel path from H-point X-reference (mm)	Total Seat Track Length (mm)
98% (1-99)	-135	145	280
97.5% (1.3-98.8)	-131	140	271
95% (2.5-97.5)	-116	124	240
90% (5-95)	-100	106	206
80% (10-90)	-79	83	162

5.3 Position H-point Travel Path in Vehicle

To position the design H-point travel path in the vehicle, construct a horizontal line through SgRP whose endpoints are the values for front and rear of the H-point travel given Table 3. For a 240 mm seat track length the endpoints will be 116 mm forward, and 124 mm rear of the H-point X reference calculated in Equation 3.

5.3.1 Add Driver Seat Position Accommodation Points (optional)

If desired, points specified in Table 4 may be positioned on the H-point travel path to represent varying levels of driver population accommodation.

TABLE 4 - ACCOMMODATION POINTS

Percent Accommodation	1	1.25	2.5	5	10	90	95	97.5	98.75	99
Distance from seat track X-reference (mm)	-135	-131	-116	-100	-79	83	106	124	140	145

5.3.2 Angle Seat Track in Side View

Select a design seat track angle (A18). Rotate the H-point travel path and the accommodation points about the SgRP to the design track angle. This line represents the design H-point travel path (Figure 9).

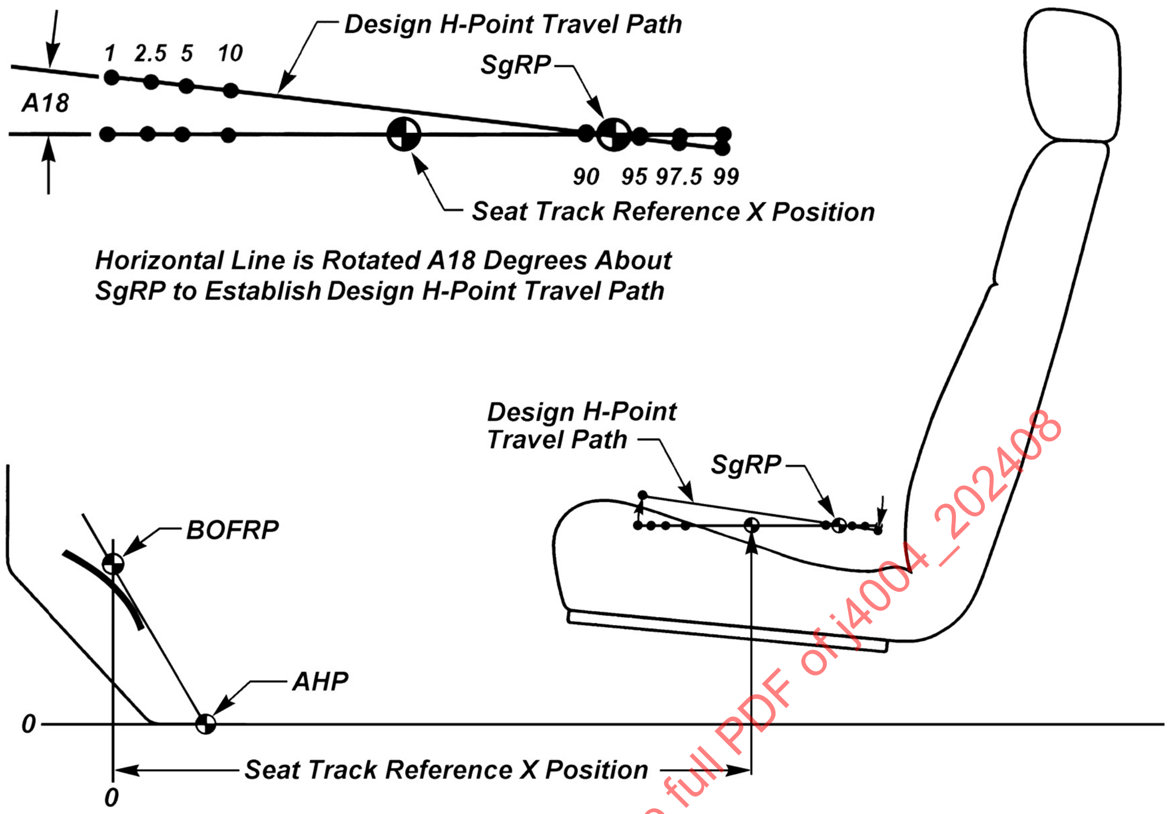

FIGURE 9 - EXAMPLE OF DRIVER SEAT POSITION ACCOMMODATION POINTS ON THE DESIGN H-POINT TRAVEL PATH

5.4 Position Seat Track in Vehicle

The seat and seat track shall be positioned in the vehicle so that the H-point moves along the design travel path. For seats with vertical adjustment, the design H-point travel path should be 20 mm above the full down position if the vertical adjustment is 40 mm or more or at the middle of the vertical adjustment if it is less than 40 mm. (Figure 7).

6. DESIGN PROCEDURES FOR 2ND OR 3RD ROW OUTBOARD SEATING POSITIONS

This procedure is used to position reference points in the vehicle’s interior space pertaining to passengers, including SgRP (second, third, or fourth, etc.), floor reference points, and floor plane angles. After this procedure is complete, many additional interior dimensions can be measured.

In order to position the HPD properly in a rear seat, the seat directly in front of it must be positioned at its SgRP. In other words, to set up the second row passenger seat, the driver or front passenger seat must be positioned at its SgRP location; to set up the third row passenger seat, the second row passenger seat must be at its SgRP location, etc.

The location of the shoe and the lower leg are specified by this procedure. If a seat with an adjustable recliner is provided, design torso angle is at the manufacturer's discretion. However, a design torso angle of 25 degrees is recommended. If the seat back does not recline that far, then the maximum torso angle is recommended as the design torso angle.

SgRP for a rear seat is at the manufacturer’s discretion.

6.1 Determine the Initial Target Values

Determine the initial target values for the dimensions listed in Table 5. (See SAE J1100 for definitions.)

TABLE 5 - VALUES NEEDED TO POSITION THE HPD FOR PASSENGERS

Dimensions	2nd Row Codes	3rd Row Codes	Final Values
Seat Height	$H30\text{-}2_{Target}$	$H30\text{-}3_{Target}$	Depending on the Z coordinate of the floor reference point defined during this procedure, the final value of seat height might be different. However, if desired and possible, the height of the seat in question can be adjusted to maintain the target value.
Depressed Floor Covering Height			Undepressed floor covering height at FRP minus 5 mm or an amount specified by the manufacturer.
Occupant Centerline	$W20\text{-}2_{Target}$	$W20\text{-}3_{Target}$	This value is not changed as a consequence of this procedure.
Torso Angle	A40-2	A40-3	Seats with an adjustable seat back: Manufacturer's discretion (set to maximum back/torso angle, if the maximum is less 25 degrees) Seats without a seat back adjustment: Manufacturer's discretion. A40 is a seat characteristic. It is neither calculated nor modified by this procedure. Rather, it is used to position the attitude of the back pan assembly.
Lumbar Support Prominence	L81-2	L81-3	L81 is a seat characteristic. It is neither calculated nor modified by this procedure. Rather, it is used to posture the back pan articulation, specifying the distance (X) of the lumbar-pelvic pivot (L/P pivot) to the torso line, measured normal to the back line. (See Figure 3.) LSP=57-X mm
Cushion Angle	A27-2	A27-3	A27 is a seat characteristic. It is neither calculated nor modified by this procedure. Rather, it is used to position the attitude of the cushion pan assembly.

6.2 Establish Seat Positions

6.2.1 Seat Position of Seat in Front

Position the seat directly in front of the current seat so that the seat in front is at its design intent location and attitude – i.e., the seat H-point is at SgRP, with the seat cushion and seat back set to reflect the correct torso angle and cushion angle.

6.2.2 Current Seat Position

If the seat being assessed is adjustable, position it at its design intent location and attitude. If the seat has an adjustable seat back recliner, set it to design intent. If the maximum torso angle of the seat is less than 25 degrees, set it to the maximum.

6.3 Position HPD (Cushion and Back Pan Assemblies), Determine SgRP

Set the HPD in the seat, while maintaining the desired target values for torso angle, cushion angle and lumbar support prominence. The location of the H-point defines SgRP.

6.4 Position Shoe Tool

Position the shoe tool on the floor with the bottom of shoe contacting the depressed floor covering, normal to the Y plane, so the shoe centerline lies laterally within 127 mm to either side of the occupant centerline. The shoe tool is placed as far forward as possible, based on the understructure and trim surfaces of the seat in front (Figure 10).

Interference above the ankle pivot circumference is not considered for positioning the shoe but will be considered when determining leg and knee clearance with short-coupled seating. Use this shoe position to define the leg room. In the rare case that the shoe does not physically fit between the seats, the rear of the shoe is positioned against the trim under the test seat with the front of the shoe intruding into the preceding seat trim and/or structure (Figure 11).

For long-coupled seating, the shoe has to be moved farther rearward in order to attach and properly position the thigh and lower leg segments. Move the shoe rearward until an ankle angle of 130 degrees is achieved with the thigh assembly attached to the H-point and the lower leg assembly attached to the shoe tool. Use this position to establish the floor reference point, floor plane angle, knee clearance (L48), leg clearance (L58), and all other dimensions except leg room (L51).

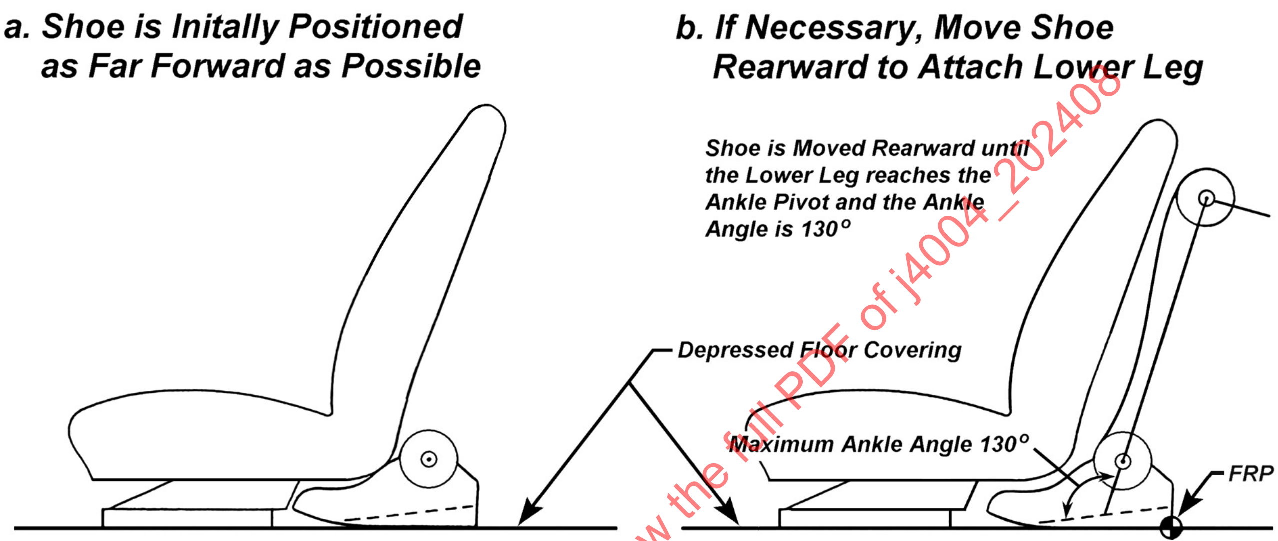

FIGURE 10 - FLOOR REFERENCE POINT (FRP)

6.5 Position Thigh and Lower Leg

Use the SgRP leg lengths of 456 mm for thigh and 459 mm for lower leg. Position the legs without moving the shoe tool while keeping the H-point on the SgRP. The thigh rotates about the H-point y-axis connecting the H1L and H1R divot points, and the lower leg rotates about the ankle in order to accomplish this. The y-coordinate of the leg is aligned to the y-coordinate of the heel of shoe (HOS). Lateral splay of the leg is not permitted.

If the preceding seat back does not interfere with the HPM knee or lower leg, measure knee clearance (L48) and leg clearance (L58) as the minimum clearance between the preceding seat back and the knee or lower leg. See SAE J1100.

If the preceding seat back interferes with the lower leg segment above the ankle circumference, proceed according to 6.6 before determining clearances (Figure 12).

6.6 Short-coupled Seating

In vehicles with short-coupled seating the seat back of the preceding seat interferes with the knee or the lower leg segment of the H-point device (Figure 11).

Measure knee clearance (or leg clearance) in CAD using the HPD and CAD data for the seat back in the vicinity of the K1 divot point and lower leg segment. Both measures will be negative values when there are interferences. If the preceding seat back interferes with the knee, knee clearance (L48) is a negative value equal to the measurement from the knee pivot center to the interference minus 51 mm. If the seat back interference is rearward of the knee pivot center add 51mm to the distance from the knee pivot center to the interference.

If the leg interferes with the preceding seat back, leg clearance (L58) is a negative value equal to the amount of maximum interference measured from the front of the lower leg normal to the leg line. See SAE J1100.

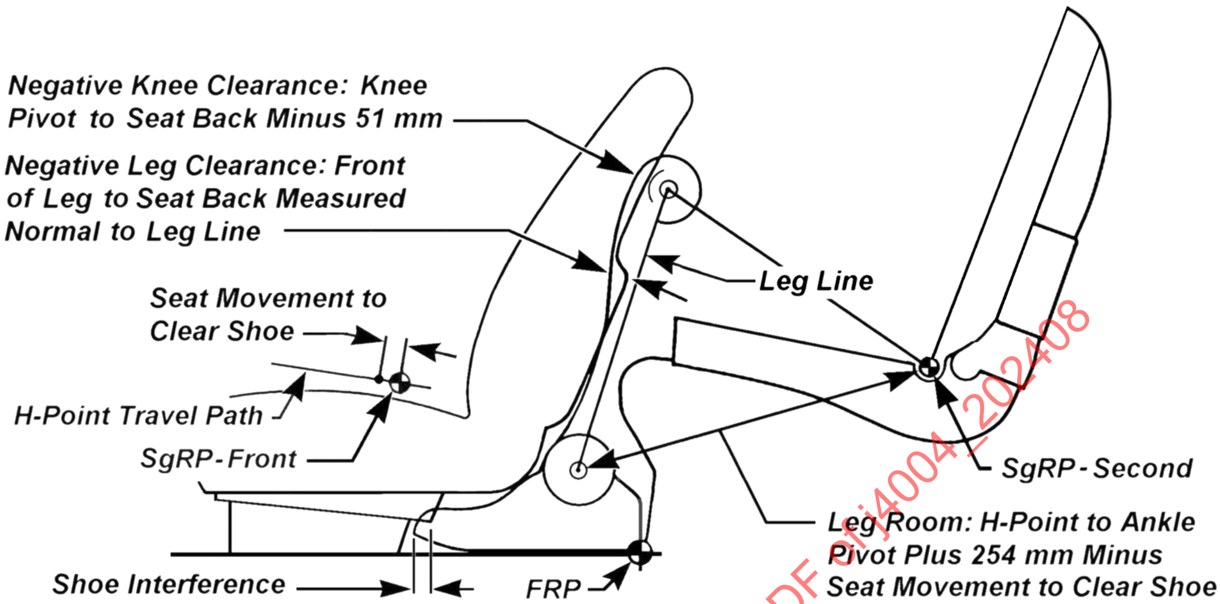

FIGURE 11 - SHOE INTERFERENCE, KNEE CLEARANCE AND LEG CLEARANCE FOR SHORT-COUPLED SEATING

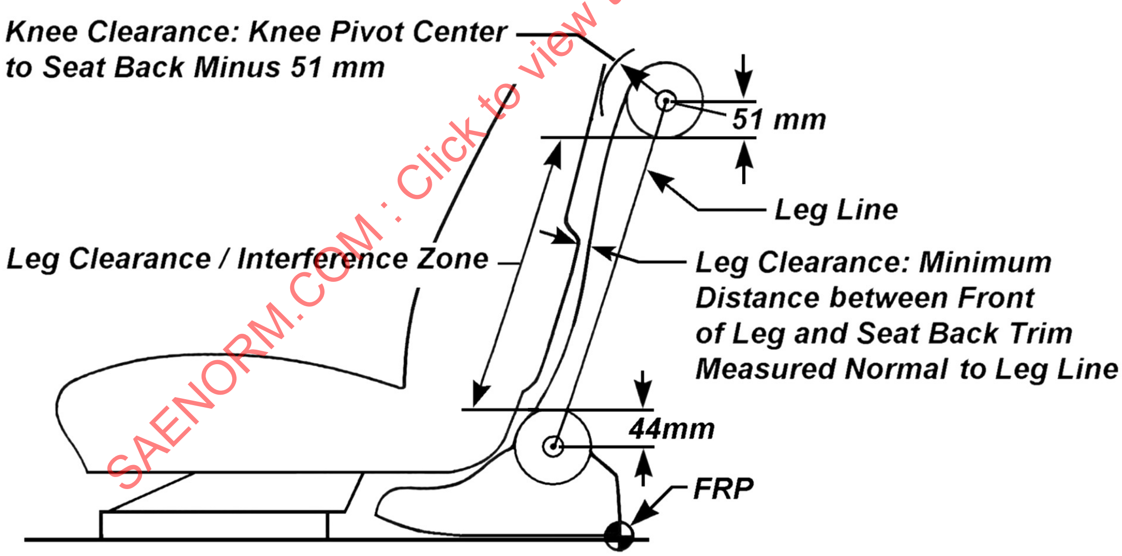

FIGURE 12 - KNEE AND LEG CLEARANCE ZONES

6.7 Decision Tree for Short- and Long-Couple Procedures

Figure 13 provides a decision tree for selecting the appropriate CAD method to use for positioning the HPD and measuring L48 and L51.

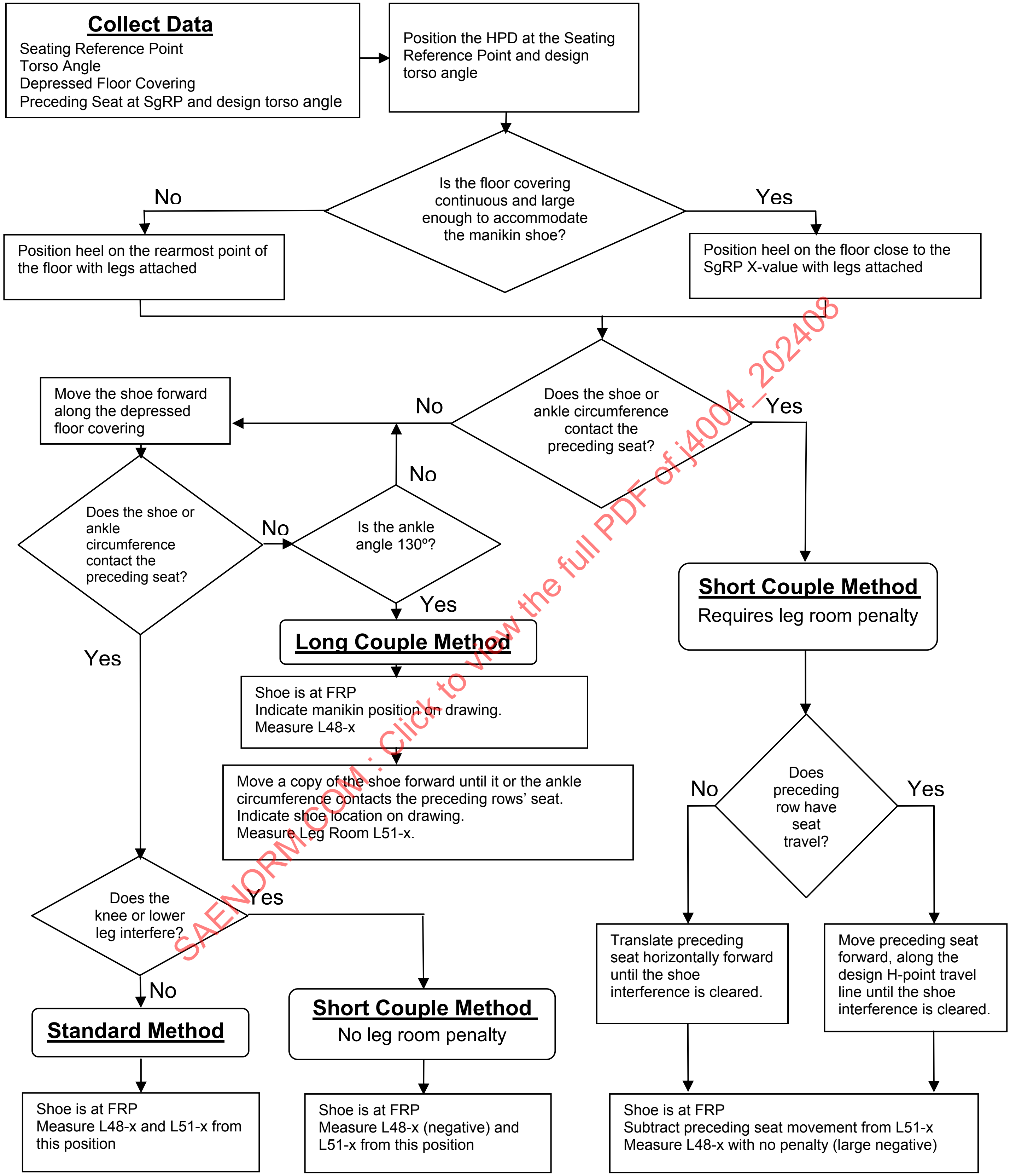

FIGURE 13 - DECISION TREE FOR COUPLE METHODS - HPD PLACEMENT FOR 2ND TO NTH ROW

6.8 Determine Dimensions

The dimensions listed in Table 6 can now be determined. The FRP is the point on the depressed floor covering contacted by the heel of shoe. The floor plane angle is defined by the shoe tool's attitude. When viewed from the side, the segment from BOF to the heel of the shoe defines the floor plane angle.

TABLE 6 - DIMENSIONS (SEE SAE J1100 FOR DEFINITIONS)

SAE J1100 Code[a]	Dimension
L31, W20, H70	SgRP X, Y, and Z coordinates
H30	Seat Height
L98 and H98	Floor Reference Point X and Z coordinates
A48	Floor Plane Angle
A40	Torso Angle
A27	Cushion Angle
A57	Thigh Angle
A42	Hip Angle
A44	Knee Angle
A46	Ankle Angle
L81	LSP
H61	Effective Head Room
L48	Knee Clearance
L58	Leg Clearance
L51	Effective Leg room

[a] A suffix (-2, -3, …) that denotes the seat row must be added to each dimension code.

7. NOTES

7.1 Marginal Indicia

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE HUMAN ACCOMMODATION AND
DESIGN DEVICES STANDARDS COMMITTEE

APPENDIX A - MODEL DESCRIPTION AND APPLICATIONS FOR OTHER DRIVER POPULATIONS

A.1 BACKGROUND

In this appendix, a more detailed description of the seat position prediction model is described. The complete model provides a method for determining driver seat track length for special cases where seat track lengths are needed for different driver populations (a different stature distribution, gender mix, or percentile accommodation).

SAE J1517 incorporated a driver seat position prediction model that is briefly described in Appendix E. This model was only valid for a 50/50 male/female U.S. driver population. It could not be readily adapted to predict seat position for other driver populations and gender mixes.

The model embodied in SAE J4004 represents a completely different approach to predicting seat position. This model predicts seat position (measured aft of BOFRP) for an individual driver in a specific vehicle, based on his/her stature and various vehicle parameters. The distribution of seat positions for a particular driver population is then built by applying a population stature distribution to the seat position prediction model.

The data used to develop the present model were collected over several years (2.2.3 and 2.2.6). Preferred seat position was measured for 50 to 120 subjects in 36 vehicles and 18 laboratory buck conditions. In each vehicle, subjects were stratified by stature so that small and large statures were overrepresented for greater accuracy in measuring seat position preference among drivers near the tails of the seat position distribution. Vehicles were selected to span a wide range of vehicle dimensions.

Within each vehicle, seat position was regressed on stature. Across vehicles, seat position was shown to be linearly related to stature, independent of gender and independent of vehicle variables. Thus, an overall slope, intercept, and error estimate (MSE, the mean squared error) were calculated by averaging the values for individual vehicles.

A.2 MODEL DESCRIPTION

The seat position prediction model in SAE J4004 represents each single-gender seat position distribution using a normal distribution. Data analysis shows that individual seat position is best predicted by stature, regardless of gender. Thus, the relationship between seat position and stature within a vehicle is the same for males and females, so one prediction equation is sufficient. Across vehicles, seat position depends only on vehicle variables, so a single equation can be used to predict the seat position of any individual (male or female) in any vehicle. Equation A1 shows this predictive relationship.

$$X = 16.8 + 0.433\,(\text{stature in mm}) - 0.24(H30) - 2.19(A27) + 0.41(L6) - 18.2t \qquad \text{(Eq. A1)}$$

Because population stature is normally distributed (within gender), and because Equation A1 is linear in stature, the same equation predicts the mean male seat position as a function of the mean male population stature. Similarly, predicted mean female seat position is given by Equation A1 when mean female population stature is entered.

The predicted standard deviations of the male and female seat position distributions can be estimated using Equation A2.

$$s_x = \sqrt{0.433^2 s_h^2 + 29.7^2} \qquad \text{(Eq. A2)}$$

where,

s_x is the standard deviation of the male or female seat position distribution
s_h is the standard deviation of the male or female stature distribution

Equation A2 represents the basic relationship between the standard deviation of a normally distributed variable and the standard deviation of a linear transformation of that variable. The variance, s_x^2, of the linear combination (seat position) is equal to the sum of two components of variance. The first is the “explained variance,” which is the slope of the relationship squared (0.433^2) multiplied by the variance of the original distribution (single-gender stature). The second component is the “unexplained variance,” which was obtained from the regression of seat position on stature. That value was estimated to be 29.7.

By substituting the standard deviation of male stature or female stature of the driver population for s_h, Equation A2 provides an estimate of standard deviation of male or female seat position. With mean and standard deviation of seat position, distributions of male and female seat position can be fully described for each vehicle. Figure A1 illustrates these distributions.

Figure A1 also illustrates the way in which driver seat position accommodations are determined from these distributions. The horizontal axis represents seat position aft of BOFRP. Although males have a more rearward average seat position, the two distributions overlap. As a result, both distributions must be considered when determining the location of fore and aft cutoff points. In Figure A1, the vertical line represents a candidate forward seat position cutoff. The area with vertical hatch marks represents the males who would be unable to sit in their preferred seat position if the front end of the seat track were located at the cutoff. The area with diagonal hatch marks represents the females who would sit forward of the cutoff. The sum of these areas as a proportion of the whole is the total percent of drivers who would be “disaccommodated” by a seat track with its front end located at the vertical cutoff.

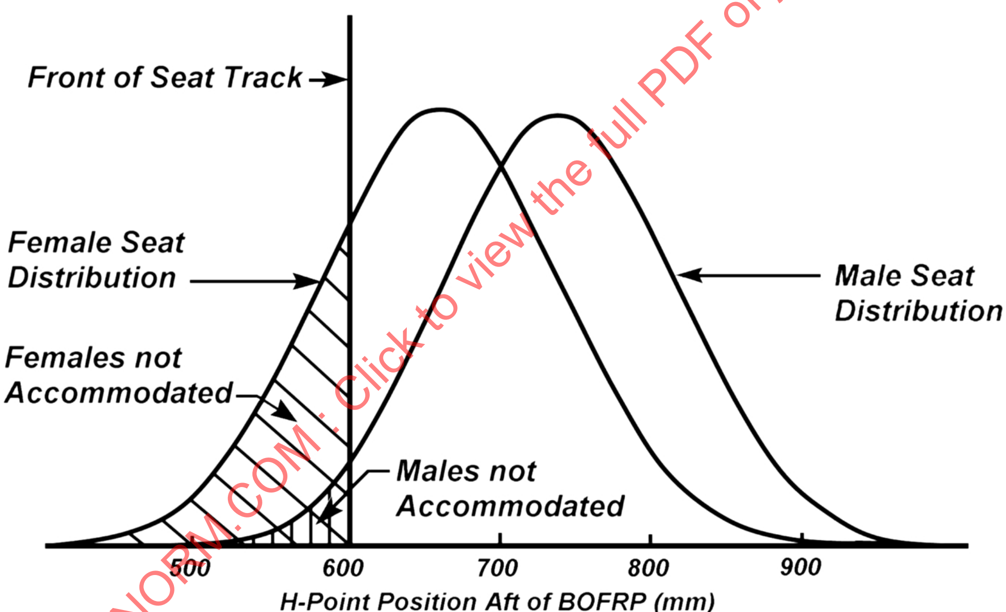

FIGURE A1 - ILLUSTRATION OF MALE AND FEMALE SEAT POSITION DISTRIBUTIONS RELATIVE TO BOFRP X-COORDINATE

For this application, the desired result is not the percent accommodation for each cutoff, but the cutoff value that corresponds to a given percent accommodation. However, because the cumulative normal distribution is not represented by a closed-form equation, the percent accommodation must be calculated for each cutoff value, and then the results must be searched for the desired accommodation level.

A.3 TOLERANCE

The seat position prediction model described represents the best estimate of the location and spread of the seat position distribution for a given vehicle, on average. For a 50/50 male/female U.S. driver population, the seat track that accommodates 95% of drivers would be 203 mm long. However, the true distribution will differ from the predicted distribution by some amount in each vehicle. Because the key result of this model is to predict the tails of the distribution, deviations from predicted mean and standard deviation of seat position have asymmetrical impact on accommodation at each tail of the distribution. Figure A2 illustrates the case where the predicted mean seat position is shifted rearward of the true underlying distribution.

In Figure A2, the right distribution represents the predicted distribution, on which seat track placement is based. The left distribution represents the true underlying seat position distribution, which, in this case, is forward of predicted. The tall vertical bars show the front and rear seat track limits, selected on the basis of the predicted seat position distribution. The light gray shading indicates the portion of the population that would have been accommodated if the mean prediction had been perfectly accurate but which is disaccommodated by the seat track placement based on the model. The dark gray shading indicates the portion of the population that would have been disaccommodated by a model with perfectly accurate prediction of the mean, but which is accommodated by the seat track placement based on the model. From this graph, it is clear that the unintentionally disaccommodated group (light shading) is larger than the unintentionally accommodated group (dark shading). A similar effect occurs with misprediction of standard deviation of seat position, but the effect shows up across vehicles, rather than within a single vehicle.

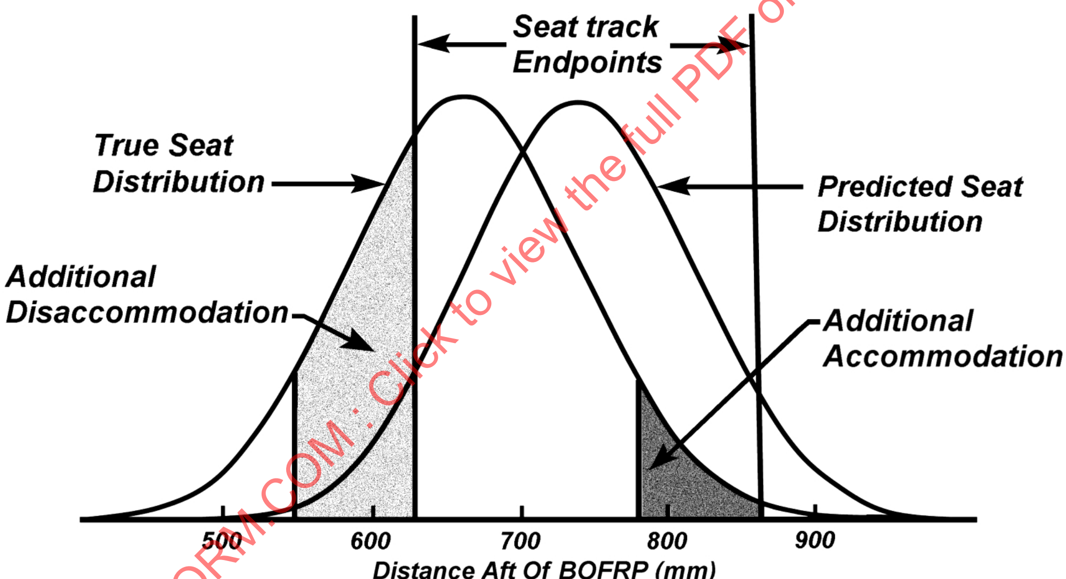

FIGURE A2 - ILLUSTRATION OF CONSEQUENCES OF MISPREDICTION IN MEAN SEAT POSITION

“Tolerance” is a statistical concept in which limits are determined such that X percent of drivers are accommodated with Y percent certainty. Accommodation is represented by X and tolerance by Y. The model as stated above has less than 50% tolerance because of the asymmetrical disaccommodation effect. To reach higher levels of tolerance, the most straightforward approach is to increase the estimate of random error in the standard deviation. Details are given in the next section.

A.4 PROCEDURE

A.4.1 Define Distributions

The distributions in Figure A1 represent seat position distributions for males and females. Defining these distributions is the first step in determining the seat track length and position that will accommodate the desired percentage of the whole driver population.

The seat position distributions for males and females are normal distributions. Each distribution is defined by its parameters, the mean and standard deviation. Because the effect of stature on seat position is the same for males and females, Equation A1, repeated below, is sufficient to determine the mean of both male and female distributions for a given vehicle. The only difference is the value of mean stature used in solving the equation. Use mean female stature to determine mean female seat position, and use mean male stature to determine mean male seat position.

$$X = 16.8 + 0.433(\text{stature in mm}) - 0.24(H30) - 2.19(A27) + 0.41(L6) - 18.2t \quad \text{(Eq. A1)}$$

Similarly, Equation A2 can be used to predict the standard deviation of male and female seat position distributions. Again, the only difference is that the standard deviation of the female stature distribution is used to determine the standard deviation of the female seat position distribution and the standard deviation of the male stature distribution is used to determine the standard deviation of the male seat position distribution.

$$s_x = \sqrt{0.433^2 s_h^2 + 29.7^2} \quad \text{(Eq. A2)}$$

A.4.2 Compute Percent Accommodation

Once the two seat position distributions are defined according to A.4.1, the percent of the distribution that lies to the left of each possible cutoff value must be tabulated. The relative proportion of males and females becomes relevant in this step. Equation A3 gives the equation necessary for this step.

$$P(k) = p_m \Phi((k - X_m)/s_m) + (1 - p_f)\Phi((k - X_f)/s_f) \quad \text{(Eq. A3)}$$

where,

- $P(k)$ is the proportion of the combined male and female population that lies to the left of cutoff k
- p_m is the proportion of males in the driver population
- p_f is the proportion of females in the driver population
- X and s are the mean and standard deviation of seat position, and
- Φ is the cumulative normal distribution

Conceptually, Equation A3 translates seat position cutoff (*k*) into a z-score and determines the proportion of the normal distribution that lies to the left of that z-score for males and females separately. The male and female proportions are then weighted by their relative driving population proportions. The result *P(k)* is the proportion of drivers who sit forward of the cutoff location. When the cutoff represents the forward endpoint of the seat track, these drivers are not accommodated. In other words, their preferred seat position would lie forward of the available track travel. When the cutoff represents the rearward endpoint of the seat track, these drivers are accommodated (at least in rearward travel), because their preferred seat position lies forward of the rearmost point on the seat track.

A.4.3 Select Cutoff with Desired Accommodation Level

The procedure described in A.4.1 and A.4.2 is repeated for a wide range of possible cutoff values. In order to select the appropriate value, the desired percentiles must be defined for both forward and rearward travel. For typical applications, the user will have a target accommodation level such as 95 percent, and the drivers who are not accommodated will be evenly split between those who sit too far forward and those who sit too far rearward. Thus, the target percentile at the forward end would be 2.5 and the target percentile at the rearward end would be 97.5. However, target accommodation does not have to be symmetrical. A 95% accommodation level could also be achieved with a 1st percentile forward cutoff and a 96th percentile rearward cutoff.

To determine the cutoff for forward travel, the table of possible cutoff values must be searched for the percentile closest to the target for forward travel. The cutoff value that corresponds to the target percentile is the value for the driver population and gender mix for forward travel. The same search procedure is applied to the rear-travel target percentile. The difference between these values is the total seat track travel necessary for the chosen accommodation level.

A.4.4 Incorporate Tolerance

The method described in A.4.1 through A.4.3 generates a seat track that is the best prediction to accommodate the target percent of drivers. However, because of the asymmetrical consequences of errors in prediction described in Section A.3, target accommodation will be achieved in only about 43% of vehicles. In order to achieve the target accommodation level more often, Equation A2, which predicts standard deviation of the seat position distribution must be replaced by Equation A2a.

$$s_x = \sqrt{0.433^2 s_h^2 + e^2} \qquad \text{(Eq. A2a)}$$

In Equation A2a, the MSE value of 29.7 is replaced by a variable (*e*) that represents the error component of the predicted standard deviation of seat position. The variable value would typically be greater than 29.7 for greater tolerance. For example, an MSE value of 43.8 gives a tolerance of 88% when the driver population is 50% male. Using this value to generate male and female seat position distributions as described in A.4.1 through A.4.3, a seat track of 240 mm is expected to accommodate 95% of drivers in 88% of vehicles.

Monte Carlo simulations were used to determine the relationship between the estimate of random error used for the model and tolerance level achieved. From these simulations, Equation A4 was developed to determine the tolerance level associated with a particular value of random error. Equation A4 depends only on the gender mix of the driver population, expressed as the percent of males.

$$t = \Phi^{-1}\left(-3.05 + 0.097e - 2.14\left|p_m - 0.5\right| + 0.067e\left|p_m - 0.5\right|\right) \qquad \text{(Eq. A4)}$$

where,

- t is tolerance,
- e is the MSE component used to generate male and female seat position distributions,
- p_m is the percent of males in the driver population, and
- Φ^{-1} is the inverse standard normal distribution

Equation A4 includes the inverse cumulative normal distribution, so it cannot be easily inverted. If the user wants to specify the tolerance level and find the corresponding value of *e*, then the equation can be solved for many different values of *e* and the list can be searched for the one that gives the desired tolerance level.

The values given in Table 3 represent a tolerance of 90% for each percent accommodation when the driver population is 50% male.

APPENDIX B - HPD SPECIFICATION AND TOLERANCES

B.1 TOLERANCES

HPD tolerances reflect dimensional variations that may occur when importing and exporting the HPD CAD data into various CAD software programs, because each program may contain default settings that can affect the accuracy of the HPD data. Also, when dealing with curved surfaces, the accuracy of the HPD surface can vary based on the number of sections used to define the surface. HPD tolerances are still being reviewed and may be reduced in the future.

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.)

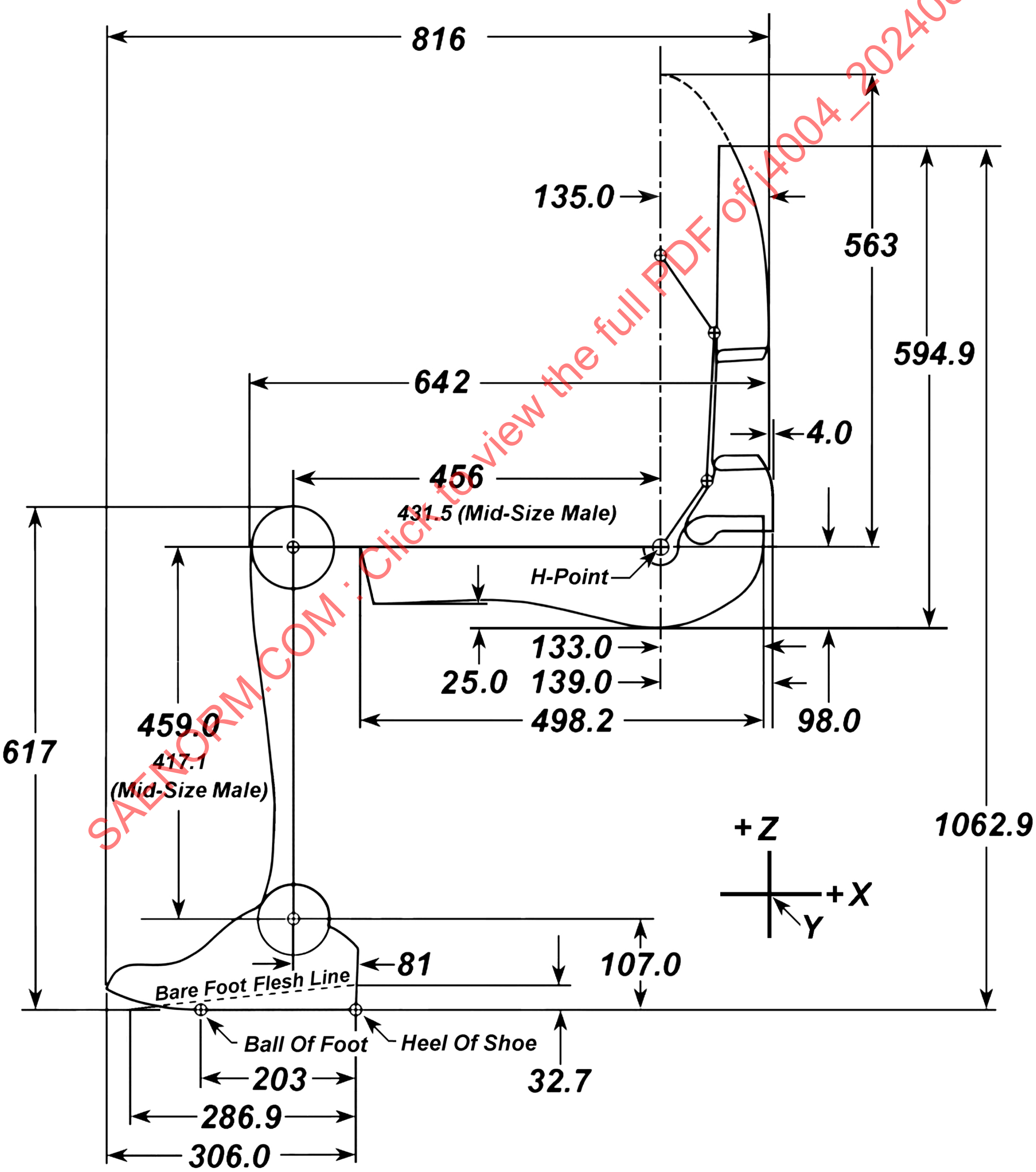

FIGURE B1 - HPD LENGTHS AND HEIGHTS, SIDE VIEW

TABLE B1 - POSTURE OF DEVICE FOR SPECIFICATIONS

Torso 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	203 mm
Ankle pivot	107 mm above HOS 81 mm forward of HOS
Bare foot flesh line Relative to BOF Relative to HOS	6.5 degrees above the bottom of shoe. Originates 286.9 mm forward of HOS. 9.9 mm above 32.7 mm above

B.4 LENGTHS

See Table B3 and Figure B1.

TABLE B3 - LENGTHS (IN mm)

Description	Value	HPD Tolerance
Overall (rearmost to foremost)	816.0	± 1.0
Overall, not counting shoe	642.0	± 1.0
Cushion Pan	498.2	± 0.5
Shoe	306.0	± 0.2
Heel of Shoe to Ball of Foot	203.0	± 0.01
Heel of Shoe to Ankle Pivot	81.0	± 0.01
Heel of Shoe to Origin of Bare Foot Flesh Line	286.9	± 0.01
H-Point to Knee Pivot	456.0	± 0.01
H-Point to Knee Pivot, w/ mid-size male leg lengths	432.0	± 0.01
H-Point to back of cushion pan	133.0	± 0.5
H-Point to back of back pan	135.0	± 0.5

B.5 WIDTHS

See Table B4.

TABLE B4 - WIDTHS (IN mm)

Description	Value	HPD Tolerance
Cushion Pan, Max. (358 mm forward of H-point)	405.8	± 1.0
Cushion Pan, at H-Point	383.3	± 0.5
Cushion Pan, at D-Point	371.0	± 1.0
Cushion Pan, at CP2 support points	401.0	± 1.0
Cushion Pan, at CP3 support points	405.1	± 1.0
Back Pan, Max. (442 mm above H-point)	384.6	± 1.0
Pelvic Segment, at BP1 support point	373.7	± 1.0
Lumbar Segment, at BP2 support point	326.0	± 1.0
Thoracic Segment, at BP3 support point	360.3	± 1.0
Shoe, Max. (at ball of foot)	110.0	± 0.01

B.6 HEIGHTS

See Table B5 and Figure B1.

TABLE B5 - HEIGHTS (IN mm)

Description	Value	HPD Tolerance
Overall	1062.9	± 1.0
Seated Height (bottom of cushion pan to top of device)	594.9	± 1.0
Cushion Pan, Max.	132.3	± 0.5
Pelvic Segment, Max.	94.9	± 1.0
Lumbar Segment, Max.	150.3	± 1.0
Thoracic Segment, Max.	255.6	± 1.0
Lumbar-Pelvic Pivot to Bottom of Cushion Pan	180.8	± 0.5
Thoracic-Lumbar Pivot to Bottom of Cushion Pan	363.5	± 0.5
H-Point to Bottom of Cushion Pan	98.0	± 0.01
H-Point to Shoulder Reference Point	563.0	± 0.1
Heel of Shoe to Ankle Pivot	107.0	± 0.01
Heel of Shoe to Bare Foot Flesh Line	32.7	± 0.01
Ball of Foot to Bare Foot Flesh Line	9.9	± 0.01
Knee Pivot Point to Ankle Pivot Point	459.0	± 0.01
Knee Pivot Point to Ankle Pivot Point, mid-size male	417.5	± 0.01
Knee Pivot Point to ‘Cross-Over’ of Lower Leg Pieces	300.0	± 0.1
Ankle Pivot Point to ‘Cross-Over’ of Lower Leg Pieces	159.0	± 0.1
Top of Knee to Bottom of Shoe	617.0	± 0.1
Sole of Shoe	3.2	± 0.1

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 BACK PAN LINKAGE MECHANISM

See Table B6. The values provided are straight-line distances, in mm.

TABLE B6 - LINKAGE DISTANCES ON HPD (IN mm)

Description	Value	Tolerance	Property
H-Point to Lumbar-Pelvic Pivot	100.0	± 0.01	These values remain constant regardless of posture/LSP setting.
Lumbar-Pelvic to Thoracic-Lumbar Pivot	183.0	± 0.01	
Thoracic-Lumbar Pivot to Sliding Thoracic Pivot	119.0	± 0.01	
H-Point to Sliding Thoracic Pivot	363.24	± 0.01	This value increases as LSP increases, and decreases as LSP decreases.
Upper Reverse Link to Thoracic-Lumbar Pivot	36.5	± 0.01	These values remain constant regardless of LSP. The reverse linkage constrains the movement of the back pan segments.
Lower Reverse Link to Lumbar-Pelvic Pivot	36.5	± 0.01	
Upper to Lower Reverse Link	159.3	± 0.01	

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 B2.

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
HPD Tolerance	All Support Points	± 0.1	± 0.1	± 0.1

[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.