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ABSTRACT

The ASPECT (Automotive Seat and Package Evaluation and Comparison Tools) manikin provides new capabilities for vehicle and seat measurement while maintaining continuity with previous practices. This paper describes how the manikin is used in the development of new designs, the audit verification of build, and in benchmarking competitive vehicles and seats. The measurement procedures are discussed in detail, along with the seat and package dimensions that are associated with the new tool.

INTRODUCTION

Procedures and tools developed by committees of the Society of Automotive Engineers (SAE) and documented in SAE recommended practices are used extensively during the vehicle design process (1).[1] The H-point manikin described in SAE J826 provides the H-point, a reference point used to predict the location of occupants in vehicles. The seating reference point (SgRP) defined in SAE J1100 locates the H-point in the vehicle workspace for drivers and passengers. Pedal plane angle (q) and the 95^{th}-percentile selected seat position curve described in SAE J1516 and J1517 are used to position the SgRP and manikin thigh, leg, and shoe. Additional measures provided by the H-point manikin and defined in SAE J1100 describe seat characteristics and the spatial relationships for seated occupants (the seating package). Assessment tools for spatial accommodation are provided by SAE J1517 (Driver Selected Seat Position), SAE J941 (Drivers' Eye Location), SAE J1052 (Driver and Passenger Head Location), and SAE J287 (Driver Hand Controls Reach).

The SAE J826 H-point manikin is used in three general application categories during the development of seating packages. In *design*, the H-point and associated reference points and measurement definitions are used to specify seating package geometry for a proposed vehicle. After a prototype of the design is constructed, it is *audited* using the H-point manikin to determine build accuracy in relation to design specifications. The H-point manikin is also used to measure vehicles from other manufacturers for which the design intent is not known, an application commonly called *benchmarking*. Audit and benchmarking differ in that the design intent and specifications are known prior to beginning an audit evaluation, while benchmarking is conducted without any previous information about the vehicle or seat design specifications.

The ASPECT manikin (also called the ASPECT Physical Manikin, or APM, to differentiate it from its CAD counterpart) provides improvements over the current H-point manikin in its ability to measure the postural support characteristics of seats (2-5). Figure 1 shows a schematic of the manikin. The H-Point is retained as the primary reference point, and a new articulated torso measures the longitudinal contour of the seatback, expressed as lumbar support prominence. The manikin also simultaneously measures seat cushion angle and seatback angle.

Unlike the current H-point manikin, the ASPECT manikin measures H-point location in a seat without being connected to the vehicle package through leg segments. The ASPECT manikin includes supplemental thigh, leg, and shoe segments that can be used to measure the package geometry, but these segments are not needed for the basic H-point measurement of the seat. This separation between seat and package measures simplifies use of the manikin and allows seats to be measured independent of the rest of the vehicle.

In this paper, proposed procedures for using the ASPECT manikin in vehicle design, audit, and benchmarking are presented. The manikin procedures are integrated with other tools developed in the ASPECT program, as well as with new accommodation models developed in coordination with ASPECT (5). These procedures and tools may be revised as they are considered for incorporation into SAE recommended practices. The proposed procedures are intended to facilitate discussion and evaluation of the new tools.

1. Numbers in parentheses denote references at the end of the paper.

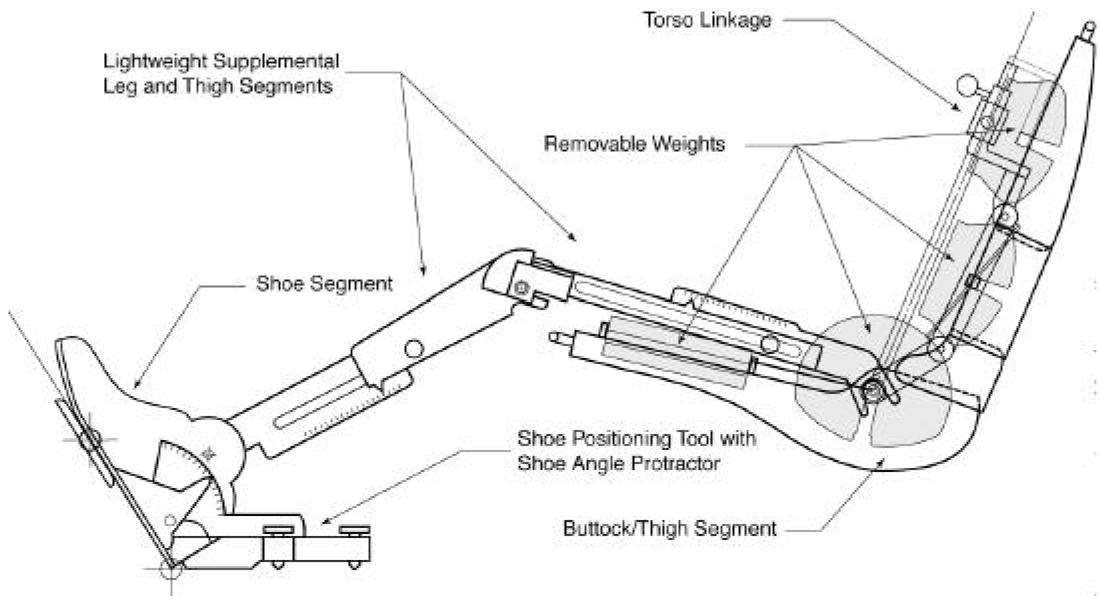

Figure 1. Schematic of ASPECT manikin, showing supplemental thigh, leg, and shoe segments.

METHODS

ASPECT MANIKIN SEAT MEASURES – The ASPECT manikin is intended primarily as a seat measurement tool with additional capability for measuring some package dimensions. Figures 2 and 3 shows a schematic of the manikin in a seat, illustrating the four primary seat characteristics measured by the manikin.

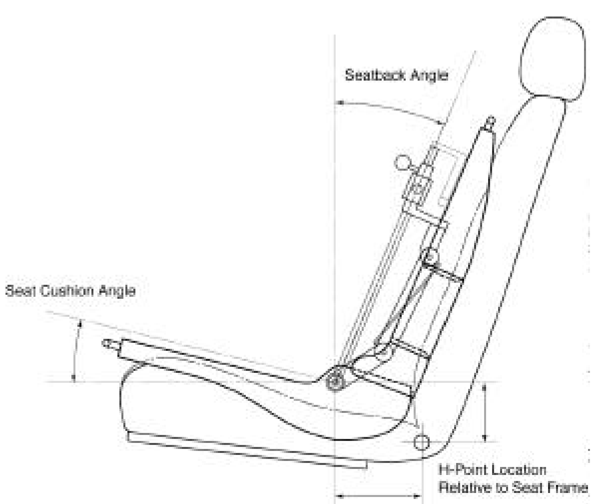

Figure 2. Schematic of ASPECT manikin, showing the manikin measures of H-point location, seatback angle and seat cushion angle.

Lumbar Support Prominence – One of the limitations of the current J826 H-point manikin that motivated the development of the ASPECT manikin is the rigid torso, which is often unstable when the manikin is installed in seats with prominent lumbar support. The ASPECT manikin includes a two-joint, articulated lumbar spine that mimics human lumbar-spine flexibility, creating a torso comprised of pelvis, abdomen (lumbar), and thorax segments. Each internal segment is attached to a contoured shell section. A connecting rod across the lumbar joints synchronizes the motion of the thorax and pelvis segments so that spine flexion is distributed approximately equally across the two joints (3). When installed in a seat, this flexible linkage allows the manikin torso to conform to the longitudinal shape of the seatback. The external shell profile of the ASPECT manikin torso conforms closely to the profile of the current manikin torso when the linkage is in its neutral position, depicted in Figure 2. However, in a seat with a prominent lumbar support, the manikin lumbar spine extends as the torso shells conform to the shape of the seatback, as shown in Figure 3.

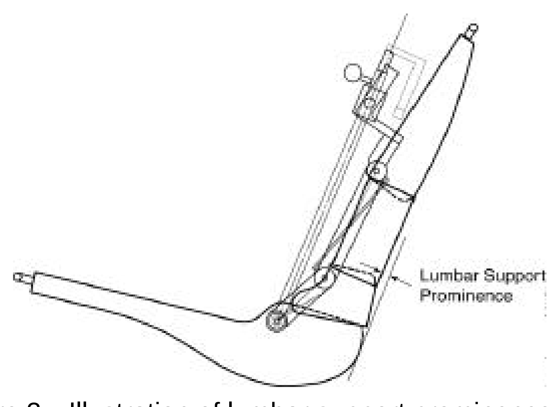

Figure 3. Illustration of lumbar support prominence measurement with the ASPECT manikin, showing a positive lumbar support prominence.

The change in spine flexion is interpreted as lumbar support prominence. The lumbar support prominence is expressed in millimeters, corresponding to the displacement of the external lumbar shell of the manikin relative to the neutral, straight-back condition. Positive lumbar support prominence indicates that the manikin linkage is extended, giving a lordotic or inward-curving shape to the external profile. Negative lumbar support prominence indicates an outward-curving or kyphotic external profile, and the lumbar prominence reading is zero when the seat produces a manikin profile that corresponds to the flat profile of the current SAE J826 manikin.

Seatback Angle – The ASPECT manikin includes a torso line that replicates the function of the torso line on the current J826 manikin and two-dimensional (2D) template for defining and measuring seatback angle. The ASPECT manikin torso line is parallel to the surface profile in the lumbar area of the manikin when installed in a seat with zero lumbar support prominence, just as the torso line of the current manikin is parallel to the external shell profile. For other levels of lumbar support prominence, the torso line remains approximately parallel to the external shell section connected to the lumbar segment of the manikin. Note that the manikin torso line does not connect the H-point with another point having an anatomical correlate, such as the shoulder. When installed in a seat, the angle of the ASPECT manikin torso line with respect to vertical defines the seatback angle. Combined with the lumbar support prominence measure, seatback angle measures the deflected surface contour of the seatback in a way that can be related to human posture.

Seat Cushion Angle – SAE J826 was recently amended to include a technique for measuring seat cushion angle. In the J826 procedure, the current manikin is installed without legs and with a modified weight distribution to obtain a measure of the orientation of the deflected seat cushion surface. This measure is a factor affecting driver-selected seat position and driver posture (6, 7). The ASPECT manikin produces a similar measure as part of the normal installation process. A thigh line is defined on the manikin at an orientation designed to replicate the seat cushion angle measure obtained with the J826 manikin. This is approximately the orientation of a line connecting the hip and knee joints of a midsize male sitting with his thighs fully engaged with the seat cushion. The thigh orientations of sitters will usually differ from the measured seat cushion angle because thigh angle is affected by factors other than seat cushion angle, such as seat height.

H-Point Location – The distances from the ASPECT manikin H-point to the bottom and rear of the manikin buttock/thigh shell profile are designed to be the same as the corresponding dimensions on the current J826 manikin. As with the current manikin, the H-point is intended to approximate the hip joint location of a human in the seat. When the ASPECT manikin is installed in a seat with a lumbar support prominence that measures zero, the ASPECT manikin H-point is intended to be coincident with the SAE J826 H-point (3). However, in seats with more- or less-prominent lumbar supports, differences between the manikins in H-point location are expected. The H-point location will not generally replicate the hip joint location of any particular category of sitter. Hip joint locations are affected by a number of factors, only some of which are measured by the manikin. The manikin H-point is one of the inputs to posture prediction models that are used to locate human hip joints relative to the vehicle and seat (4).

ASPECT MANIKIN PACKAGE MEASURES – When the ASPECT manikin is installed in a vehicle with the seat positioned so that the manikin H-point is at the seating reference point (SgRP), the supplemental thigh, leg, and foot tools can be used to measure the package geometry. Figure 4 shows the manikin with the supplemental segments used to measure both driver and rear seats. The measures obtained using these procedures are essentially the same as those obtained with the current J826 manikin, so only a few will be discussed here.

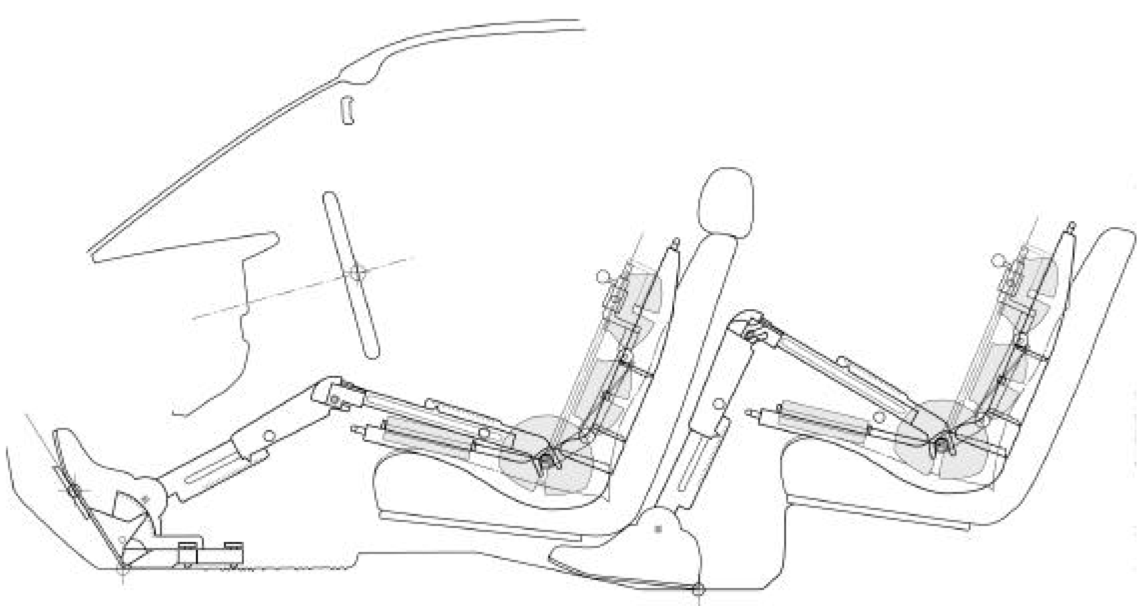

Figure 4. ASPECT manikin used to measure driver and rear seat package geometry.

<u>*Thigh Angle*</u> – The vertical distance from the SgRP to the heel rest surface, denoted H30 in SAE J1100 for the driver seat, is the seat height. Because the ASPECT manikin thigh segment is independent of the weighted manikin buttock/thigh shell, the manikin measures a thigh angle (relative to horizontal) that is generally greater than the seat cushion angle. The thigh angle is determined by the package geometry, specifically the seat height. In fact, using the practices described in this paper for locating the pedal reference point, shoe angle, and SgRP, thigh angle can be calculated directly from seat height.

<u>*Knee Angle*</u> – Knee angle is the included angle between the thigh and leg segments, and is essentially identical to the measure denoted L44 in SAE J1100. The angle is measured in a vertical plane only. Because the knee angle is measured with the seat located at the SgRP and with defined leg and thigh segment lengths, it does not necessarily represent the knee angles of any particular occupants.

<u>*Hip Angle*</u> – The hip angle is measured between the manikin thigh segment and the torso line (back angle). The back angle is either set to design or to a default value used for benchmarking, and the thigh angle is determined by seat height. As with the other angles measured using the manikin lower extremities, the hip angle does not necessarily represent typical posture measures for any occupant category. Rather, these angles provide dimensions that can be used to compare geometry across vehicle seat packages. Because the angles for the driver seating position are direct functions of the manikin geometry, the SgRP, and the pedal reference point, the angles of the thigh and leg segments are likely to be more useful for quantifying rear seat packages. Table 1 lists some of the vehicle and seat dimensions for the driver defined and measured using the ASPECT manikin. Measures shown in *italics* are not currently in SAE J1100.

NEW DEFINITIONS FOR SGRP AND PEDAL REFERENCE POINT – In conjunction with the ASPECT program, new proposals have been developed to improve the definitions of SgRP and pedal reference points. These new methods are presented in detail elsewhere (5). Using the new procedures, a pedal reference point (PRP) is defined on the pedal independent of the rest of the package, using only the local pedal and floor geometry. The manikin shoe plane angle is set using a linear function of seat height (H30) that is based on average observed driver foot angles. The new SgRP locator line determines the SgRP location aft of the PRP as a function of seat height. The intersection between the SgRP locator line and the H-point travel path defines the SgRP.

USE OF THE ASPECT MANIKIN IN OCCUPANT PACKAGING AND SEAT DESIGN

<u>*Occupant Packaging*</u> – The ASPECT manikin is used in vehicle design mainly through reference to its geometry and measurement capability. Since the ASPECT manikin is primarily a seat measurement tool, most of the design tasks involving the ASPECT manikin concern the seat, but the supplemental manikin leg, thigh, and shoe can be used to establish clearance specifications. CAD representation of the ASPECT manikin can be used to depict these dimensions. For example, knee and shin clearance guidelines based on the current J826 2D template can be readily adapted for use with the ASPECT manikin geometry. As part of the package design, the ASPECT manikin measures of the seat can be specified. In fact, some seat measurements, such as seat cushion angle, must be specified for use with the new accommodation models (5, 7).

Table 1. Proposed Measures to Define Vehicle Seats And Packages *(New measures are shown in italics.)*

APM Measures - Driver (New SAE J826 measures to be defined in SAE J1100)	**Application in Vehicle Design and Development**	
	Seat	**Package**
PRP location relative to car grid		x
*Pedal Plane Angle LXX**		x
*Heel Rest Z Plane**		x
*Heel Rest Z Line**		x
H-Point location relative to seat frame	x	
*Back Angle SL240D**	x	
Cushion Angle SL200D (replaces old L27)*	x	
*Lumbar Support Prominence SL250D**	x	
SgRP location relative to car grid		x
Chair Height H30		x
*Shoe Plane Angle LXX**		x
AHP x, y, z location relative to car grid		x
*Thigh Angle LXX**		x
Hip Angle L42 (similar to old L42)		x
Knee Angle L44 (similar to old L44)		x
Foot Angle L46 (similar to old L46)		x
Seatback Deflection @ selected locations	x	
Seat Cushion Deflection @ selected locations	x	
Percent Load Deflection @ selected locations	x	

*New dimension codes are shown. The S prefix designates a specific seat dimension, while the D suffix (for driver) designates a specific location in the vehicle.

Seat Design – Each of the measurements that can be made with the manikin corresponds to a potential specification for seat design. The H-point location relative to the seat frame is specified, as are the seat cushion angle and lumbar support prominence. A particular manikin-measured (seat) back angle is selected to correspond to a particular seatback frame orientation. In addition, the manikin H-point, torso line, and thigh line can be used as references to define many additional seat measures. Appendix D describes a large number of proposed seat dimensions, many of which are referenced to the ASPECT manikin.

USE OF THE ASPECT MANIKIN FOR AUDIT AND BENCHMARKING – The primary use of the ASPECT manikin is measuring vehicle seats and packages. The measurement is considered an audit if the primary purpose is to assess the extent to which a seat or vehicle meets with design intent. In an audit measurement, the design positions of the vehicle and seat components to be used during the measurement have been previously specified by the vehicle manufacturer. Benchmarking with the ASPECT manikin uses very similar procedures to measure a vehicle for which the design intent is not known. Consequently, the positions and settings of vehicle components and adjustments must be determined using standardized guidelines to ensure compatibility of the measurements across vehicles. To simplify the presentation, the audit procedures will be described first, followed by the changes to the procedures necessary for a benchmarking measurement.

Seat Measurement – A seat measurement begins by setting the seat components to the designated configuration. The seat cushion frame angle and seatback frame angle are set to the design position, meaning the default values set by the vehicle designer. Any other adjustments, such as lateral bolsters or adjustable lumbar supports, are set to their design positions. In effect, the seat components are placed in the positions and orientations that are expected to produce particular manikin measurements. The audit determines if the seat build has met the intent.

The manikin is then installed in the seat, using the procedure in Appendix A. A muslin cloth identical to the one currently specified in J826 is laid on the seat to standardize the friction under the manikin. The manikin is placed on the seat and the torso linkage is unlocked to allow the torso to conform to the shape of the seatback. If desired, the manikin buttock/thigh segment can be placed on the seat first, followed by the torso, which connects to the buttock/thigh segment at the H-point. Weights are added to the buttock/thigh pan first, then to the torso. After each loading step, calibrated springs are used to push the manikin into the seat and built-in levels are used to ensure that the manikin is aligned with the seat. After all of the weights have been added, the torso linkage is locked to prevent movement during measurement, completing the installation. The locations of reference points on the manikin can be recorded using coordinate measurement equipment, and the seat cushion angle, back angle, and lumbar support prominence can be read from scales on the manikin or by using inclinometers placed on specified manikin measurement surfaces.

Package Measurement – For package measurement, the manikin is used with the supplemental thigh, leg, and shoe segments. Because these segments do not interact dynamically with the vehicle or seat, most of the package measurements can be performed in CAD after measuring the seat with the manikin and recording the locations of a few points on the accelerator pedal and floor. However, the entire procedure can also be conducted physically, in a vehicle or mockup. Appendix C describes the entire procedure using parallel steps for physical and CAD measurement.

For the driver seat, the first step is to establish the pedal reference point (PRP) on the accelerator pedal, as shown in Figure 5. The PRP is defined on the undepressed accelerator pedal. On a physical pedal, the PRP may be located by positioning the manikin shoe tangent to the pedal. Usually the pedal will be blocked to keep it from moving during measurement, and pivoting pedals must be measured in their rest position. A shoe alignment fixture provided with the manikin holds the shoe in place against the pedal, simultaneously locating the PRP and the heel rest Z plane. On a curved pedal, the tangent point can be difficult to locate physically, although it is no more difficult than the current procedures for locating AHP and BOF. The procedure is straightforward in CAD. Figure 5 shows the PRP and heel rest Z plane established with the manikin shoe and shoe alignment fixture.

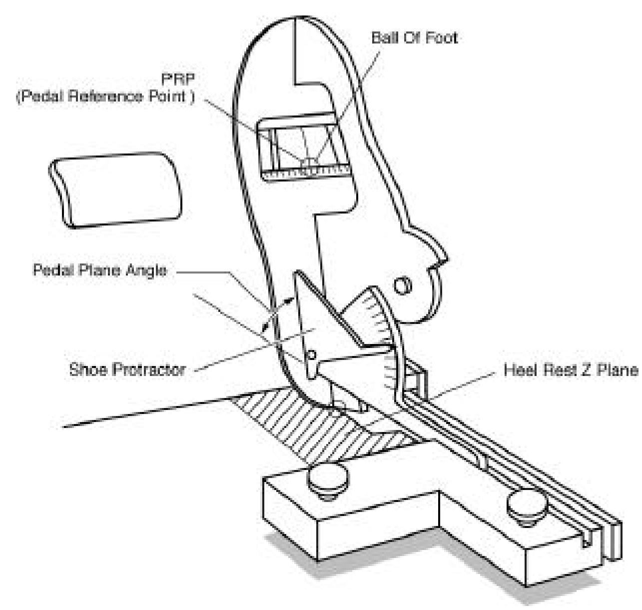

Figure 5. Establishing PRP and heel rest Z plane.

Next, the ASPECT manikin is installed in the seat, following the procedures described above and in Appendix A. The seat may be positioned anywhere within its track travel range, provided that the seat cushion and seatback have the appropriate orientations with respect to vertical. For an audit measurement, the seat track, seatback recliner, and any other seat adjustments would be placed in their design positions. Seat position will typically be specified with regard to seat track position, such as three detents forward of full rear. Alternatively, the positions of some fiducial points on the seat frame could be specified with respect to other reference points on the vehicle. For an audit measurement, this detailed information is commonly provided.

The SgRP position above the heel rest Z plane defines H30, the seat height. H30 is input to the shoe angle equation to determine the appropriate shoe plane angle, and a protractor is used with the shoe alignment fixture to orient the shoe appropriately. Contact is maintained between the shoe and accelerator pedal, but the contact point need not be the PRP.

With the manikin and shoe in place, adding the lightweight thigh and leg segments completes the installation. The thigh and leg are adjusted to 452-mm and 436-mm lengths, respectively, which are based on average lower extremity dimensions for men matching the SgRP reference stature (3, 5). Coordinate measurement equipment, portable inclinometers, or other equipment can then be used to record the manikin segment positions and orientations. Figure 6 shows some of the package-related dimensions that can be measured using the supplemental thigh, leg, and shoe tools. These dimensions are often quantified in CAD rather than with physical measurements.

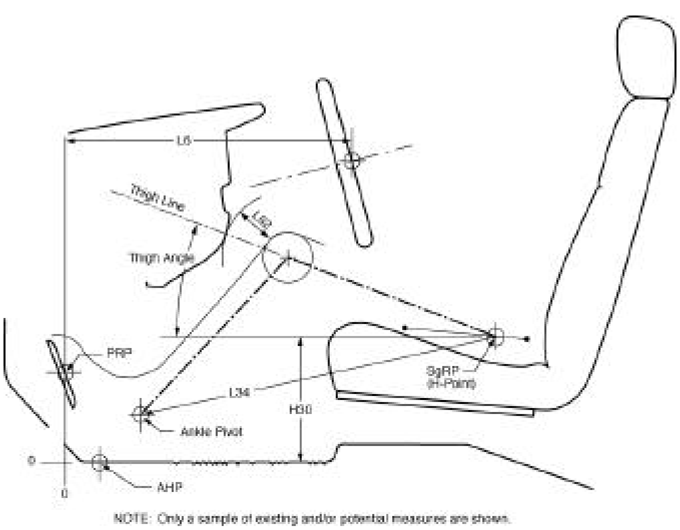

Figure 6. Measuring driver package dimensions.

<u>Benchmarking</u> – Use of the manikin for benchmarking is similar to the audit installation process, except that the appropriate positions of the seat and its components are not known in advance. As part of the process of developing ASPECT manikin usage procedures, a preliminary set of guidelines for setting adjustable components in benchmarking applications has been developed. Table 2 lists some of the proposed settings, which specify that components be set to the least restrictive settings or to the middle of the adjustment range. Lateral bolsters, for example, are set to the least restrictive position. Some pneumatic lumbar support adjusters are difficult to set to a middle position, so a minimum-prominence setting is proposed for all adjustable lumbar supports. Lumbar support height adjusters are set to the middle of the travel range. Seat cushion angle is set to the middle of the travel range for seats without height adjustment and to the orientation obtained in the full-down, full-rear position for seats with adjustable height and angle. Seatback angle must be set using the manikin. A typical average value of driver-selected seatback angle (22 degrees) has been chosen as the default for Class A vehicles, and a more upright angle (18 degrees) for Class B vehicles. Recommended settings for other seat adjustments will be developed as needed for potential standardization in SAE J826. If manufacturers use these settings as the design position, a benchmarking measurement of a vehicle will yield measurements that are close to the design intent, fulfilling the purpose of standardized, industry-wide measures.

After the seat components are set to their default positions, the manikin is installed using the procedures described in Appendix A. The location of the H-point is measured relative to one or more targeted reference points on the seat. The targeted reference points should maintain a constant dimensional relationship with the H-point throughout the range of seat track travel. Usually these points are on a part of the seat frame above the track adjuster.

Table 2. Proposed Default Seat Adjustments for Use in Benchmarking Measurements

Adjustment	Setting
Seat Cushion Angle (seats without height adjustment)	Middle of range
Seat Cushion Angle (seats with height adjustment)	Angle obtained with the seat full down/full rear
Seatback Angle (Class A vehicles: passenger cars, station wagons, MPVs and light trucks)	22 degrees, as measured with the ASPECT manikin
Seatback Angle (Class B vehicles: heavy trucks and buses)	18 degrees, as measured with the ASPECT manikin
Lumbar Support Prominence	Minimum setting
Lumbar Support Height	Middle of range
Seat Bolsters	Minimum, least restrictive setting

The seat is exercised through its full range of travel, including vertical and angle adjustment. The targeted seat reference point locations are measured at the extremes of travel. Using the measured relationship between the H-point location and the seat reference points, the H-point travel path can be determined. For a two-way, linear seat track, two measurements are sufficient to define the H-point travel path. For a typical “six-way” seat adjuster, which can move horizontally, vertically, and change seat cushion angle, the H-point travel path has a rectangular appearance. Figure 7 shows a typical H-point travel path for a height-adjustable driver seat. In general, the H-point travel path should not be determined by tracking the actual manikin H-point as it moves with the seat, because the H-point measurement is defined, for packaging purposes, only with the seat at the design or default orientation. Further, during the time required to move the seat through its range of motion, the manikin position may change due to compression of the seat foam. However, it may be useful to measure the seat track movement with the manikin in the seat, because the manikin weight may produce small deflections in the seat mounting hardware.

Next, the SgRP position within the H-point travel path must be determined relative to the PRP and heel rest Z plane previously established. For a linear seat track, the SgRP location is the intersection between the previously described SgRP locator line and the H-point travel path. For a height-adjustable seat, SgRP is defined as the mid-point between the intersections of the SgRP locator line with the top and bottom of the H-point travel path, putting the SgRP at the middle of the height adjustment range. For a linear track, this calculation is performed by finding the intersection of two lines, a problem readily solved using a spreadsheet or a hand calculator. Determining SgRP location for a height-adjustable seat is more complex, but can be readily accomplished graphically, either on paper or in CAD.

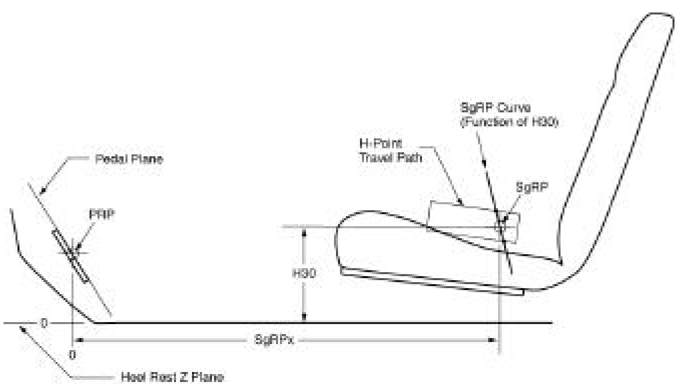

Figure 7. Illustration of H-point travel path with SgRP location.

Using the targeted seat reference points, the seat is moved into a position such that the manikin H-point is located at the SgRP. The manikin is installed as before, and the H-point location is measured to verify that it is positioned at the SgRP. For seats with discrete seat track adjusters, the positioning of the track detents may preclude accurate positioning, in which case the nearest detent should be used. Small changes in seat position to accurately locate the H-point on the SgRP are appropriate if they can be accomplished quickly without changing the manikin position relative to the seat. With the manikin positioned so that the H-point is located at the SgRP, the leg and thigh segments are added to complete the installation.

Most benchmarking measurements can be made without physically positioning the seat with the H-point at SgRP by performing the thigh and leg segment installation in CAD. On the physical seat, the H-point location is measured relative to reference points on the seat, and the H-point travel path is determined by moving the seat while tracking the reference points. Recording the locations of a few points on the accelerator pedal and floor completes the necessary data collection from the vehicle. In CAD, the PRP can be determined and the SgRP locator line positioned appropriately. Using the H-point travel path, the SgRP position is determined and the corresponding seat height is used to determine the shoe angle. The thigh and leg segments are then added, completing the virtual installation.

Passenger Seats – Passenger seat procedures are similar to those used for the driver seat. For front seats, no fore-aft shoe position is specified, so only a seat measurement is required. For other seating positions, a different shoe tool is used than the one used for the driver seat. The newly developed rear-seat shoe tool, shown in Figure 4, represents the simplified shape of two shoes placed directly adjacent. When measuring a rear seat, the seat in front of the measured location, if adjustable, is set to the SgRP (design) position. The shoe tool is then placed on the floor in front of the seating position, typically centered on the occupant centerline, and moved forward until its forward progress is stopped by the front seatback or other components. In certain seating packages, the resulting position is marked, and the front seat is moved forward to facilitate access. The manikin, including the thigh and leg segments, is installed to measure the package geometry.

ADDITIONAL SEAT MEASUREMENTS – SAE J1100 defines hundreds of dimensions, but few of these are seat dimensions. In an effort to develop a standardized terminology for seat design similar to the package dimensions that have facilitated vehicle interior design practices, an ASPECT-IAP task group developed a set of seat dimensions. These dimensions include some that are measured using the ASPECT manikin, and others that can be measured without a manikin. Figure 8 illustrates some of the proposed dimensions. Appendix D contains a complete description of the newly defined measures, which will be considered for incorporation in SAE J1100.

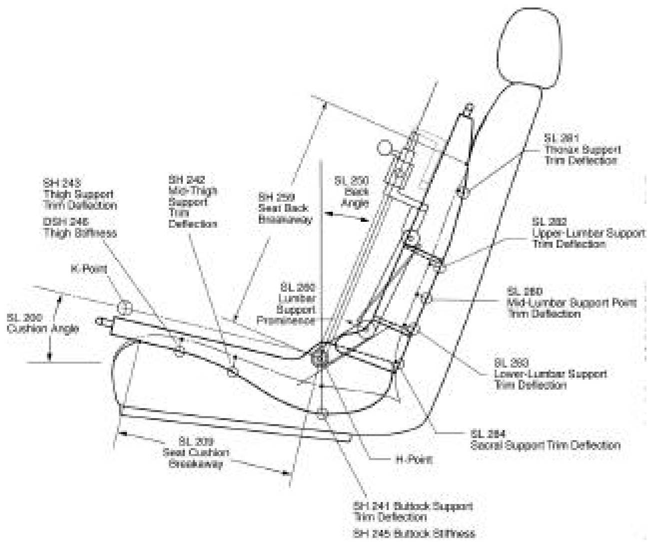

Figure 8. Some proposed seat dimensions based on ASPECT manikin geometry (see Appendix D).

The ASPECT manikin can also be used to obtain measures of seat stiffness that may be more closely related to the experience of the vehicle occupant than measures obtained using conventional techniques. The ASPECT manikin weights are designed to be installed incrementally. For example, the twelve weights in the buttock/thigh shell can be installed in three equal distributions of four weights. If the H-point and thigh reference point locations are measured at each step in the process, curves can be plotted showing the deflection of these points as a function of the fractional manikin load. The slopes of these curves provide measures of local seat cushion stiffness and can be used to compare and specify these properties of seats. Similar seat stiffness measures can be obtained on the seatback, where the change in the lumbar support prominence reading during loading is a useful measure of the stiffness of the lumbar support. These deflection measurements are currently being evaluated along with other manikin procedures.

DISCUSSION

The ASPECT manikin was developed as an improvement on the current SAE J826 H-point manikin, preserving many of the important performance features while providing improved ease of use and additional measurement capability. The ASPECT manikin is integrated into a new set of vehicle design and evaluation practices that include new pedal reference points and a standardized SgRP location (3, 5). The installation and usage procedures described in this paper represent an evolution of the current design practice incorporating the additional functionality of the new tools. The new manikin was produced in the context of a research program that substantially expanded the available information concerning the influence of vehicle, seat, and anthropometric factors on occupant posture. Drawing on these research results, the new measures obtained with the manikin can be used to represent human occupants more accurately during the design process. The use of the manikin in design is facilitated by related CAD tools, including occupant posture-prediction models and three-dimensional human body reference forms (5).

During the course of the ASPECT program, the research team examined a number of applications for which the current J826 manikin is used that go beyond its basic role in defining vehicle and seat reference points. These include modified procedures, such as the techniques used in crash dummy positioning (9), and the use of the manikin with add-on devices, such as the Head Restraint Measuring Device (10) and the Belt Fit Test Device (11). These techniques use the J826 manikin as a surrogate for human positioning information and as a platform for mounting measuring tools. Because the new ASPECT manikin performance in vehicle seats is different from that of the current manikin, the current add-on tools, such as the head-restraint and belt-fit measuring devices, cannot be used directly with the ASPECT manikin. However, the extensive vehicle occupant posture data collected during the ASPECT program can be used to develop similar tools to perform these measurements using the ASPECT manikin, with potentially greater accuracy and ease of use (4, 5, 8).

The procedures described in this paper are proposals based on currently available information. Additional evaluations of the manikin and procedures are underway at the companies participating in the ASPECT program. After modifications to the manikin and procedures are made in response to industry evaluations, the SAE Design Devices Committee will consider the manikin for incorporation into SAE J826 and new measurement definitions for SAE J1100.

ACKNOWLEDGEMENTS

The definitions and procedures described in this paper were assembled as part of the ASPECT program and the AAMA-funded accommodation model development. ASPECT participants are BMW, DaimlerChrysler, Ford, General Motors, Johnson Controls, Lear Corporation, Magna, PSA-Peugeot-Citroen, Toyota, Volkswagen of America, and Toyota. The authors would like to thank the representatives from each of these companies who participated in the program. Particular thanks go to members of two subcommittee task groups: the IAP Seat Dimensions Task Group and the IAP/SAE Pedal Reference Point Task Group. The IAP Seat Dimensions Task Group, chaired by Mari Milosic (Magna), includes Shane Goodhall and Gary Rupp (Ford), John Sadek (Magna), Kuntal Thakurta (Johnson Controls), Marilyn Vala (Lear Corporation), and Ronald Roe (UMTRI). The IAP/SAE Pedal Reference Point Task Group, chaired by Ronald Roe (UMTRI), includes Igor Gronowitz, Howard Estes, Ken Socks and John Brzustowicz (DaimlerChrysler), Gary Rupp and Manfred Heck (Ford), Dave Benedict (Toyota), and Debra Senytka (GM).

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APPENDIX A

MANIKIN INSTALLATION PROCEDURE

1. Be sure the seat has been unloaded for 30 minutes prior to installation.
2. Set the seat at the proper position and attitude for the check.
3. Place the muslin cloth in the seat. Fold the cloth into the crease between the seatback and seat cushion to prevent the cloth from stretching around the manikin when depressing the seat.
4. Place the buttock/thigh pan in the seat with the back of the pan lightly against the seatback and visually center the manikin laterally.
5. With torso articulation locked in the negative range (less than zero setting), set the torso with the H-Point pin in the H-Point saddle on the buttock/thigh pan. Slide both locking cylinders inward to lock torso to thigh/buttock pan. <u>Be sure that the outer portions of the sacral panel are outside the buttock pan</u>. Alternatively, place the manikin in the seat with the buttock/thigh pan already connected to the torso section.
6. Unlock torso articulation. Rock the manikin laterally to level according to the bubble level on the thigh/buttock pan.
7. Install two pelvis weights followed by two thigh weights and check for level. Throughout the installation process the weights are installed in pairs, one on each side of the manikin centerline, progressively forward or upward from the H-Point.
8. Push the thigh/buttock pan rearward into the seatback with a 100-N (22-lb) load. (Use the spring-loaded button on the thigh/buttock pan and push until depressed <u>twice</u>.)
9. Check again to see if the manikin is level.
10. Continue installing pairs of pelvis weights followed by pairs of thigh weights. Check for level and push the thigh/buttock pan rearward into the seatback with a 100-N (22-lb) load twice, until all 12 weights are installed.
11. Install two abdomen weights followed by two thorax weights. Apply 13-N (3-lb) load with torso button twice. Note that the abdomen and thorax weights are the same and are symmetrical.
12. Continue installing pairs of abdomen weights followed by pairs of thorax weights and application of a 13-N (3-lb) load twice, until all 12 weights are installed.
13. Lock the torso articulation.
14. Record manikin H-Point location, lumbar support prominence, seatback angle and seat cushion angle. (The pointer reference bubbles for seat cushion angle and seatback angle must be leveled prior to reading.)

APPENDIX B

PEDAL AND SHOE REFERENCE POINT DEFINITIONS

Definitions Related to the Reference Manikin Shoe

- Ball Of Foot (BOF) – A point on the sole of the shoe, mid width, 203 mm from the Heel. This definition can be the same as 3.16.2 in SAE J1100 June 98.
- Heel Of Shoe (HOS) – A point at the bottom of the shoe heel, mid width, that contacts the floor. This definition would replace 3.16.1 in SAE J1100 June 98.
- Bottom Of Shoe (BOS) – A line in side view from the Ball Of Foot to Heel.

Pedal And Floor Definitions Related to the Package, Independent Of The Reference Manikin

- Heel Rest Z Plane – The flat compressed carpet surface below and behind the accelerator pedal that supports the Heel (HOS), assumed parallel to the Z Plane. In certain cases the plane will be inclined in the fore/aft direction sloping up or down toward the driver.
- Heel Rest Z Line – A line on the compressed carpet surface under the accelerator pedal that supports the center of the heel (HOS), assumed as a flat surface parallel to the Z Plane. The plan view Heel Rest Z Line will be normal to the Y plane but in certain cases will be inclined in the fore/aft direction sloping up or down toward the driver.
- Pedal Plane – A plane normal to the Y plane tangent to the pedal surface at a point on the plane, in side view, 203 mm from the Heel Rest Z Plane.
- Pedal Reference Point (PRP) – A point on the pedal surface at mid width, defined at tangential contact with the Pedal Plane, 203 mm from the Heel Rest Z Plane.
- Initial Floor Point (IFP) – Side view location on the Heel Rest Z-Plane at the Pedal Plane intersection when the Pedal Plane is tangent to the accelerator pedal surface 203 mm from the Heel Rest Z Plane.
- Pedal Plane Angle (PPA) – Side view angle from the horizontal defined by the Pedal Plane.

Note that the preceding definitions do not require information on reference manikin shoe geometry other than 203 mm from Ball Of Foot to Bottom Of Heel

Reference Manikin Shoe Position Definitions Related to the Package

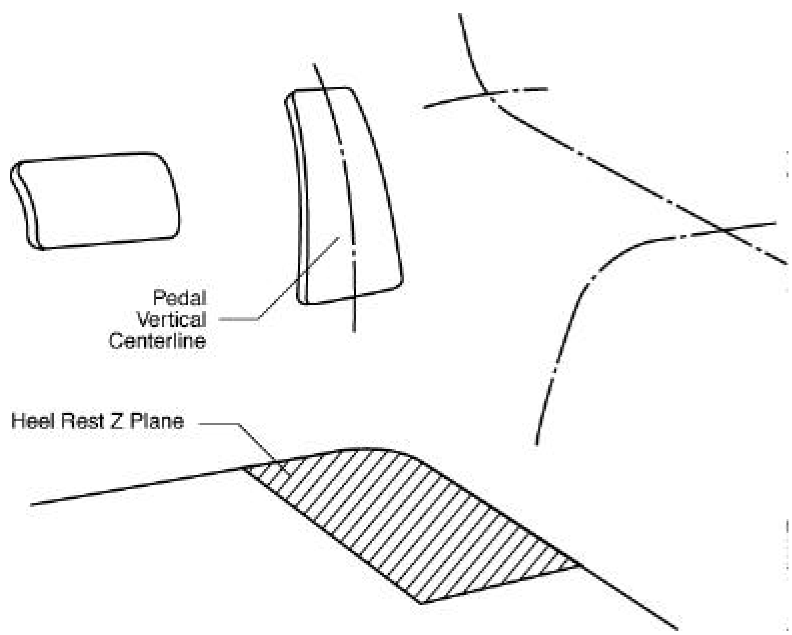
- Shoe Plane* – A plane normal to the Y plane defined by the Bottom Of Shoe (BOS) contacting the pedal and the Heel Rest Z Plane at the Floor Reference Point (FRP old AHP).
- Shoe Plane Angle (α)* – A specific side view angle from the horizontal for the Shoe Plane defined by: $\alpha = 76 - 0.08$ (H30). This equation describes the mean expected angle for users based on the mid-size male reference manikin anthropometry.
- Accelerator Heel Point (AHP) – A point on the Heel Rest Z Plane defined by the Bottom Of Shoe (BOS) contacting the pedal at angle α. If the distance between the PRP and FRP is 203 mm the IFP will be the same as the FRP.
- AHP to PRP Lateral Offset – The outboard displacement of the AHP from the PRP caused by center console or tunnel interference with the shoe.

*Since SAE J1100 uses the word foot to define Foot Angle (inside the shoe) relative to the lower leg it is appropriate to use *Shoe* for definitions relative to the shoe surface.

APPENDIX C

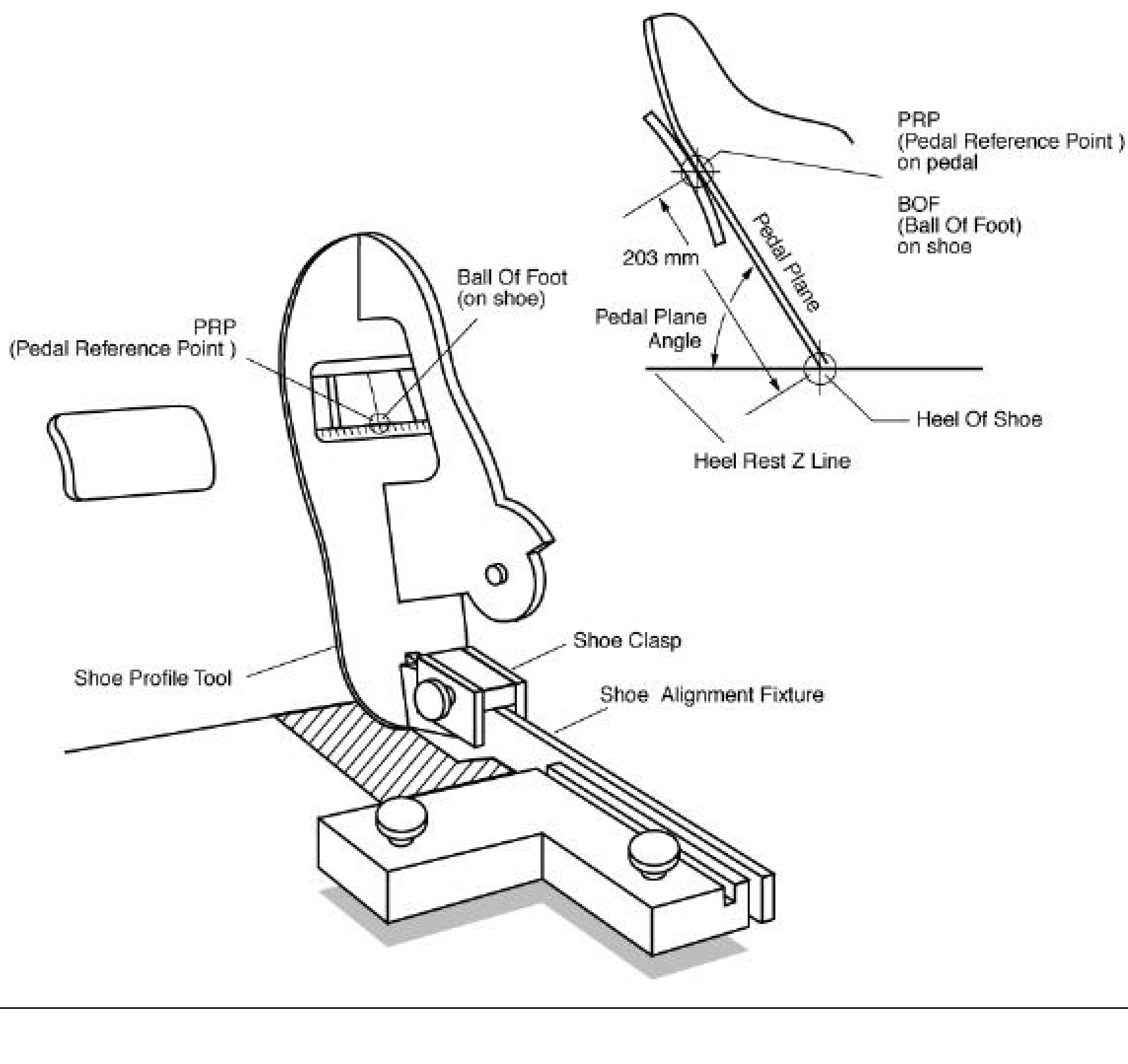
AUDITING AND BENCHMARKING USING THE ASPECT PHYSICAL MANIKIN (APM)

1. Locate Pedal Vertical Centerline and Heel Rest Z Plane	
Using Physical Tools	***Using CAD Tools***
Place masking tape on pedal face and mark a vertical centerline that bisects the width of the pedal. Determine the flat portions of the floor below the pedal centerline and establish the Heel Rest Z Plane.	Establish vertical centerline on face of pedal that bisects the width of the pedal. Determine the flat portions on the floor below the pedal centerline and establish the Heel Rest Z Plane.



2. Determine PRP (Pedal Reference Point) Location

Using Physical Tools	***Using CAD Tools***
Install the shoe profile alignment fixture. Align the fixture parallel to the Y plane (rocker trim) with the heel support runner on the Heel Rest Z Plane centered laterally under the pedal centerline at the bottom of the pedal. This is an initial lateral position for the PRP. Level the fixture with the adjustment screws. Install the shoe profile tool tangent to the pedal at the Ball Of Foot, then iterate the shoe profile and fixture laterally until the Ball of Foot is at the pedal centerline, or is limited by tunnel or center console interference (limit of the Heel Rest Z-Plane). Verify the PRP (side view 203 mm tangent point on pedal face centerline from the depressed trim at the Heel Rest Z Plane) using the shoe profile tool. Lock the shoe profile tool in place with the shoe clasp. Mark this location on the pedal surface at the pedal vertical centerline. Note that the Ball Of Foot lateral position scale may show that the foot profile tool is not centered on the pedal vertical centerline PRP location due to center console or tunnel interference.	Install the shoe profile on the layout parallel to the Y plane with the heel on the Heel Rest Z Plane and the Ball Of Foot on the shoe tangent tot he pedal surface. Shift the profile inboard until the Ball Of Foot is at the pedal centerline or is limited by tunnel or center console interference (limit of the Heel Rest Z-Plane). Verify the PRP (side view 203 mm tangent point on pedal face centerline from the depressed trim at the Heel Rest Z Plane) using the shoe profile. Note that the Ball Of Foot lateral position scale may show that the foot profile tool is not centered on the pedal vertical centerline PRP location due to center console or tunnel interference. If this is an audit and pedal build deviation is not a consideration, the design PRP, Heel Rest Z Plane and Pedal Plane may be used.



<table>
<tr><th colspan="2">3. Determine Heel Rest Z Line and AHP to PRP Lateral Offset</th></tr>
<tr><th>Using Physical Tools</th><th>Using CAD Tools</th></tr>
<tr><td>The Heel Rest Z Line defines the lateral location of the foot profile tool and is never inboard of the PRP. Typically, the Heel Rest Z Line is laterally at the same Y coordinate as the PRP. If the floor is contoured outboard of the PRP due to a center console or tunnel, a longitudinal <u>Heel Rest Z Line</u> must be defined at this more outboard location at the transition point from a flat surface. If the shoe was installed properly in the previous step, the lateral scale at the Ball Of Foot will indicate the offset and define the PRP to AHP (Heel Rest Z-Line) Lateral Offset.</td><td>The Heel Rest Z Line defines the lateral location of the foot profile and is never inboard of the PRP. Typically, the Heel Rest Z Line is laterally at the same Y coordinate as the PRP. If the floor is contoured outboard of the PRP due to a center console or tunnel, a longitudinal <u>Heel Rest Z Line</u> must be defined at this more outboard location at the transition point from a flat surface. Establish and center the shoe profile on this line.</td></tr>
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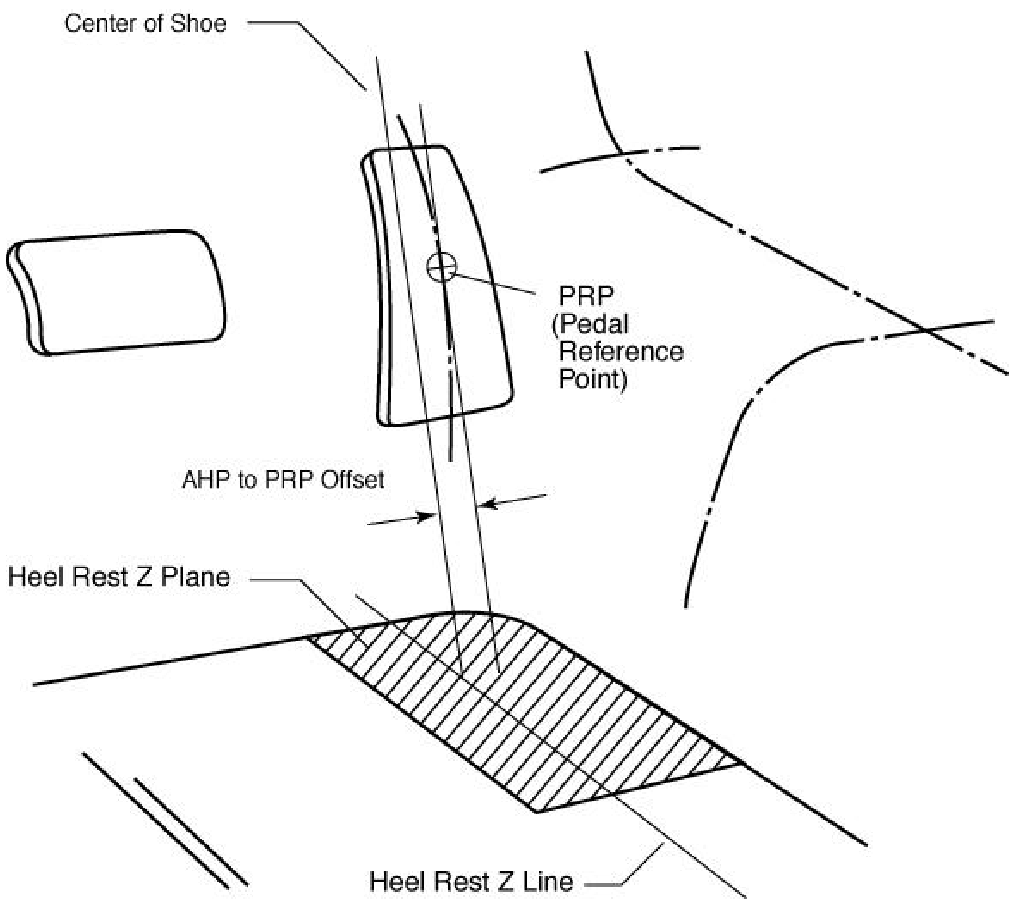
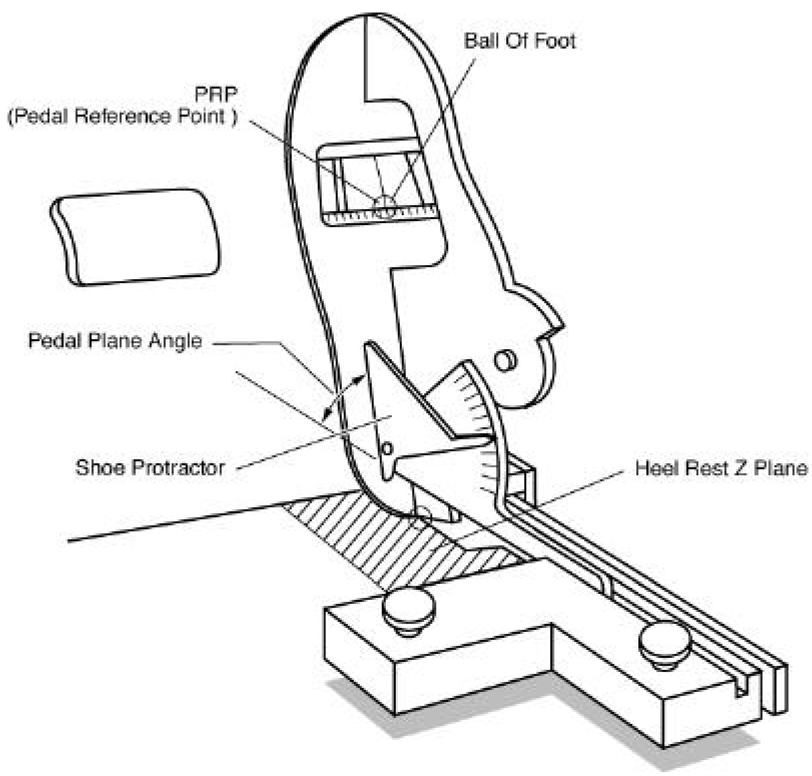


4. Determine Pedal Plane Angle	
Using Physical Tools	***Using CAD Tools***
Slide the shoe angle protractor against the shoe and read the angle. At this shoe profile tool position the angle indicates the Pedal Plane Angle.	At this shoe profile position, the side view angle of the Bottom Of Shoe from the horizontal defines the Pedal Plane Angle.



5. Place All Seat Adjustments at Design or Default Positions

This step must consider the differences between auditing and benchmarking. Auditing will use design settings where as benchmarking will require standard settings established for comparative purposes. Table C1 lists default settings for use in benchmarking.

Table C1. Default Seat Adjustments for Use in Benchmarking Measurements

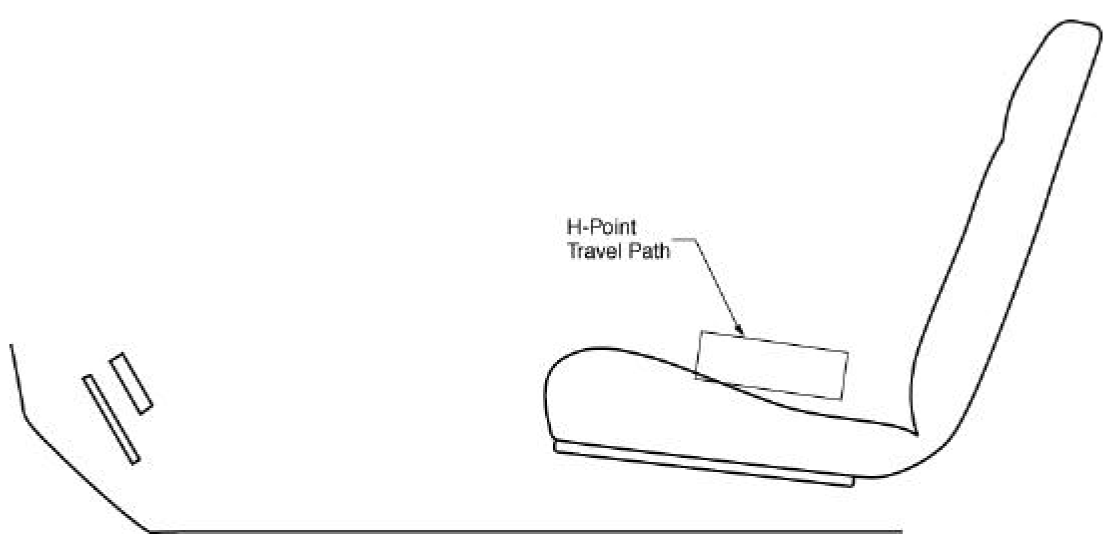
Adjustment	Setting
Seat Cushion Angle (seats without height adjustment)	Middle of range
Seat Cushion Angle (seats with height adjustment)	Angle obtained with the seat full down/rear
Seatback Angle (Class A vehicles: passenger cars, station wagons, MPVs and light trucks)	22 degrees, as measured with the ASPECT manikin
Seatback Angle (Class B vehicles: heavy trucks and buses)	18 degrees, as measured with the ASPECT manikin
Lumbar Support Prominence	Minimum setting
Lumbar Support Height	Middle of range
Seat Bolsters	Minimum, least restrictive setting

6. Load the APM in the Seat and Record Data

Record H-Point coordinates, Cushion Angle, Back Angle, Lumbar Support Prominence and other seat measures as needed. The ASPECT Physical Manikin loading procedure is described in Appendix A.

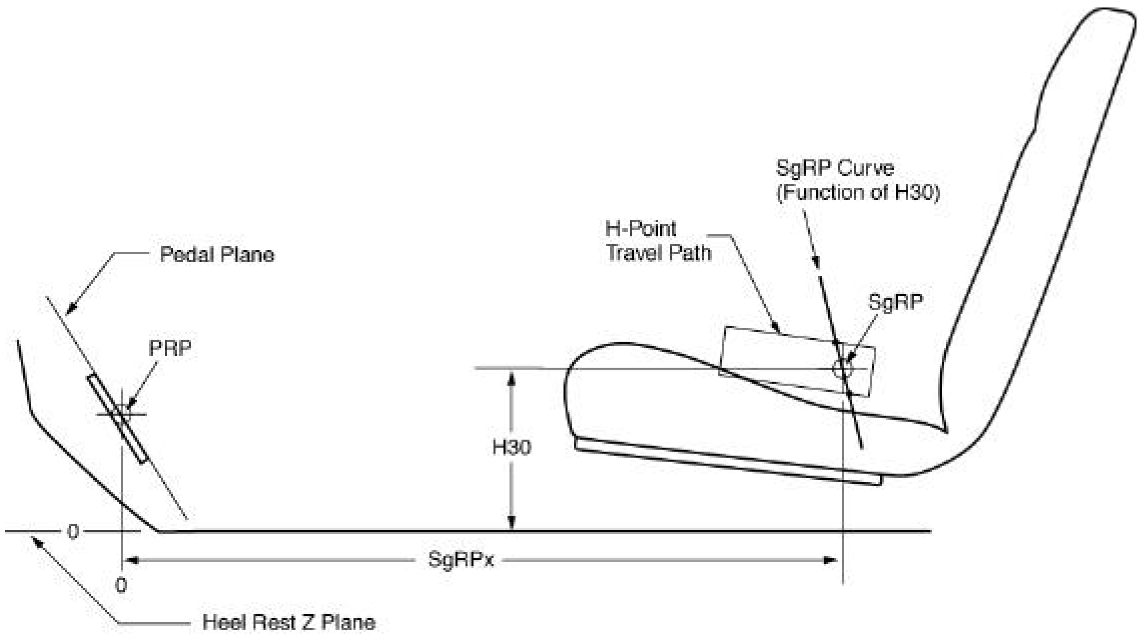
7. Determine the H-Point Travel Path

Using Physical Tools	*Using CAD Tools*
Determine the H-Point travel path from points on the seat as the seat is adjusted through the extremes of the travel path. While these data can be obtained from the vehicle seat, the information must usually be translated to a drawing or CAD system to determine SgRP location.	Plot the H-Point travel path according to the extremes of the travel path. If this is an audit and seat adjuster build deviation is not a consideration, the design travel path may be used.



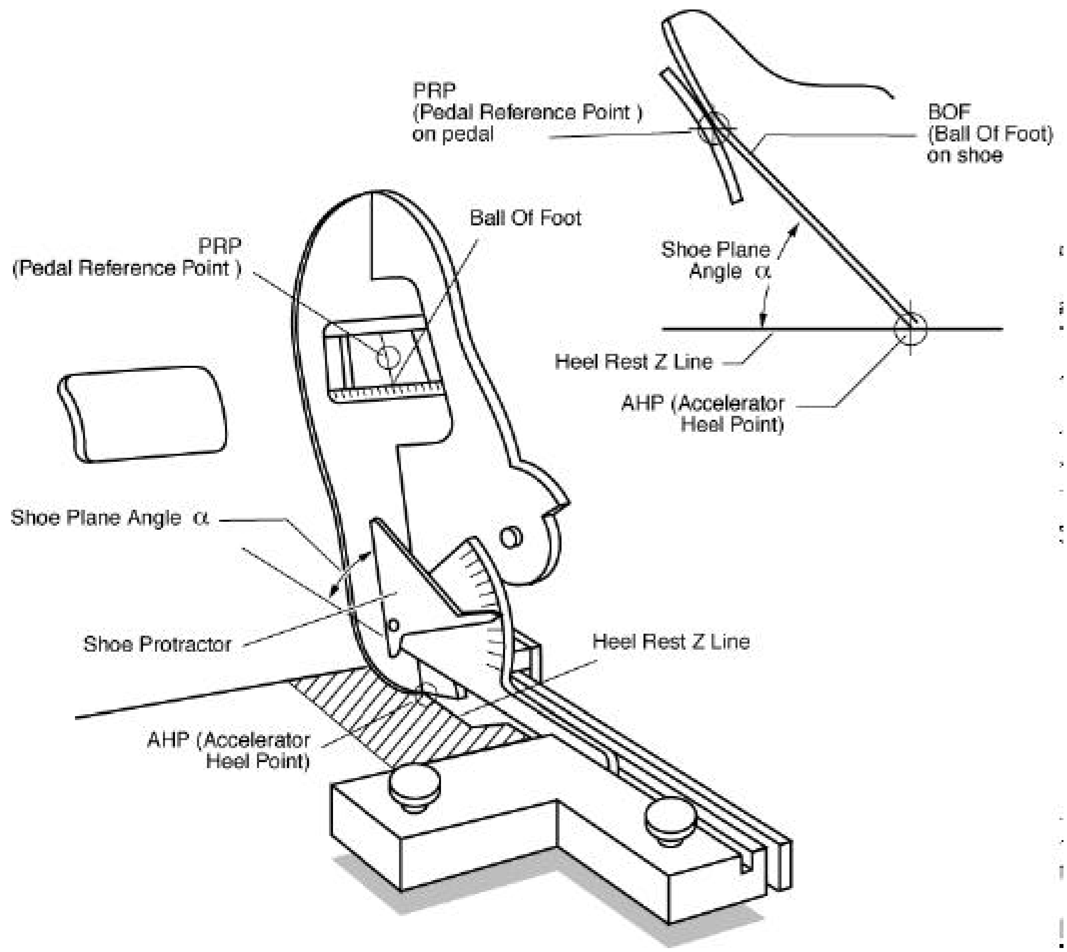
8. Determine SgRP location and obtain Seat Height (H30)	
Using Physical Tools	***Using CAD Tools***
(Use procedures for CAD tools.)	Calculate or determine SgRP location at the intersection of the H-Point travel path and the SgRP line. If the H-Point travel path includes vertical travel, define the SgRP at the midpoint between the upper and lower intersections between the travel path and the SgRP locator line. The SgRP line is a function of Seat Height H30 and is referenced to the Pedal Reference Point for x and Heel Rest Z Plane for z. Position the seat at the SgRP and determine H30. This step is typically done on a drawing board or in CAD.

SgRPx = 1038.2 – 0.3945 (H30)



9. Calculate Shoe Plane Angle α and Determine the APM Shoe Position

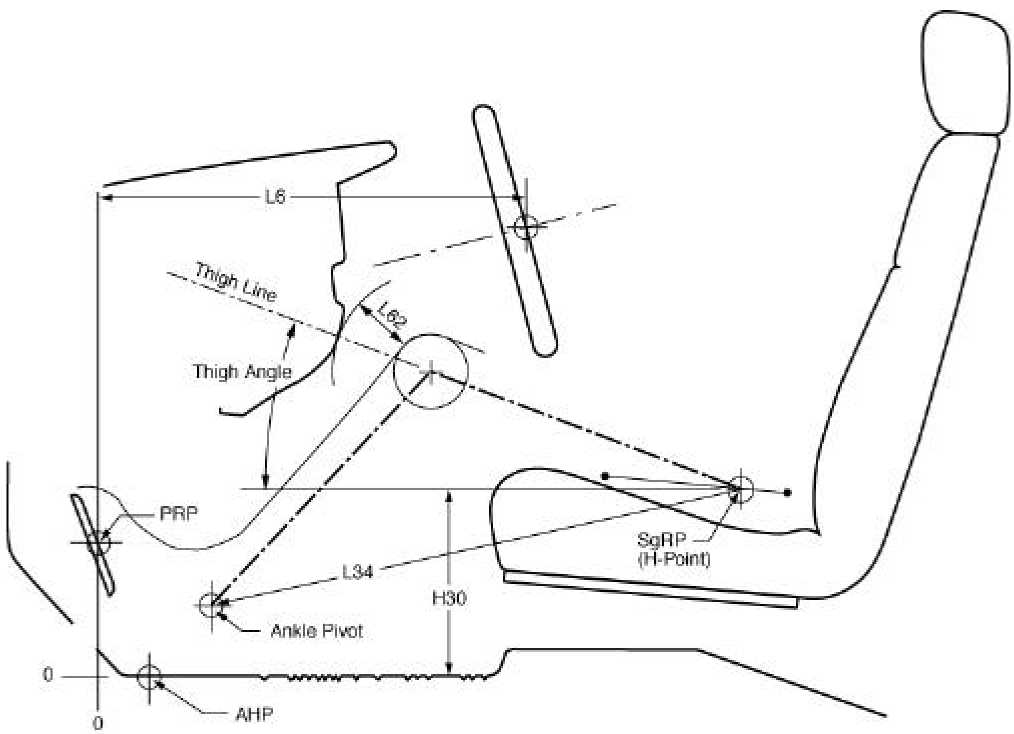
Using Physical Tools	***Using CAD Tools***
Calculate Shoe Plane Angle (α) using H30. Reposition the shoe profile tool (usually the heel moves rearward for vehicles designed using the J1516 pedal plane angle) to obtain the angle α on the shoe protractor. Maintain pedal contact with the Bottom Of Shoe and floor contact with the Heel Of Shoe, then tighten the shoe clasping knob. The Ball Of Foot on the shoe may not be at the PRP and may not contact the pedal.* Heel Of Shoe location at this position on the floor defines the AHP. The Heel Of Shoe will be on the Heel Rest Z Line.	Calculate Shoe Plane Angle (α) using H30. Position the shoe profile with the Bottom Of Shoe at angle α, such that the Bottom Of Shoe and Heel Of Shoe contact the pedal and floor, respectively. The Ball Of Foot on the shoe may not be at the PRP and may not contact the pedal.* Heel Of Shoe location at this position on the floor defines the P. Floor contact will be on the Heel Rest Z Line.



α = 76 - 0.08(H30) where H30 is in mm and α is in degrees

*If the accelerator pedal is initially designed using α as the Pedal Plane Angle and there are no build deviations, the Ball Of Foot will be at the PRP and the Pedal Plane will coincide with the Shoe Plane.

10. Determine Foot Angle, Angle, Hip Angle and Any Additional Package Measures	
Using Physical Tools	***Using CAD Tools***
Install the supplemental leg and thigh at the ankle pivot on the shoe profile tool and at the H-Point (SgRP). Read the indicators and obtain the desired measurements.*	Locate the supplemental leg and thigh profiles at the ankle pivot and SgRP. Obtain the appropriate measurements.



NOTE: Only a sample of existing and/or potential measures are shown.

* Certain package measures will require CAD or a physical drawing of the information collected, along with the vehicle interior configuration.

APPENDIX D

SEAT DIMENSIONS AND REFERENCE POINTS

This appendix was developed from the technical report of the ASPECT IAP Seat Dimensions Task Group Report. This task group was formed to develop seat dimensions for potential inclusions in SAE J1100. Objectives of the group were to proposed seat geometry reference points and measurement definitions that would:

1. Facilitate geometric evaluation of seats using the ASPECT Physical Manikin (APM), and
2. Provide the basis for future revisions to SAE J1100 (Motor Vehicle Dimensions).

To meet these objectives two types of seat geometry reference points and measurements were developed:

- ASPECT Physical Manikin *dependent*, that utilize the seat characterization capabilities of the APM to quantify seat measurements.
- ASPECT Physical Manikin *independent*, that provide simple field measures obtained without the use of the APM. These measures are described at locations on the seat that approximate the location of similarly defined APM measures.

These measurement proposals were initially presented at the June 1998 IAP meeting and have been updated to agree with ASPECT Physical Manikin development as of December 11, 1998. Additional updates will be required as the APM is validated and finalized. Comments and alternative proposals will be welcomed.

SEAT GEOMETRY REFERENCE POINTS – APM Reference Points are shown in Figure 1 and are described below.

T/A Pivot (Thorax/Abdomen Joint) – A pivot representing the flexible connection between the thorax and upper lumbar spine.

A/P Pivot (Abdomen/Pelvis Joint) – A pivot representing the flexible connection between the lower lumbar spine and the pelvis.

H-Point – A point on the APM that corresponds to the H-Point obtained with the J826 manikin and is the pivot at the intersection of the APM thigh line and pelvis line.

K Point – A point at the forward end of the Thigh Line on the seat pan 356 mm forward of the H-Point.

Torso Line – A line on the APM, in side view, that connects the H-Point to a sliding point on the thorax. The angle of this line defines the Back Angle of the seat. At Neutral Posture this angle corresponds to the old SAE J826 manikin Torso Line.

Neutral Posture – See Lumbar Support Prominence (SL260)- APM torso articulation that produces a back profile (sacrum, abdomen and thorax) that is a straight line. This profile corresponds to the SAE J826 back profile.

Thigh Line – A line on the APM seat pan in side view between the H-Point and K Point.

Pelvis Line – A 100 mm line on the APM back pan between the A/P Pivot and the H-Point.

Abdomen Line – A 182 mm line on the APM back pan between the T/A Joint and the A/P Joint.

Thorax Support Points – Points on the APM back contact surface 87 mm either side of C/LO, 365 mm above the H-Point, normal to the Torso Line when the Lumbar Support Prominence is zero.

Upper-Lumbar Support Point – A point on the APM back contact surface at C/LO projected from a point along the Torso Line 238 mm above the H-Point, normal to the Torso Line when the Lumbar Support Prominence is zero.

Mid-Lumbar Support Point – A point on the APM back contact surface at C/LO projected from a point along the Torso Line 172 mm above the H-Point, normal to the Torso Line when the Lumbar Support Prominence is zero.

Lower-Lumbar Support Point – A point on the APM back contact surface at C/LO projected from a point along the Torso Line 106 mm above the H-Point, normal to the Torso Line when the Lumbar Support Prominence is zero.

Sacrum Support Point – A point on the APM lower back contact surface at C/LO, 40 mm above the H-Point, normal to the Torso Line when the Lumbar Support Prominence is zero.

Thigh Support Points – Points on the APM cushion contact surface 112 mm either side of the C/LO projected from points 250 mm along the Thigh Line forward of the H-Point, normal to the Thigh Line.

Mid-Thigh Support Points – Points on the APM cushion contact surface 87 mm either side of the C/LO projected from points 150 mm along the Thigh Line forward of the H-Point, normal to the Thigh Line.

Buttock Support Point (D-Point) – A point on the APM cushion contact surface at C/LO under the H-Point, 75° clockwise from the Thigh Line.

Stiffness – Percent load per trim deflections at given support points. Since stiffness may not be linear this may be best expressed as a plot of percent load versus trim deflection.

Breakaway – Locations where the deflected trim separates from the manikin surface.

Mean Head Profile – Reference manikin mean male head with hair, referenced to the Back Angle.

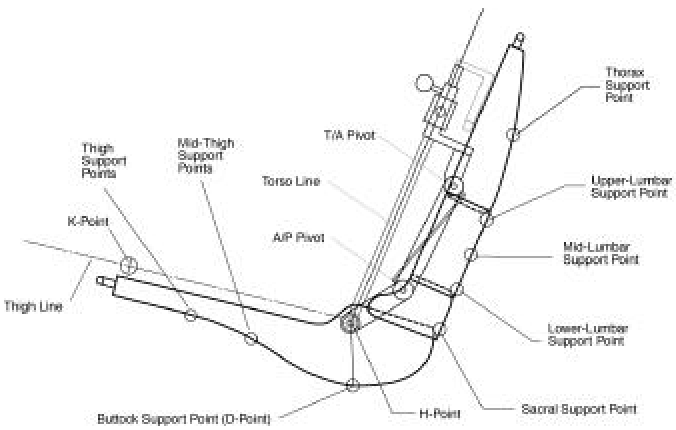


Figure 1. ASPECT Physical Manikin seat geometry reference points and definitions.

SEAT GEOMETRY REFERENCE POINTS INDEPENDENT OF THE ASPECT PHYSICAL MANIKIN – These dimensions, shown in Figure 2, are reference points intended to facilitate seat measurements when ASPECT physical manikin data are not available.

Cushion Point (Bite Line) – A point on the undeflected seat cushion trim at C/LO, at the intersection of a 65° line (clockwise from horizontal-25°) tangent to the undeflected seat back trim. If the 65° line extends beyond the rear of the seat cushion, define the Cushion Point on a line that extends rearward of the cushion, planar to the undeflected cushion surface rearward of the H-Point. If there is bridging trim between the back and cushion, first establish two points; the 65° line intersection for an upper point and the bridging trim intersection at the cushion for a lower point. Then establish a single point vertically below the upper point and horizontally rearward of the lower point. If the seat back is adjustable, it is placed in design position.

Undeflected Back Line – A line established from a vertical tangent to the lower undeflected seat back contour to a point on the undeflected seat back surface 350 mm above the Cushion Point at CL/O. The definition of these points ignores local depressions and/or seam lines. The angle of this line attempts to approximate the angle of the Torso Line as measured with the manikin..

Undeflected Cushion Line – A Line established from the Cushion Point forward to a point tangent to the top of the seat cushion at CL/O. The angle of this line attempts to approximate the angle of the Thigh Line as measured with the manikin.

Lumbar Contour Point – A point on the undeflected seat back contour at C/LO determined by the tangent point of a line parallel to the Back Line. The definition of this point ignores local depressions and/or seam lines.

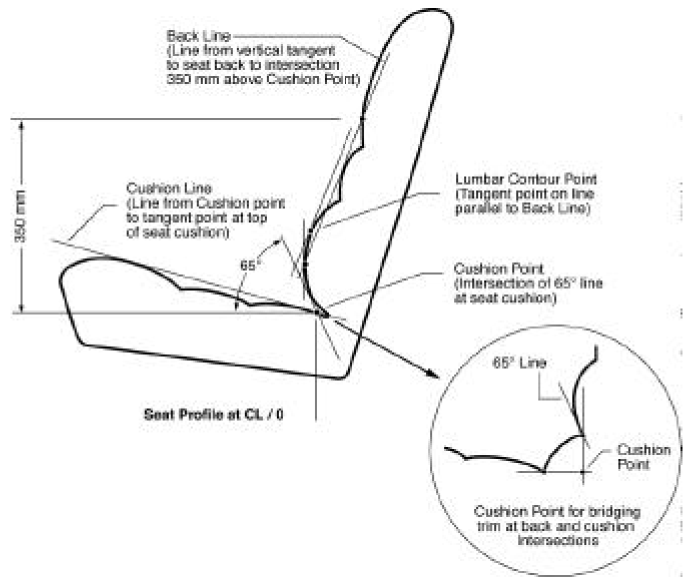


Figure 2. Seat geometry reference points and definitions independent of the ASPECT Physical Manikin

SEAT DIMENSION DEFINITIONS – Typically SAE J1100 measurements are grouped according to L, W and H. dimensions. Here, it is desirable to order the definitions, starting with simple field measures (related to x, y and z axes, 100 series dimensions) to more complex ASPECT manikin related measures (related to manikin, 200 series dimensions). Additional groupings are provided according to seat cushion (100 to 149 and 200 to 249) and seat back (150 to 199 and 250 to 299). The field measures are taken along vehicle x, y and z reference lines, whereas the ASPECT manikin measures are taken relative to the H-Point, Thigh Line and Torso Line. The ASPECT manikin related measures are preferred for seat assessment.

These measures will apply to any designated seating position; driver, passenger, front or rear. It will be necessary to provide a code to identify both seat dimensions and seat location. This is proposed with an S (for seat) prefix for L, W and H measurements followed by the seated location immediately after the dimension code numerals. For example, SxxxD for Driver Seating, SxxxFO for Passenger Seating First row Outboard side, SxxxSC Passenger Seating Second row Center and SxxxTO for Passenger Seating Third row Outboard side. The proposed dimension definitions that follow are for the driver.

Corresponding definitions for other seated positions are the same but would be identified with proper codes for location in the vehicle.

SEAT BOLSTERS AND INSERTS – New measures are provided that describe seat cushion and back contour in terms of bolster configuration. See the description that follows and Figure 3.

Bolster – Raised contour at outer edges of the seat cushion and seat back.

Insert – Essentially flat trim separating bolsters on the seat cushion and seat back, Usually defined with a seam or trimmed line.

MEASUREMENT CONSIDERATIONS – Note that obtaining many of these new measures will require point-taking and CAD application. Unloaded trim profiles are defined at reference locations determined with the manikin. It will also be necessary to account for manikin loaded seat frame deflection (primarily seat back) for accurate determination of trim deflection measurements.

SEAT FIDUCIAL POINTS – A minimum of three points are required for each designated seat position in a seat. It is desirable that a pair of points have common x and z coordinates. It would be ideal if the paired points were symmetrical about the centerline of seat. If the seat cushion and seatback have disengaging adjustment paths it may be desirable to have additional points such that each element has three points. These point must be easily located and generally visible with a minimum of trim removal.

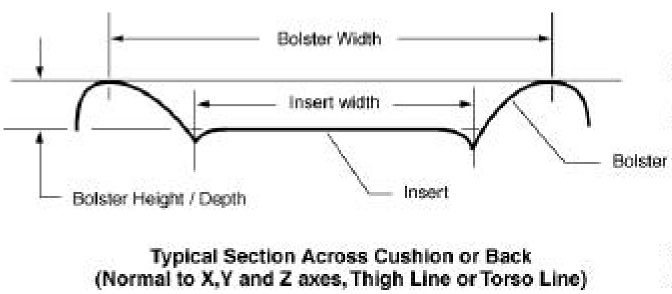


Figure 3. Seat bolster and insert geometry.

SEAT CUSHION MEASUREMENTS DEFINED INDEPENDENT OF THE ASPECT PHYSICAL MANIKIN (RELATIVE TO VEHICLE X, Y AND Z AXES)

Seat Cushion Length (SL 101D) – Horizontal distance from the Cushion Point to a vertical line tangent to the front of the cushion trimmed surface at C/LO.

Seat Cushion Length To Seat Back (SL 102D) – Horizontal distance from a vertical tangent to the front of the seat back to a vertical tangent to the front of the cushion trimmed surface at C/LO.

Undeflected Cushion Line Angle (SL 103D) – Angle of the Undeflected Cushion Line from the horizontal.

Maximum Seat Cushion Width (SW 103D) – Width across the seat cushion soft trim surface at the widest point.

Rearward-Seat Cushion Width (SW 104D)Width across the seat cushion soft trim surface 130 mm horizontally forward of the Cushion Point.

Mid-Seat Cushion Width (SW 105D)The width across the seat cushion soft trim surface 280 mm horizontally forward of the Cushion Point.

Forward-Seat Cushion Width (SW 106D) – Width across the seat cushion soft trim surface 380 mm horizontally forward of the Cushion Point.

Maximum Overall Seat Cushion Width (SW 107D) – The width across the seat cushion below the Cushion Point including all trim covers and adjustment hardware.

Rearward-Seat Cushion Bolster Height (SH 121D) – Height of the bolster above the insert 130 mm horizontally forward of the Cushion Point. If there is no defined insert, default to an insert 280 mm wide.

Mid-Seat Cushion Bolster Height (SH 122D) – Height of the bolster above the insert 280 mm horizontally forward of the Cushion Point. If there is no defined insert, default to an insert 280 mm wide.

Forward-Seat Cushion Bolster Height (SH 123D) – Height of the bolster above the insert 380 mm horizontally forward of the Cushion Point. If there is no defined insert, default to an insert 280 mm wide.

Maximum Seat Cushion Bolster Height (SH 120D) – Maximum height of the bolster above the insert along the seat cushion between the bite line and front of the cushion. If there is no defined insert, default to an insert 280 mm wide. Indicate amount horizontally forward of Cushion Point.

Rearward-Seat Cushion Bolster Width (SW 121D) – Width of the bolsters between highest Points 130 mm horizontally forward of the Cushion Point.

Mid-Seat Cushion Bolster Width (SW 122D) – Width of the bolsters between highest points 280 mm horizontally forward of the Cushion Point.

Forward-Seat Cushion Bolster Width (SW 123D) – Width of the bolsters between highest Points 380 mm horizontally forward of the Cushion Point.

Rearward-Seat Cushion Insert Width (SW 131D) – Width of the insert between the bolsters 130 mm horizontally forward of the Cushion Point.

Mid-Seat Cushion Insert Width (SW 132D) – Width of the insert between the bolsters 280 mm horizontally forward of the Cushion Point.

Forward-Seat Cushion Insert Width (SW 133D) – Width of the insert between the bolsters 380 mm horizontally forward of the Cushion Point.

Maximum Seat Cushion Insert Width (SW 130D) – Maximum width of the insert between the bolsters along the seat cushion forward of the Cushion Point. Indicate the amount horizontally forward of Cushion Point. In certain cases insert width is not definable.

SEAT CUSHION DIMENSIONS MEASURED RELATIVE TO ASPECT PHYSICAL MANIKIN GEOMETRY – These measurements are made relative to lines and reference points defined using the ASPECT Physical Manikin. Figure 4 depicts these dimensions.

Cushion Angle (SL 227D) – Angle of the Thigh Line from the horizontal with the APM loaded in the seat with the seat at design attitude.

Seat Cushion Length To H-Point (SL 201D) – Distance from the H-Point parallel to the Thigh Line to a line normal (90°) to the Thigh Line tangent to the front of the cushion at C/LO.

Seat Cushion Width At H-Point (SW 204D) – Width across the seat cushion soft trim surface at the H-Point on a plane normal (90°) to the Thigh Line (Cushion Angle).

Seat Cushion Width At Mid-Thigh Support Point (SW 205D) – Width across the seat cushion soft trim surface 150 mm forward of the H-Point along the Thigh Line (Cushion Angle) on a plane normal (90°) to the Thigh Line.

Seat Cushion Width At Thigh Support Point (SW 206D) – Width across the seat cushion soft trim surface 250 mm forward of the H-Point along the Thigh Line (Cushion Angle) on a plane normal (90°) to the Thigh Line.

Seat Cushion Breakaway To H-Point (SL 209D) – Distance from the H-Point to the breakaway point on the APM thigh pan measured parallel to the Thigh Line (Cushion Angle). This measure is taken at the mean of two points on the underside of the thigh pan 112 mm each side of C/LO. If the seat cushion is adjustable, it is placed in design position.

Seat Cushion Bolster Height At H-Point (SH 221D) – Height of the bolsters above the insert along the seat cushion at the H-Point, normal (90°) to the Thigh Line (Cushion Angle). If there is no defined insert, default to an insert 280 mm wide.

Seat Cushion Bolster Height At Mid-Thigh Support Point (SH 222D) – Height of the bolsters above the insert along the seat cushion 150 mm forward of the H-Point, normal (90°) to the Thigh Line (Cushion Angle). If there is no defined insert, default to an insert 280 mm wide.

Seat Cushion Bolster Height At Thigh Support Point (SH 223D) – Height of the bolsters above the insert along the seat cushion 250 mm forward of the H-Point normal (90°) to the Thigh Line (Cushion Angle). If there is no defined insert, default to an insert 280 mm wide.

Seat Cushion Bolster Width At H-Point (SW 221D) – Width between the highest points on the bolsters at the H-Point.

Seat Cushion Bolster Width At Mid-Thigh Support Point (SW 222D) – Width between the highest points on the bolsters 150 mm forward of the H-Point, normal (90°) to the Thigh Line (Cushion Angle).

Seat Cushion Bolster Width At Thigh Support Point (SW 223D) – Width between the highest points on the bolsters 250 mm forward of the H-Point, normal (90°) to the Thigh Line (Cushion Angle).

Seat Cushion Insert Width At H-Point (SW 231D) – Width of the insert between the bolsters along the seat cushion at the H-Point. In certain cases this measure is not definable.

Seat Cushion Insert Width At Mid-Thigh Support Point (SW 232D) – Width of the insert between the bolsters 150 mm forward of the H-Point, normal (90°) to the Thigh Line (Cushion Angle). In certain cases this measure is not definable

Seat Cushion Insert Width At Thigh Support Point (SW 233D) – Width of the insert between the bolsters 250 mm forward of the H-Point, normal (90°) to the Thigh Line (Cushion Angle). In certain cases this measure is not definable

Buttock Support Trim deflection (SH 241D) – Distance from the Buttock Support Points to the undeflected seat cushion surface measured normal (90°) to the Thigh Line (Cushion Angle).

Mid-Thigh Support Trim Deflection (SH 242D) – Distance from the Mid-Thigh Support Points to the undeflected seat cushion surface measured normal (90°) to the Thigh Line (Cushion Angle).

Thigh Support Trim Deflection (SH 243D) – Distance from the Thigh Support Points to the undeflected seat cushion surface measured normal (90°) to the Thigh Line (Cushion Angle).

Buttock Stiffness (SH 245D) – Predetermined loads divided by the displacement of the Buttock Support Point. Since stiffness may not be linear, this measure has several reported values and may be best expressed in graph form.

Thigh Stiffness (SH 246D) – Predetermined loads divided by the displacement of the Thigh Support Points. Since stiffness may not be linear, this measure has several reported values and may be best expressed in graph form.

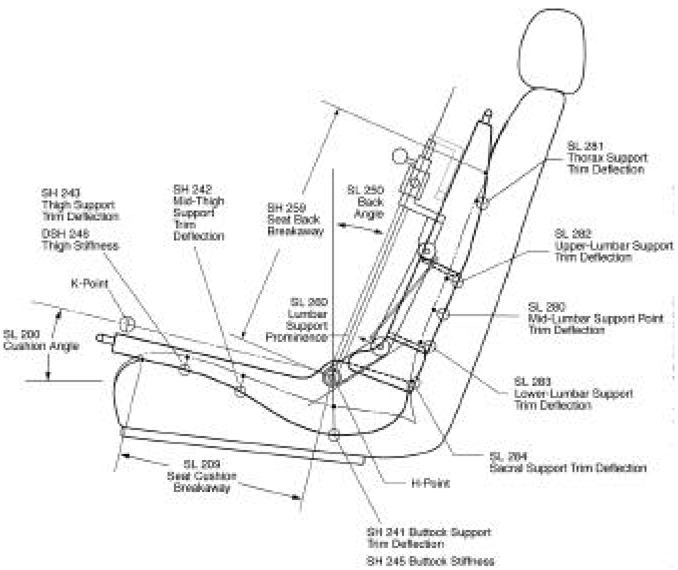


Figure 4. Seat geometry measurements made with respect to ASPECT Physical Manikin geometry.

SEAT BACK MEASUREMENTS DEFINED INDEPENDENT OF THE ASPECT PHYSICAL MANIKIN (RELATIVE TO VEHICLE X, Y AND Z AXES)

Seat Back Height Without Head Restraint (SH 151D) – Vertical distance from the Cushion Point to a horizontal line tangent to the top of the seat back trimmed surface at C/LO. If the seat back is adjustable, it is placed in design position.

Seat Back Height With Head Restraint (SH 152D) – Vertical distance from the Cushion Point to a horizontal line tangent to the top of the head restraint trimmed surface at C/LO. If the seat back is adjustable, it is placed in design position. If the headrest is adjustable, it is placed in the full down position. Note that if the seat has an integral headrest, the previously defined measure “Seat back Height Without Head Restraint” is not taken.

Lumbar Contour Height (SH 153D) – Vertical distance from the Cushion Point to the Lumbar Contour Point at C/LO. If the seat back is adjustable, it is placed in design position.

Seat Back Width (SW 155D) – The width across the soft trim surface at the widest point.

Maximum Seat Back Width (SW 150D) – Width across the back including all trim covers and adjustment hardware.

Lower Seat Back Width Cushion Point (SW 154D) – Width of the soft trim 70 mm above the Cushion Point.

Mid-Seat Back Width (SW 152D) – Width of the soft trim 200 mm above the Cushion Point.

Upper Seat Back Width (SW 151D) – Width of the soft trim 330 mm above the Cushion Point.

Lower Seat Back Bolster Depth (SL 161D) – Offset of the bolsters horizontally forward of the insert 70 mm above the Cushion Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Mid-Seat Back Bolster Depth (SL 162D) – Offset of the bolsters horizontally forward of the insert 200 mm above the Cushion Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Upper Seat Back Bolster Depth (SL 163D) – Offset of the bolsters horizontally forward of the insert 330 mm above the Cushion Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Maximum Seat Back Bolster Depth (SL 160D) – Maximum depth of the bolster forward of the insert above the above the Cushion Point-Line. If there is no defined insert, default to an insert 280 mm wide. Indicate amount above or below the Lumbar Contour Point. If the seat back is adjustable, it is placed in design position.

Undeflected Back Line Angle (SL164D) – Angle of the undeflected Back Line from the vertical.

Lower Seat Back Bolster Width (SW 163D) – Width of the bolsters between most forward points 70 mm above the Cushion Point.

Mid-Seat Back Bolster Width (SW 162D) – Width of the bolsters between most forward Points 200 mm above the Cushion Point.

Upper Seat Back Bolster Width (SW 161D) – Width of the bolsters between most forward Points 330 mm above the Cushion Point.

Lower Seat Back Insert Width (SW 173D) – Width of the insert between the bolsters 70 mm above the Cushion Point. In certain cases this measure is not definable.

Mid-Seat Back Insert Width (SW 172D) – Width of the insert between the bolsters 200 mm above the Cushion Point. In certain cases this measure is not definable.

Upper Seat Back Insert Width (SW 171D) – Width of the insert between the bolsters 330 mm above the Cushion Point. In certain cases this measure is not definable.

SEAT BACK DIMENSIONS MEASURED RELATIVE TO THE ASPECT PHYSICAL MANIKIN – Seat back dimensions are illustrated in Figure 4.

Unloaded Back Angle Differential (SL 251D) – Effective back angle change between no load and APM load relative to design Back Angle. Use fiducial points on seat back to measure loaded and unloaded angle change.

Back Angle (SL 250D) – Angle of the Torso Line from the vertical with the reference manikin loaded in the seat with the seat at design attitude as specified by the manufacturer. *The ASPECT procedures may require a specified back angle for consistent measurement of seat characteristics. A specified Back Angle would only be applicable for adjustable seat backs unless the specified angle was used as the fixed back design angle. An additional definition would be required for fixed seat backs (SL 241?). Specified Back Angle (SL 240) could read, Angle of the Torso line from the vertical with the reference manikin loaded in the seat with the seat at design attitude is as follows:*

Class A vehicles------------22°

Class B vehicles-----------18°

Values for these specified angles would be finalized based on observed usage in the corresponding vehicle types with nominal package geometry. Note that this definition of Back Angle added in parenthesis is not part of the IAP Seat Dimensions Task Group study but part of ASPECT application considerations that are under study at UMTRI.

Lumbar Support Prominence (SL 260) – Displacement of the side view centerline profile of the APM lumbar seat contact surface relative to the position at neutral posture with the reference manikin loaded in the seat at design settings. Zero prominence is defined when the back profile of the manikin is a straight line (old SAE J826 contour). Values greater than 0 indicate a concave profile. If there is adjustable lumbar support, maximum and minimum Lumbar Support Prominence values may be obtained by repeating a manikin drop at each of the extreme settings. Generally Lumbar Support Prominence (and H-Point location) will be determined at the minimum setting.

Seat Back Height From H-Point Without Head Restraint (SH 251D) Distance from the H-Point along the Torso Line (Seat Back Angle) to the intersection at a line normal to the Torso Line, tangent to the top of the seat back at CL/O. Head restraint is excluded. If the seat back is adjustable, it is placed in design position.

Seat Back Height From H-Point With Head Restraint (SH 252D) – Distance from the H-Point along the Torso Line to the intersection at a line normal (90°) to the Torso Line, tangent to the top of the headrest at C/LO. If the seat back is adjustable, it is placed in design position. If the head restraint is adjustable it is placed in the full down position. If the seat has an integral head restraint, the previously measure “Seat back Height To H-Point without Head Restraint” is not taken. This dimension is similar to ECE Head Restraint Height.

Seat Back Breakaway To H-Point (SH 259D) – Distance from the H-Point to the breakaway points on the manikin back measured parallel to the Torso Line. This measure is taken at the mean of two points on the back of the back pan 87 mm each side of C/LO. If the seat back is adjustable, it is placed in design position.

Seat Back Width At Thorax Support Point (SW 251D) – Width across the soft trim surface in a plane normal (90°) to the Torso Line at the Thorax Support Point.

Seat Back Width At Mid-Lumbar Support Point (SW 252) – Width across the soft trim surface in a plane normal (90°) to the Torso Line at the Mid-Lumbar Support Point.

Seat Back Width At H-Point (DSW 254) – Width across the soft trim surface in a plane normal (90°) to the Torso Line at the H-Point.

Seat Back Bolster Depth At Thorax Support Point (DSL 261D) – Offset of the bolsters forward of the insert normal (90°) to the Torso Line at the Thorax Support Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Seat Back Bolster Depth At Mid-Lumbar Support Point (SL 262D) – Offset of the bolsters forward of the insert normal (90°) to the Torso Line at the Mid-Lumbar Support Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Seat Back Bolster Depth At H-Point (SL 264D) – Offset of the bolsters forward of the insert normal (90°) to the Torso Line at the H-Point. If there is no defined insert, default to an insert 280 mm wide. If the seat back is adjustable it is placed in design position.

Seat Back Bolster Width At Thorax Support Point (W 261D) – Width of the bolsters between most forward points in a plane normal (90°) to the Torso Line at the Thorax Support Point.

Seat Back Bolster Width At Mid-Lumbar Support Point (SW 262D) – Width of the bolsters between most forward points in a plane normal (90°) to the Torso Line at the Mid-Lumbar Support Point.

Seat Back Bolster Width At The H-Point (SW 264D) – Width of the bolsters between most forward points in a plane normal (90°) to the Torso Line at the H-Point.

Seat Back Insert Width At Thorax Support Point (SW 271D) – Width of the insert between the bolsters in a plane normal (90°) to the Torso Line at the Thorax Support Point.

Seat Back Insert Width At Mid-Lumbar Support Point (SW 272D) – Width of the insert between the bolsters in a plane normal (90°) to the Torso Line at the Mid-Lumbar Support Point.

Seat Back Insert Width At H-Point (SW 274D) – Width of the insert between the bolsters in a plane normal (90°) to the Torso Line at the H-Point.

Thorax Support Trim Deflection (SL 281D) – Distance from the Thorax Support Point on the manikin to the undeflected trim, measured normal (90°) to the Torso Line.

Mid-Lumbar Support Trim Deflection (SL 282D) – Distance from the Mid-Lumbar Support Point on the manikin to the undeflected trim, measured normal (90°) to the Torso Line with the seat at design Back Angle.

Sacral Support Trim Deflection (SL 284D) – Distance from the Sacrum Support Point on the manikin to the undeflected trim, measured normal (90°) to the Torso Line with the seat at design Back Angle. If the manikin surface does not reach the trim, this measure is redefined Sacral Relief (SL 285D).

HEAD RESTRAINT MEASUREMENTS

Head Clearance To Head Restraint (SL 301D) – Distance from the back of the Mean Head Profile normal to the Torso Line to a plane parallel to the Torso Line tangent to the front surface of the head restraint at CL/O.

Top Of Head To Top Of Head Restraint (SH 302D) – Vertical distance from top of Mean Head Profile to top of head restraint trimmed surface at CL/O. This value is negative if the head is below the restraint.

Head Restraint Width (SW 303D) – Width across trimmed surfaces of the head restraint at widest points.

Head Restraint Height (SH 304D) – Vertical height across trimmed surfaces of head restraint at CL/O.

Head Restraint Depth (SL 305D) – Horizontal Depth across trimmed surfaces of head restraint at CL/O.

TORSO RESTRAINT MEASUREMENTS (SEAT BELTS) – See Regulation 14, Uniform Provisions Concerning The Approval Of Vehicles With Regard To Safety-Belt Anchorages, E/ECE/324, E/ECE/TRANS/505, 16 December 1992

NOTES ON DEVELOPMENT OF SEAT DIMENSIONS – Seat dimensional data were collected and reviewed by the ASPECT IAP Seat Dimensions Task Group to develop a set of measures that would be useful to evaluate the geometry of automotive seats. The seat measurement proposals assembled in this document are the result of this effort.

Dimensional data from existing production seats were used to develop measurement definitions for bolster and insert geometry on seat cushions and seat backs as well as cushion lengths and back heights. Many of these seats were used to develop Cushion Point and Lumbar Contour Point definitions. The various measures are described in Figure 1.

Vehicles used at UMTRI for various driver seating and packaging studies had been previously measured in detail. These seats were H-Point checked and surface scanned and therefore provided an excellent set of “as measured” data available in drawing form. It must be noted, however that the dimensional H-Point data is related to the present J826 manikin. The data may require some adjustment to reflect ASPECT measurements. The measurement descriptions are provided in Figure 1, 2, 3, and 4.

These vehicle seat drawings were use to refine the Cushion Point, Lumbar Contour Point and Lumbar Support Point definitions and develop the Back Line and Cushion Line definitions. The field measurement locations of bolster and insert geometry as well as cushion and back widths were adjusted to fit the locations for the manikin related measures. This was accomplished by studying the horizontal and vertical relationships between Cushion-Point and H-Point. The x axis difference between H-Point and Cushion-Point is generally consistent (115 mm to 145 mm) with a mean value of 130 mm. This value was used to “align” the location of reference points locations for field measurements with manikin H-Point dependent measures for seat cushion and seat back geometry. Vertical H-Point to Cushion-Point data varies more, in one case due to a seat with extensive bridging trim between the seat back and cushion. Excluding the one unusual case resulted in a mean value of 83 mm. The relationships between manikin independent (field) and manikin dependent measures are defined as follows:

Seat Cushion – manikin independent measures horizontally forward of Cushion Point, 130 mm, 280 mm and 380 mm correspond to manikin dependent measures forward of H-Point along the Thigh Line of 0 mm, 150 mm and 350 mm respectively. Note that an 130 mm horizontal offset from H-Point to Cushion Point is used. Typical Cushion Angles (15°) and projection of the manikin dependent measures normal from the Thigh Line to the seat cushion surface produces similar reference locations on the seat surface for manikin independent (field) measurements and manikin dependent measurement definitions.

Seat Back – manikin independent measures vertically above Cushion Point, 70 mm, 200 mm, and 330 mm correspond to manikin dependent measures above H-Point along the Torso Line of 40 mm, 172 mm, and 365 mm. Note that an 83 mm vertical offset from the H-Point to the Cushion Point is used. Unlike the seat cushion, back angle geometry and offset of the manikin Torso Line to the seat surface torso contact points complicate a direct comparison of the values. At a 20° Back Angle, 90° Hip Angle, and at neutral posture, the manikin independent points (70 mm 200 mm, and 330 mm) translate, at seat contact, to be very close to the 40 mm, 172 mm, and 365 mm points relative to the manikin. Both manikin dependent and independent points are not yet finalized and may be redefined at different locations.

A number of different attempts were made to define Back Line. The goal was to produce a field measure (manikin independent) for Back Line that would be generally parallel to the present manikin measured Torso Line. The resulting definition is a line from a vertical tangent to the lower undeflected seat back contour to a point on the undeflected seat back surface 350 mm above the Cushion Point at CL/O. The definition of these points ignores local depressions and/or seam lines.