

Evaluation of the Seat Index Point Tool for Military Seats

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ABSTRACT

This study evaluated the ISO 5353 Seat Index Point Tool (SIPT) as an alternative to the SAE J826 H-point manikin for measuring military seats. A tool was fabricated based on the ISO specification and a custom back-angle measurement probe was designed and fitted to the SIPT. Comparisons between the two tools in a wide range of seating conditions showed that the mean SIP location was 5 mm aft of the H-point, with a standard deviation of 7.8 mm. Vertical location was not significantly different between the two tools (mean - 0.7 mm, sd 4.0 mm). A high correlation ($r=0.9$) was observed between the back angle measurements from the two tools. The SIPT was slightly more repeatable across installations and installers than the J826 manikin, with most of the discrepancy arising from situations with flat seat cushion angles and either unusually upright or reclined back angles that caused the J826 manikin to be unstable. The investigators who performed the measurements indicated that the SIPT was easier to use. The data show that the SIPT is a reasonable substitute for the SAE J826 manikin when ease-of-use considerations favor the SIPT, such as restricted space around the seat, low seat heights, or low cushion angles. Human posture measurements in seats with large discrepancies between the tools will be needed to determine which provides a better prediction of sitter position.

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INTRODUCTION

The H-point manikin documented in SAE J826 (SAE International 2015) was developed in the early 1960s in response to the need for a three-dimensional tool to represent vehicle occupants in the design process. Prior to that time, the standard reference point for taking seat dimensions was the "seat reference point" (SRP) located on the lateral seat centerline at the bight of the undeflected seat contour. The use of the SRP was problematic because the seat bight point was difficult to define and measure on seats with contoured surfaces. The relationship between the SRP and occupant positions also varied considerably across seats, both because of differences in seat contour and deformation under occupant loading.

The SAE J826 manikin, also called an H-point machine, addressed these issues by establishing a set of reference points and dimensions that could be more consistently related to occupant posture and position (see Reed et al. 1999 for a summary of the evolution of the H-point manikin). The manikin is constructed of rigid back and seat pans that simulate the human torso and thigh pivoting at hip or "H-point" with additional articulation points at the hip, knee and ankle. When the manikin is installed in a seat, body segment weights are applied to provide seat penetration equivalent to deflection a median male of 76 kg (167 lb). The thigh and leg segment lengths

used for most measurements are similar to 95th percentile values for U.S. men. [Figure 1](#) shows the SAE J826 H-point machine in use in a passenger car.



Figure 1. J826 H-point manikin installed in a vehicle.

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. SAE J1100 contains dozens of dimensions measured relative to the manikin. Federal Motor Vehicle Safety Standards (FMVSS) use the location of H-point for defining acceptable safety belt anchorage zones, and the H-point is used as a target for positioning crash test dummies prior to impact testing. The H-point manikin is also used to define and measure the seat back angle (SAE A40) and seat cushion angle (A27).

The H-point manikin is not widely used in the design and assessment of seats for military vehicles. In part, this is due to the lack of standards or guidelines requiring the use of a manikin-based reference point. MILSTD-1472G, which specifies human engineering requirements for military systems, bases dimension requirements for seats and vehicle driver workstations on a SRP similar to the reference point replaced by H-point in the 1960s.

In recent studies, University of Michigan Transportation Research Institute (UMTRI) has used the J826 H-point manikin to establish reference points for quantifying Soldier posture and positioning, opening the way to more widespread use of the SAE tool in military seating (Reed and Ebert 2013). However, preliminary testing of the H-point manikin in military seats and vehicles demonstrated significant challenges. The H-point manikin could effectively be used in driver seats in truck-like vehicles, such as the HMMWV. However, the size and limited articulation of the manikin made it difficult or impossible to use in many squad seating conditions and in the driver seats of some vehicles. The H-point manikin is unstable in seats with seat back angles close to vertical and with flat, short seat cushions, particularly those with minimal deformation.

Consequently, the study team looked for alternative methods for establishing reference points in these situations. The SAE J4002 manikin, also known as H-point manikin (HPM) II, was considered. In the 1990s, UMTRI led an industry-funded program to develop a new H-point manikin (Reed et al. 1999). The HPM-II, which is described in SAE J4002, was specifically developed to enable measurement of seats independent of the vehicle package by using optional, removable leg and foot components. The back section of the manikin is removable to facilitate installation, and the three-piece back articulates to conform to contoured seat backs. However, like the J826 manikin, the HPM-II is unstable with short, flat seat cushion and upright seat back angles. The HPM-II is also not widely available in industry and is expensive to purchase.

Consulting with colleagues in the off-highway seating industry led the team to consider the Seat Index Point Tool (SIPT). The SIPT is widely used to establish a reference point similar to the H-point in seats used for construction, forestry, agriculture, and other off-highway vehicles. SAE J1163 describes a SIPT that appears to have

been developed to provide a reference point similar to that obtained with the H-point machine. However, discussions with seating colleagues indicated that the ISO 5353 SIPT, which has some differences in contour, is universally used in place of the J1163 version of the SIPT.

Based on this information, the current study was formulated with the objective of evaluating the ISO 5353 SIPT for applications to military vehicle seating in situations in which the J826 manikin could not be used. A SIPT was constructed based on the ISO specifications and a large series of tests were conducted to compare outcomes with the J826 H-point manikin. Because the ISO SIPT lacks the capability to measure back angle, a lightweight probe to measure the seat back angle in a manner analogous to the back angle measurement of the SAE J826 manikin was developed and tested.

Both the SIPT and H-point manikin provide a reference point in the general area in which a sitter's hips are expected to lie. However, neither point should be interpreted as a hip point or a hip joint center location, because (1) the distribution of sitter's hip locations relative to the SIP or H-point is affected by a number of variables, including body size and the presence of body armor, and (2) average hip locations are generally *not* collocated with these reference points. Instead, sitter hip locations and other aspects of posture are predicted relative to these reference points through measurements of sitters in a range of conditions. For more information on predicting Soldier posture relative to seat reference points, see Reed and Ebert (2013).

METHODS

Using the SIPT to Measure Back Angle

One important limitation of the ISO 5353 manikin for the current application is that it lacks the capability of measuring seat back angle. Because a fixed seat back angle has a strong influence on sitter posture (Reed and Ebert 2013), a back angle measurement is needed for military seating applications. The goals of the development effort were (1) create an easy-to-use add-on for the SIPT that did not change the performance of the SIPT, (2) obtain a measure well correlated with the J826 back angle measure in seats for which both tools could be used.

As a first step, a pivot point was added to the SIPT at the side-view location of the SIP (the weight locating bar is not at the SIP). Several prototypes were developed with sliding vertical and horizontal components to allow testing of a range of geometries. The seat contact area was varied from a small point of contact to rectangles and other shapes, and a range of vertical contact locations tested.

After initial testing, the leading candidate was a horizontal bar with a 25-mm circular cross section (cylinder). During testing on military seats, the horizontal dimension proved to be too short for seats with relief for a hydration pack. Extending the cylinder laterally created

problems for seats with lateral contouring or bolsters, so the final design incorporates the lateral contouring of the H-point machine, as shown in Figures 2 and 3. The dimensions of the back angle probe are shown in Appendix A. The back angle is defined as the angle of the vertical member originating from the SIP with respect to vertical.

Functional Comparison to SAE J826

The SIPT and J826 machine were installed in a range of vehicle seats. Seats equipped with adjustable back angles were measured at a wide range of back angles. In each case, a FARO Arm coordinate digitizer was used to record the left and right H-point or SIP locations. An electronic inclinometer was applied to manikin or SIPT surfaces to measure seat cushion angle and seat back angle. The data were analyzed to compare J826 and SIPT measures and to assess repeatability and reproducibility.

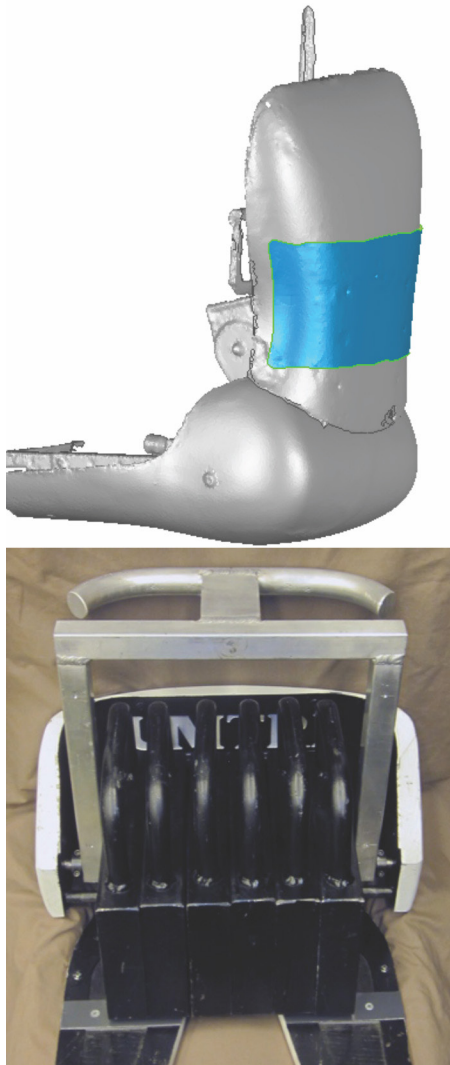


Figure 2. The final design of the back probe is based on the lateral contour of the J826 manikin in the lumbar area.



Figure 3. SIPT in seats used in the Seated Soldier Study (Reed and Ebert 2013).

RESULTS

H-Point vs. SIP

Figure 4 shows the position of the SIPT relative to H-point in the installations in all seats and conditions. The SIPT was on average 5 mm rearward of H-point (sd 7.8) but no significant difference in vertical location was observed (mean -0.7, sd 4.0 mm). In three of the test conditions, the SIP was more than 20 mm rearward of the H-point.

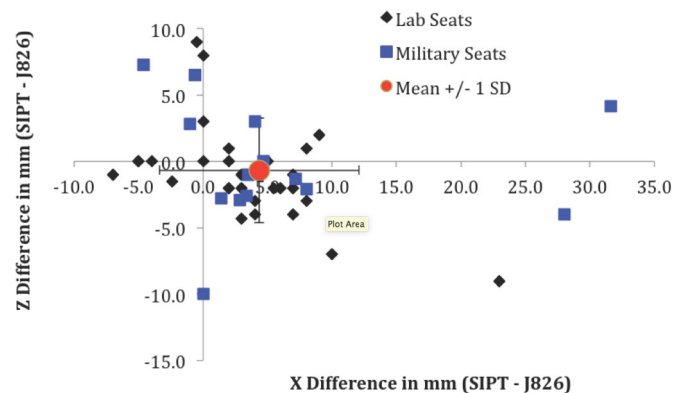


Figure 4. Comparison of SIP relative to J826. Positive values indicate that the SIP was rearward of the H-point.

Back Angle Measurement

The plot in Figure 5 shows the relationship between the seat back angle measured with the SIPT relative to the J826, demonstrating a strong correlation ($r = 0.92$). The functional relationship is given by