SAE International™ SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Motor Vehicle Drivers' Eye Locations

Foreword—This SAE Recommended Practice describes the eyellipse, a statistical representation of driver eye locations, which is used to facilitate design and evaluation of vision in motor vehicles. Examples of eyellipse applications include rearview mirror size and placement, wiped and defrosted areas, pillar size and location, and general exterior field of view. These applications are covered in other SAE and ISO practices.

This revision of the eyellipse is the most significant update to SAE J941 since its inception. The new eyellipses differ from the old eyellipses in the following ways:

a. The axis angles in plan view and rear view are parallel to vehicle grid.
b. The side view x-axis angle is tipped down more at the front.
c. For the 95 percentile eyellipse (99th shown in parentheses):
    1. The x-axis length is 7.5 (18.9) mm longer.
    2. The y-axis is 44.6 (63.6) mm shorter.
    3. The z-axis is 7.4 (10.1) mm longer.
d. The centroid location is generally higher and more rearward.
e. The centroid location in side view is a function of packaging geometry (SgRP, steering wheel location, seat cushion angle, and the presence or absence of a clutch pedal).
f. The eyellipse is no longer positioned according to the drivers' design seat back angle.
g. The eyellipse for seat tracks shorter than 133 mm in length has an x-axis length unchanged from the prior SAE J941. The y and z axis lengths, and the centroid location, are based on the new values/ equations given in this document.
h. Neck pivot (P) and eye (E) Points are based on the previous plan view sight lines to rearview mirrors and A-pillars, but are adjusted to the shape and location of the new eyellipses.

New additions, incorporated as appendices to this document, are summarized as follows:

a. Fixed seat eyellipses for the United States user population at a 50/50 gender mix and 95 and 99% tangent cutoffs (Appendix B).
b. A procedure for calculating adjustable and fixed seat eyellipses for any user population stature and gender mix at selected percent tangent cutoffs. (Appendices A and C).
c. Tables providing comparisons between tangent cutoff eyellipses and inclusive eyellipses. An eyellipse of inclusion can be constructed using these tables (Appendix D).

Eyellipses for Class B vehicles are unchanged from prior versions of SAE J941 (Appendix E).

Appendices are informative only and are not normative requirements of this document.

TABLE OF CONTENTS

1. Scope—This SAE Recommended Practice establishes the location of drivers' eyes inside a vehicle. Elliptical (eyellipse) models in three dimensions are used to represent tangent cutoff percentiles of driver eye locations.

Procedures are provided to construct 95 and 99% tangent cutoff eyellipses for a 50/50 gender mix, United States user population.

Neck pivot (P) points are defined in Section 6 to establish specific left and right eye points for direct and indirect viewing tasks described in SAE J1050. These P Points are defined only for the adjustable seat eyellipses defined in Section 4.

This document applies to Class A Vehicles (Passenger Cars, Multipurpose Passenger Vehicles, and Light Trucks) as defined in SAE J1100. It also applies to Class B vehicles (Heavy Trucks), although these eyellipses have not been updated from previous versions of SAE J941.

The appendices are provided for information only and are not a requirement of this document.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J826—Devices for use in Defining and Measuring Vehicle Seats and Seating Space
SAE J941 (1997)—Motor Vehicle Drivers' Eye Locations
SAE J1050—Motor Vehicle Driver and Passenger Head Position
SAE J1100—Motor Vehicle Dimensions
SAE J1516—Accommodation Tool Reference Point
SAE Paper 650464—Automobile Driver Eye Position, J.F. Meldrum (1965)
SAE Paper 720200—Driver Head and Eye Positions, D.C. Hammond and R.W. Roe (1972)
SAE Paper 750356—Describing the Driver's Workspace Eye, Head, Knee, and Seat Positions, R.W. Roe (1975)
SAE Paper 852317—Describing the Truck Driver Workspace, N.L. Philippart and T.J. Kuechenmeister (1985) (in SAE SP 712)

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this specification.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1517—Driver Selected Seat Position
SAE Paper 680105—The Eyellipse and Considerations in the Driver's Forward Field of View, W.A. Devlin and R.W. Roe (1968)
SAE Paper 980012—Development of an Improved Driver Eye Position Model, M.A. Manary, et al (1998) (in SAE SP-1358)
M.S. Sanders (1983), "U.S. Truck Driver Anthropometric and Truck Workspace Data Survey," Final Report submitted to SAE, Warrendale, PA
B.E. Shaw and M.S. Sanders (1984), "Female U.S. Truck Driver Anthropometric and Truck Workspace Data Survey," Final Report submitted to SAE, Warrendale, PA

2.2.2 OTHER PUBLICATION—Available from UMTRI, RIPC, 2901 Baxter Road, Ann Arbor, MI 48109-2150. Email: umtridocs@umich.edu, 734-764-2171.

W.A. Devlin (1975), "Visibility Design Guide," Proposed SAE Recommended Practice (also, ISO/ TC159/ SC4(USA1)6), SAE Driver Vision Committee, Troy, MI

3. Definitions

3.1 Eyellipse—A contraction of the words eye and ellipse used to describe the statistical distribution of eye locations in three-dimensional space located relative to defined vehicle interior reference points. See Figure 1.

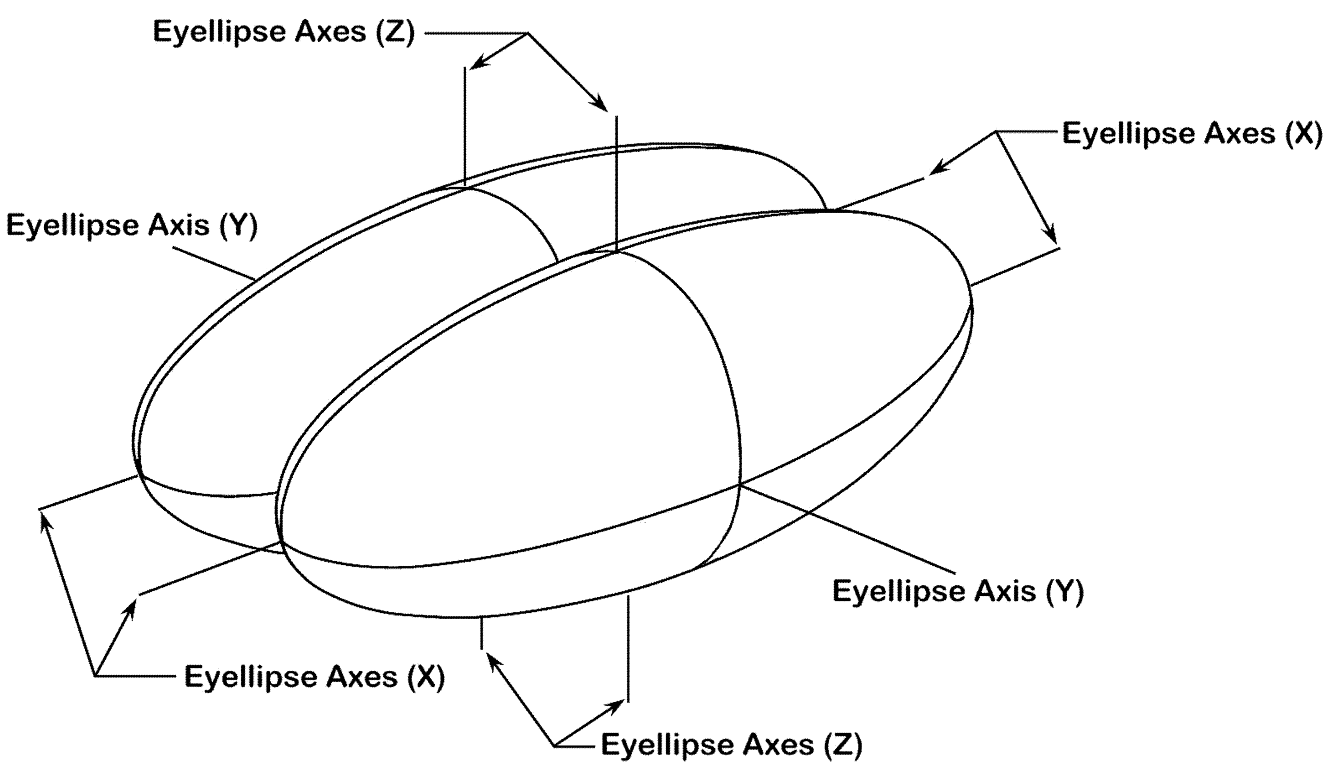

FIGURE 1—TYPICAL THREE-DIMENSIONAL TANGENT CUTOFF EYELLIPSES FOR THE LEFT AND RIGHT EYES

3.2 Cyclopean Eye or Mid-Eye Point—Mid-point between left and right eye points and/or left and right eyellipse centroids at centerline of occupant.

3.3 Tangent Cutoff Plane—Plane tangent to an eyellipse.

NOTE— When projected at a specified angle or to a specific target, a tangent cutoff plane may be considered a sight plane. In a two-dimensional view, a sight plane may be considered a sight line. See Figure D1 in Appendix D.

3.4 Tangent Cutoff Eyellipse—Three dimensional eyellipse derived as the perimeter of an envelope formed by an infinite number of planes dividing the eye locations so that P percent of the eyes are on one side of the plane and (100 – P) percent are on the other. See Appendix D.

3.5 Neck Pivot Points (P Points)—Points about which a driver's head turns on a horizontal plane. See Figure 2.

3.6 Neck Pivots, P1 and P2—Neck (head) pivot points used to position eye points for measuring the driver binocular obstruction due to A-pillars at the left and right side of the vehicle. See Figure 2.

3.7 Neck Pivots, P3 and P4—Neck (head) pivot points used to position eye points for measuring driver field of view from rearview mirrors located to the left and right of the driver. See Figure 2.

3.8 Eye Points (E Points)—Two points representing the left and right eyes of the driver, used in conjunction with a Neck Pivot Point to describe specific viewing tasks. See Figure 3.

3.9 Inclusive Eyellipse—Eyellipse that contains a specified percentage of drivers' eyes inside its boundaries.

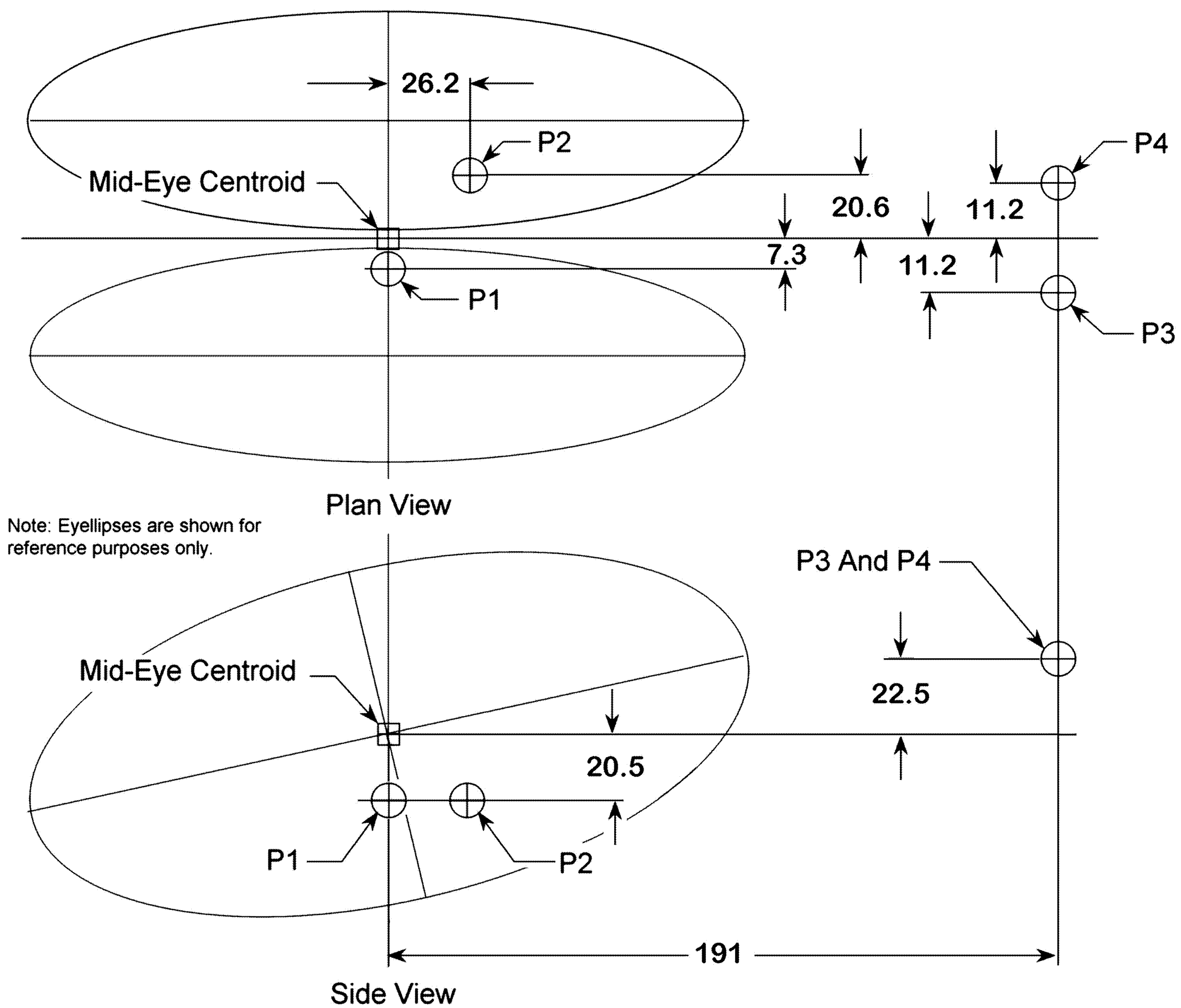

FIGURE 2—P-POINT LOCATIONS RELATIVE TO 95TH PERCENTILE EYELLIPSE MID-EYE CENTROID WITH SEAT TRACK TRAVEL >133 mm

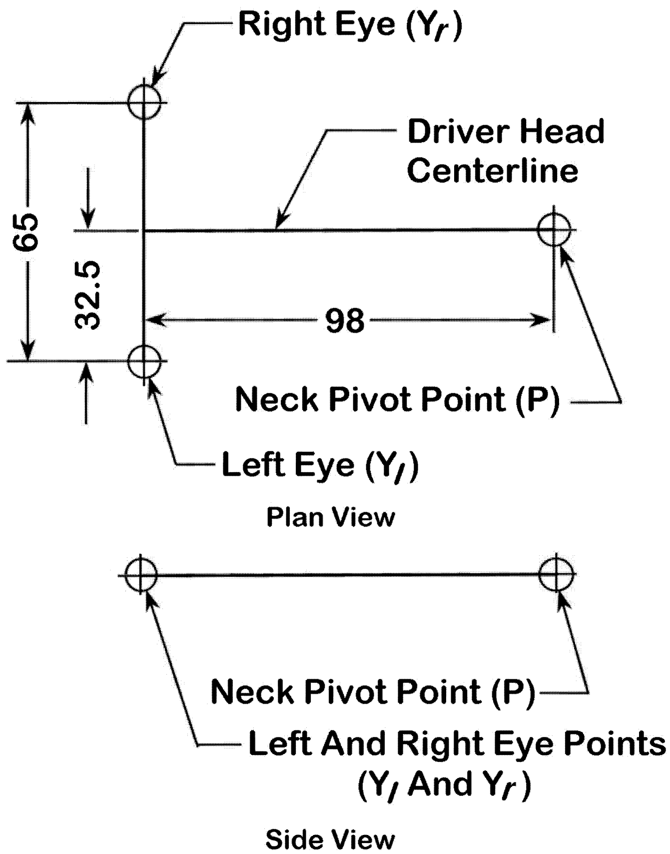

FIGURE 3—NECK PIVOT POINT AND ASSOCIATED EYE POINTS

3.10 Dimensions and Definitions in SAE J826 and SAE J1100

a. H-POINT
b. SEATING REFERENCE POINT, SgRP
c. PEDAL REFERENCE POINT (PRP)
d. ACCELERATOR HEEL POINT (AHP)
e. H-POINT TRAVEL PATH
f. A19 — SEAT TRACK RISE
g. H30 — SEAT HEIGHT
h. L6 — PEDAL REFERENCE POINT (PRP) TO STEERING WHEEL CENTER
i. CLASS A and CLASS B VEHICLES

4. ***Adjustable Seat 95 and 99% Tangent Cutoff Eyellipses for the United States User Population at a 50/50 Male/Female Gender Mix***—These eyellipses are based on the user populations described in Table 1. Driver eyellipses for a 50/50 gender mix shall be used for designing Class A vehicles.

TABLE 1—REFERENCE ANTHROPOMETRY (NHANES III)[1]

Gender	Mean Stature mm	Standard Deviation of Stature mm
Males	1755	74.2
Females	1618	68.7

1. Source: U. S. National Heath and Nutrition Examination Survey (NHANES III).
Height for males (and females) 20 years and older, number of examined persons, standard error of the mean, and selected percentiles, by ethnicity/race, age: United States, 1988-1994, obtained from http://www.cdc.gov/nchs/. Standard deviations for each gender were estimated by dividing the difference between the 95th and 5th percentiles by the difference in z scores (3.29).

The 95 and 99% tangent cutoff eyellipses for a 50/50 gender mix are constructed from tables and equations given in 4.1 through 4.2.1. These eyellipses are applicable to driver and front outboard passenger seat locations.

4.1 Axis Lengths—Axis lengths are given in Table 2. See Figure 4.

TABLE 2—LEFT AND RIGHT EYELLIPSE AXIS LENGTHS (TRUE VIEW)

Seat Track Travel (TL23)	Percentile	X Axis Lengths	Y Axis Lengths	Z Axis Lengths
> 133	95	206.4	60.3	93.4
	99	287.1	85.3	132.1
1 - 133	95	173.8[1]	60.3	93.4
	99	242.1[1]	85.3	132.1

1. For seat track travels of 100 to 133 mm, the eyellipse x-axis length was retained from the prior SAE J941.
No new eye position data was collected for these shortened seat track travels.

4.2 Axis Angles—The eyellipse is aligned with the vehicle axes in plan view (Z plane) and rear view (X plane), but it is tilted down at the front in side view (Y plane).

4.2.1 SIDE VIEW ANGLE, β—In side view the angle of the eyellipse is

$$\beta = 12.0 \qquad \text{(Eq. 1)}$$

where,

β is in degrees (positive, tipped down at the front from horizontal).

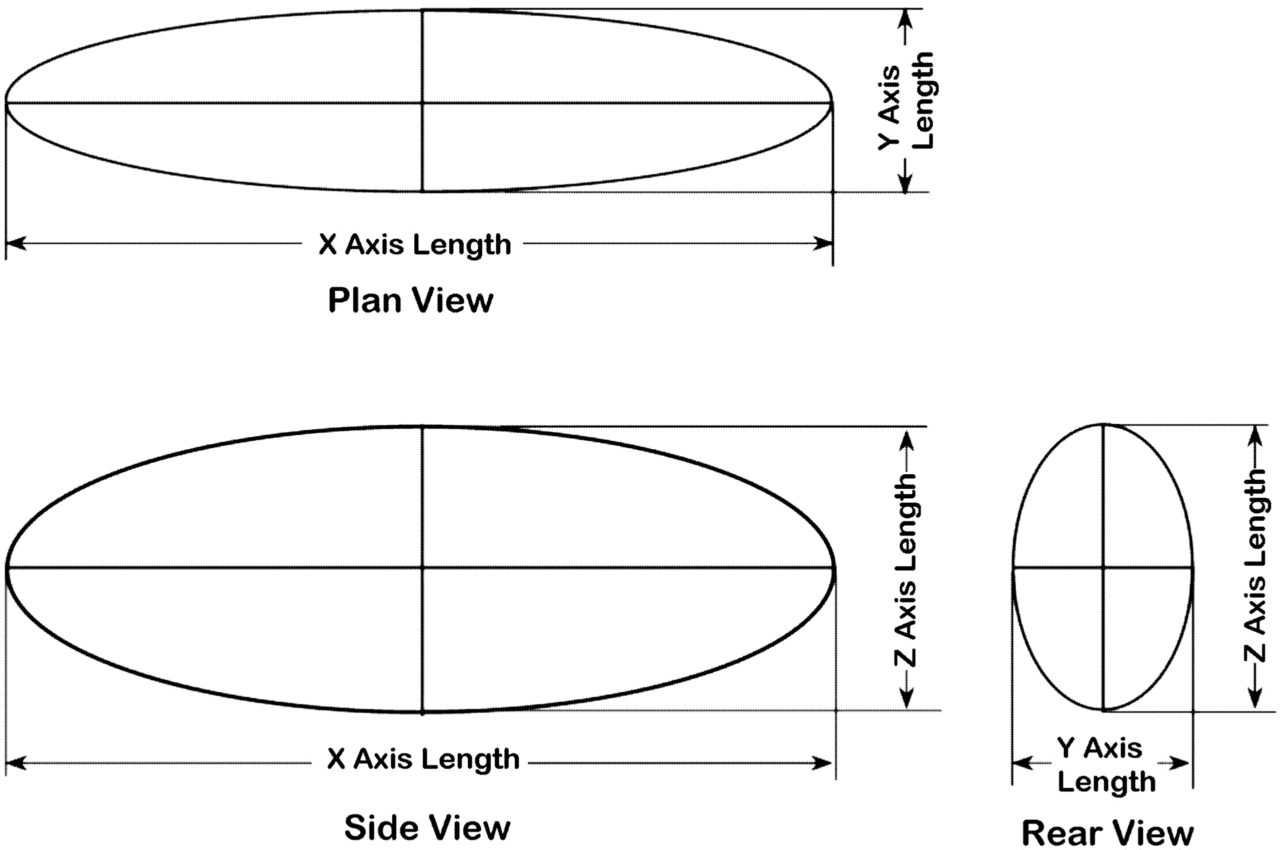

FIGURE 4—ADJUSTABLE SEAT TANGENT CUTOFF EYELLIPSE FOR ONE EYE, THREE VIEWS

4.3 Centroid Locations—Equations 2, 3, and 4 are used to calculate the eyellipse centroid location. See Figure 5.

$$X_c = L1 + 664 + 0.587(L6) - 0.176(H30) - 12.5t \quad \text{(Eq. 2)}$$

$$Y_{cl} = W20 - 32.5 \quad \text{(Eq. 3)}$$

$$Y_{cr} = W20 + 32.5 \quad \text{(Eq. 4)}$$

$$Z_c = H8 + 638 + H30 \quad \text{(Eq. 5)}$$

where

L1 is the PRP x coordinate,
L6 is steering wheel center to PRPx
H30 is the z coordinate of the SgRP, measured vertically from AHP
t is transmission type (1 with clutch pedal, 0 without clutch pedal)
W20 is SgRP y coordinate and
H8 is AHP z coordinate

For seats with vertical adjustment, Equations 2 to 4 were developed with H30 set at the middle of the adjustment range. If manufacturers define SgRP at a position other than this mid-height, the accuracy in locating the vertical position of the eyellipse will be reduced.

4.3.1 LEFT, RIGHT, MID-EYE CENTROIDS—The distance between the left eye centroid, Y_{cl}, and right eye centroid, Y_{cr}, is 65 mm. The mid-eye (cyclopean eye), Y_{cycl}, is located on the occupant centerline at W20.

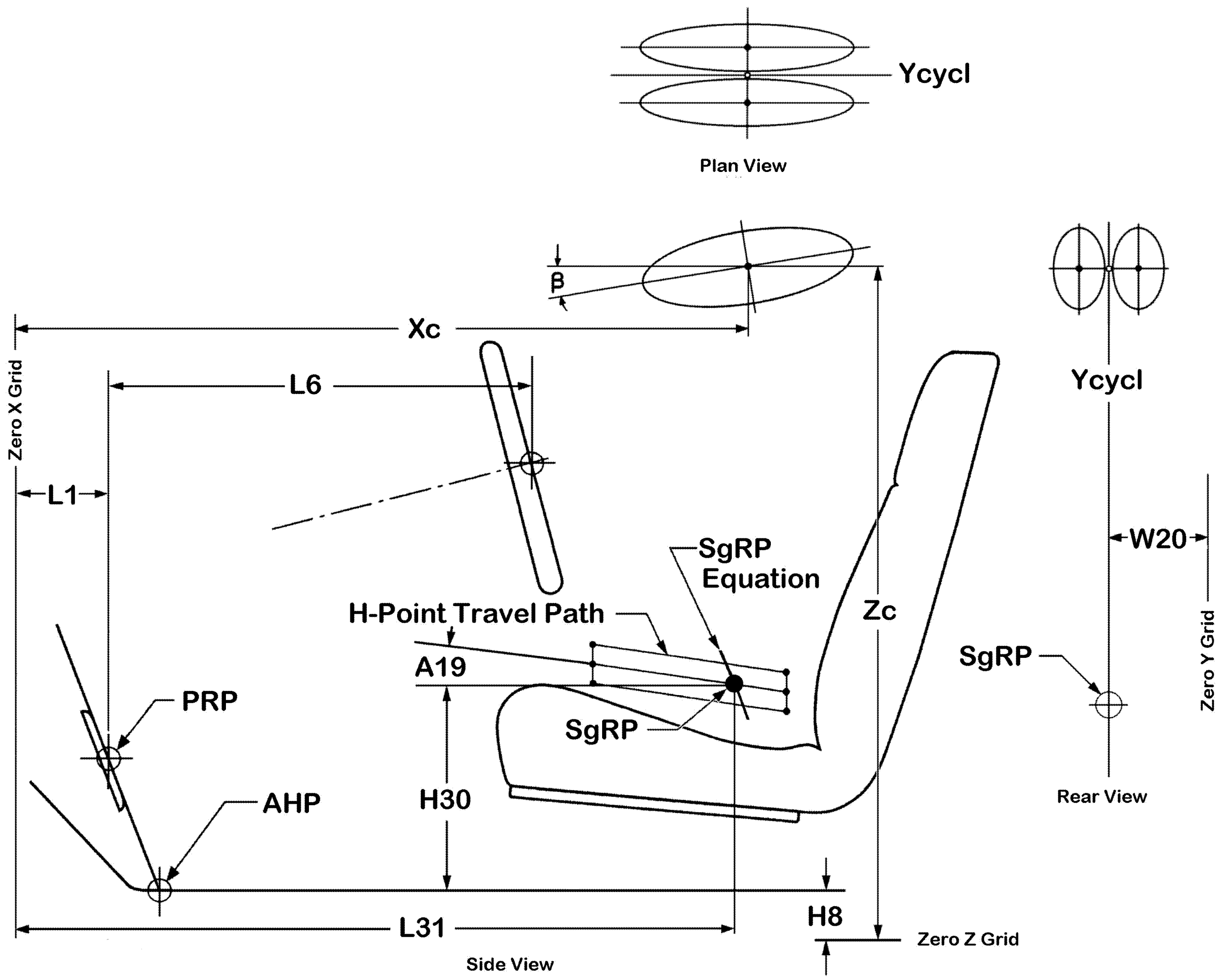

FIGURE 5—EYELLIPSE PACKAGE FACTORS, SIDE VIEW AXIS ANGLE, AND CENTROID LOCATION

5. Eyellipse Locating Procedure, Class A vehicles

5.1 Determine seat characteristics A19, W20, H30.

5.2 Determine H8 and L6.

5.3 Determine t based on the percentage of vehicle production that has a clutch pedal. If 50% or more of anticipated production has a clutch pedal, set t=1. Otherwise, set t=0.

5.4 Construct identical left and right eyellipses based on the axes given in Table 2. Locate the centroids using Equations 2, 3, and 4.

5.5 Tilt the front of the eyellipse x-axis down in side view according to Equation 1.

6. ***Neck Pivot (P) and Eye (E) Points: Locating Procedure, Class A Vehicles—***These points are defined to simplify application of the eyellipse for specific viewing tasks requiring head and eye rotation in plan view. (See SAE J1050.) Neck pivot (P) points provide a plan view head rotation pivot center so the left and right eye (E) points can be repositioned for these specific viewing tasks. These P points are derived from a 95th percentile, 50/50 gender mix eyellipse. To determine the P-points, tangents were constructed to a forward target (A-pillar or exterior rearview mirror). Each P-point was derived so that its left and right eye points were as close as possible to a tangent point on the surface of a 3D 95th percentile eyellipses. P-points were not developed for 99th percentile eyellipes.

6.1 Neck Pivot (P) Points—Locate these points relative to the cyclopean (mid-eye) eyellipse centroid using values given in Table 3. See Figure 2.

TABLE 3—NECK PIVOT POINTS RELATIVE TO THE 95TH PERCENTILE EYELLIPSE MID-EYE CENTROID

Seat Track Travel	Neck Pivot Point (P-Points)	X	Y (Left-hand drive)	Y (Right-hand drive)	Z
>133 mm	P1	0	–7.3	+7.3	–20.5
>133 mm	P2	26.2	+20.6	–20.6	–20.5
>133 mm	P3	191.0	–11.2	+11.2	+22.5
>133 mm	P4	191.0	+11.2	–11.2	+22.5
<133 mm	P1	16.3	–7.3	+7.3	–20.5
<133 mm	P2	39.2	+20.6	–20.6	–20.5
<133 mm	P3	175.0	–11.2	+11.2	+22.5
<133 mm	P4	175.0	+11.2	–11.2	+22.5

Note that + values of X are rearward of the centroid, + values of Y are right of the centroid, and + values of Z are above the centroid.

6.1.1 The X, Y, and Z values in the Table 3 may be added to Equations 2, 3, and 4, respectively, to obtain P Point locations relative to vehicle grid.

6.2 Eye (E) Points—Position the eye (E) points relative to the P points as shown in Figure 3 and the following equations:

$$Ex = Px - 98 \quad \text{(Eq. 6)}$$

$$E_i = Py - 32.5 \quad \text{(Eq. 7)}$$

$$E_r = Py + 32.5 \quad \text{(Eq. 8)}$$

$$Ez = Pz \quad \text{(Eq. 9)}$$

where:

Px, Py, and Pz is the (x,y,z) coordinate of the P point,
Ex, Ez is the (x,z) coordinate for the left and right eye point,
E_l and E_r are the y-coordinate of the left eye and right eye, respectively.

7. Notes

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

PREPARED BY THE SAE DRIVER VISION STANDARDS COMMITTEE

APPENDIX A

ADJUSTABLE SEAT TANGENT CUTOFF EYELLIPSES FOR ANY USER POPULATION STATURE DISTRIBUTION AND GENDER MIX [INFORMATIVE]

In this Appendix, a procedure is given for constructing eyellipses for driver populations that are different from the standard population listed in Table 1, either because the underlying stature distribution is different, the gender mix is different, or a different tangent cutoff contour is desired. The user can apply the equations given in this appendix for gender mixes containing 25% to 75% females. For larger or smaller percentages of females in the driver population, the eyellipse side view axis angle and centroid z location will be incorrect.

A.1 Axis Angles—The eyellipse is aligned with the vehicle axes in plan view (Z plane) and rear view (X plane), but it is tilted in side view (Y plane). In side view the angle of the eyellipse is given in Equation A1. See Figure 5.

$$\beta = 18.6 - (A19) \qquad \text{(Eq. A1)}$$

A.2 Reference Centroid Location—The reference centroid, calculated using Equations A2 through A4, is based on a population defined by NHANES III anthropometry and consisting of 50% males and 50% females. The mean stature for the reference population is 1686 mm.

$$X_{cref} = L1 + 664 + 0.587(L6) - 0.176(H30) - 12.5t \qquad \text{(Eq. A2)}$$

$$Y_{cref} = W20 \qquad \text{(Eq. A3)}$$

$$Z_{cref} = H8 + 638 + H30 \qquad \text{(Eq. A4)}$$

where:

L1 is the x coordinate of the PRP
L6 is steering wheel center to PRP x distance
W20 is the y coordinate of the seat centerline
H8 is the z coordinate of the AHP
H30 is the z-coordinate of the SgRP, measured vertically from AHPz and
t is the transmission type (1 with clutch pedal, 0 without clutch pedal)

For seats with vertical adjustment, Equations A2 to A4 were developed with H30 set at the middle of the adjustment range. If manufacturers define SgRP at a position other than this mid-height, the accuracy in locating the vertical position of the eyellipse will be reduced.

A.3 Axis Lengths

A.3.1 (X) Axis Length—In this section the term side view axis length refers to the true length of the eyellipse x axis, not the projected horizontal length in side view. Figures A1 and A2 illustrate the calculation of side view axis length.

The location of drivers' eyes along the side view axis is related to their stature by a factor of 0.473. That is, two drivers with stature differing by 10 mm will, on average, have eyes located 4.73 mm apart along the side view axis, with the taller driver rearward. Similarly, two populations with mean stature differing by 10 mm will, on average, have eyellipse centroids located 4.73 mm apart along the side view axis. Calculation of side view axis length takes into account the eye location distributions of two sub-populations of each driver population, one for males and one for females. Because males and females differ in average stature, their distributions will also differ in average location along the side view axis.

$$M = 0.473\ (S_M - S_R)$$
$$F = 0.473\ (S_F - S_R)$$

where
S_M = male mean stature
S_F = female mean stature
S_R = reference stature (1686 mm)

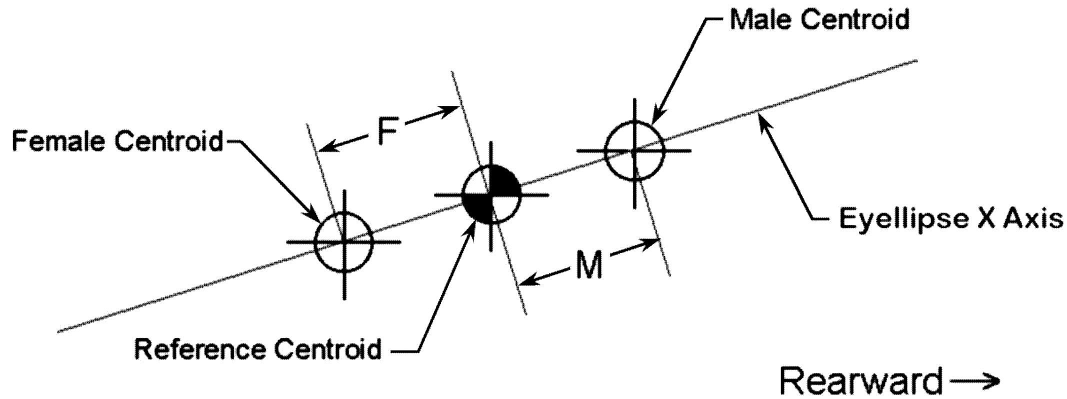

FIGURE A1—SIDE VIEW LOCATION OF THE MALE AND FEMALE EYE CENTROIDS RELATIVE TO THE REFERENCE CENTROID

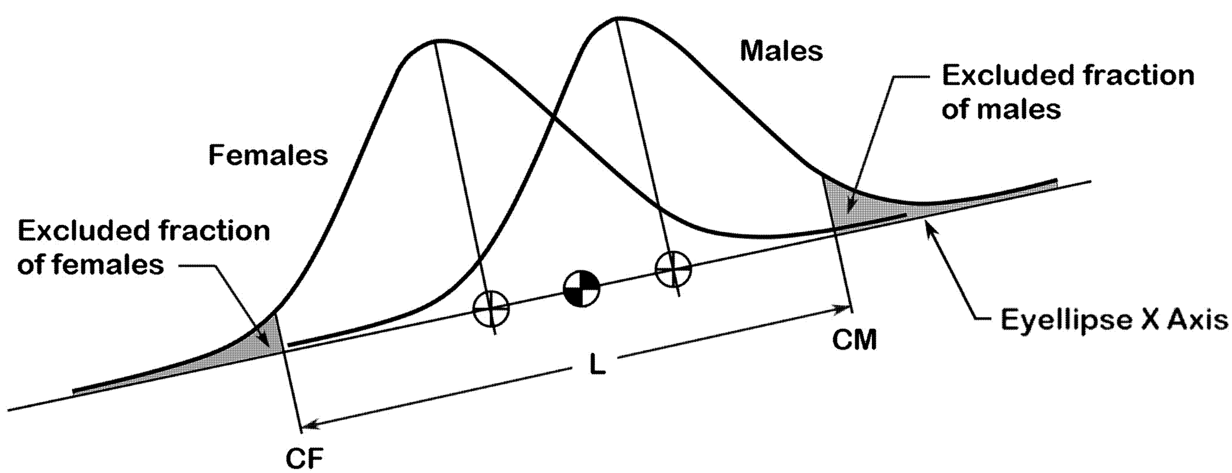

FIGURE A2—DETERMINATION OF EYELLIPSE X-AXIS END POINTS AND LENGTH

In addition, the variability of the underlying stature distributions must be taken into account. The process of determining side-axis length involves constructing the population eye-location distribution along that axis and then finding the upper and lower cutoff points that represent the boundaries of the eyellipse along the side view axis. The underlying distribution of eye locations in side view is a mixture of two normal distributions, one for males and one for females.

To simplify calculation of the boundaries, the reference centroid will be treated as the zero point along the side view axis, and the boundaries will be calculated as offsets from the reference. First, the centers of the male and female distributions (relative to the reference) should be calculated using Equations A5 and A6.

$$M = 0.473(S_M - S_R) \qquad \text{(Eq. A5)}$$

$$F = 0.473(S_F - S_R) \qquad \text{(Eq. A6)}$$

where:

M and F are the mean male and female eye centroids along the side view axis, relative to the reference centroid
S_M and S_F are the mean male and female stature

The standard deviation of each component distribution is calculated using Equations A7 and A8.

$$sd_M = \sqrt{(0.473)^2\sigma_M^2 + (41.87)^2} \qquad \text{(Eq. A7)}$$

$$sd_F = \sqrt{(0.473)^2\sigma_F^2 + (41.87)^2} \qquad \text{(Eq. A8)}$$

where:

sd_M and sd_F are the standard deviation of the male and female eye location distributions along the side view axis,
σ_M and σ_F are the standard deviations of the male and female stature distributions.

The two means and standard deviations define two overlapping normal distributions along the side view eyellipse x-axis (Figure A2). These can then be used with Equations A9 and A10 to determine lower (forward) and upper (rearward) eyellipse boundaries.

$$1 - q = p_M\Phi((CF - M)/sd_M) + (1 - p_M)\Phi((CF - F)/sd_F) \qquad \text{(Eq. A9)}$$

$$q = p_M\Phi((CM - M)/sd_M) + (1 - p_M)\Phi((CM - F)/sd_F) \qquad \text{(Eq. A10)}$$

where

p_M is the proportion of males in the population
CF is the forward boundary of the eyellipse along the side view axis, relative to the reference centroid
CM is the rearward boundary of the eyellipse along the side view axis, relative to the reference centroid
q is the eyellipse cutoff percentile and
Φ is the cumulative normal distribution

To find the upper and lower boundaries of the eyellipse along the side view axis, Equations A9 and A10 must be solved iteratively for CF and CM. Breaking the equation down, the portion inside parentheses that appears twice in each equation is the z-score of the lower or upper boundary with respect to the male or female eye-position distribution (along the side view axis). The cumulative normal distribution returns the proportion of the distribution that lies below (forward) of the upper or lower boundary. In Equation A9, for example, there is an expression for the proportion of the female population whose eyes lie below the lower cutoff, and an expression for the proportion of the male population whose eyes lie below the lower cutoff. These proportions are then combined in a weighted average based on the relative proportions of males and females in the driver population.

The last step is to compute x-axis length, which is simply the difference between CM and CF.

$$\text{Xaxis\_length} = CM - CF \qquad \text{(Eq. A11)}$$

A.3.2 Y and Z Axis Lengths—Since stature distribution does not affect axis length along the other two axes, their calculation is relatively simple. The only variable is the eyellipse cutoff percentile. The distributions along these two axes are modeled as single normal distributions with fixed standard deviations. Finding the axis endpoints is simply a matter of using the inverse normal cumulative distribution to solve for the cutoff points that exclude the appropriate proportion of the population. Equations A12 and A13 contain the specific formulas.

$$\mathrm{Yaxis\_length} = 18.34\,(\Phi^{-1}(q) - \Phi^{-1}(1-q)) \quad \text{(Eq. A12)}$$

$$\mathrm{Zaxis\_length} = 28.39\,(\Phi^{-1}(q) - \Phi^{-1}(1-q)) \quad \text{(Eq. A13)}$$

A.4 Final Centroid Location—The forward and rearward boundaries of the eyellipse x axis were computed relative to the eyellipse reference centroid. The boundaries may not be symmetrical around the reference centroid location. Thus, the final centroid must be computed according to Equations A14 through A16. These equations place the final centroid in vehicle grid at the midpoint between the two side view axis cutoff points, and along the centerline of occupant.

$$x_c = x_{cref} + \frac{(CF + CM)}{2}\cos\beta \quad \text{(Eq. A14)}$$

$$y_c = y_{cref} \quad \text{(Eq. A15)}$$

$$z_c = z_{cref} + \frac{(CF + CM)}{2}\sin\beta \quad \text{(Eq. A16)}$$

A.5 Eyellipses for Selected World Populations—Stature values given in Table A1 may be used to construct eyellipses for the specified populations by using the equations given in this appendix. The user is cautioned that eyellipses derived in this way have not been verified with field testing.

TABLE A1—POPULATION ANTHROPOMETRY[1]

Country	Gender	Mean Stature (mm)	Standard Deviation of Stature (mm)	Mean Seated Height (mm)
USA	Males	1755	74.2	919.5
	Females	1618	68.7	856.2
Japan	Males	1672.7	62.4	901.3
	Females	1544.8	61.2	838.4
Netherlands	Males	1806.2	80	944
	Females	1690	70	887

1. Data for Japan supplied by Toyota. Data for Netherlands supplied by TNO.

A.5.1 Axis Lengths—Eyellipse axis lengths for a driver population consisting of an equal number of males and females, and a seat track length >133 mm, are given in Table A2.

TABLE A2—LEFT AND RIGHT EYELLIPSE AXIS LENGTHS (mm)

Country	Percentile	X Axis Lengths	Y Axis Lengths	Z Axis Lengths
Japan	95	195.1	60.3	93.4
	99	271.5	85.3	132.1
Netherlands	95	202.0	60.3	93.4
	99	283.1	85.3	132.1

Note that the difference in x-axis lengths among the USA, Japan, and Netherlands populations is very small, indicating that the 95th or 99th eyellipses given in Table 2 are sufficient for most design purposes.

A.5.2 Centroid Location—Compared to North American and European populations, Japanese are shorter in average stature, and have a larger average ratio of sitting height to stature. These anthropometric differences will likely require an adjustment to the location of their eyellipse centroid. Testing with Japanese drivers is necessary to derive or validate an equation for locating the centroid.

Similarly, because the Netherlands population is taller on average than the reference USA population, resulting in higher seated eye heights, a different equation for locating the eyellipse centroid may also be needed for that population.

A.5.2.1 ESTIMATE BASED ON ANTHROPOMETRY—One approach, based strictly on anthropometry, is to adjust the eyellipse centroid Z value (from SgRP) proportionate to the ratio of average seated heights of the target population to USA seated heights, as follows:

$$Z_{cref} = H8 + H30 + 638 * (\text{target population mean seated height/USA mean seated height}) \quad \text{(Eq. A17)}$$

Adjust the eyellipse centroid X value from the PRP using equation A5 (which is based on the difference between average stature of the target population and average stature of USA population), as follows:

$$X_{cref} = L1 - 12.5t + [664 + 0.587(L6) - 0.176(H30)] + 0.473 * (\text{target population mean stature - USA mean stature}) * \cos\beta \quad \text{(Eq. A18)}$$

Table A3 gives the adjustments in centroid location from the USA centroid for a population having an equal mix of males and females, using anthropometry values from Table A1 and Equations A17, A18.

TABLE A3—CHANGE IN EYELLIPSE CENTROID LOCATION[1] (50% MALE POPULATION)

Country	X	Y	Z
Japan	–36	0	–13
Netherlands	28	0	20

1. NOTE: Positive numbers are rearward and up from USA centroid.

APPENDIX B

FIXED SEAT 95 AND 99% TANGENT CUTOFF EYELLIPSES FOR THE UNITED STATES ADULT POPULATION AT A 50/50 GENDER MIX [INFORMATIVE]

B.1 Background—Fixed seat eyellipses apply to seated positions with no H-Point or back angle adjustment. The eyellipse centroid is located relative to the fixed seat H-Point (SgRP). The only vehicle factor affecting location of the fixed seat eyellipse is the seat back angle, A40. Other seat adjustments are assumed fixed at the manufacturers design specifications.

These eyellipses are based on the user populations described in Table 1, Section 4. The 95th and 99th percent eyellipses are constructed from tables and equations described in Sections B.1 through B.3. Fixed seat eyellipses for other percent tangent cutoffs and gender mixes can be calculated using procedures in Appendix C.

If the seat has a fixed back angle with limited H-Point adjustment, or if both H-point and back angle are adjustable, there are no data available on which to base a procedure for selecting or locating an eyellipse.

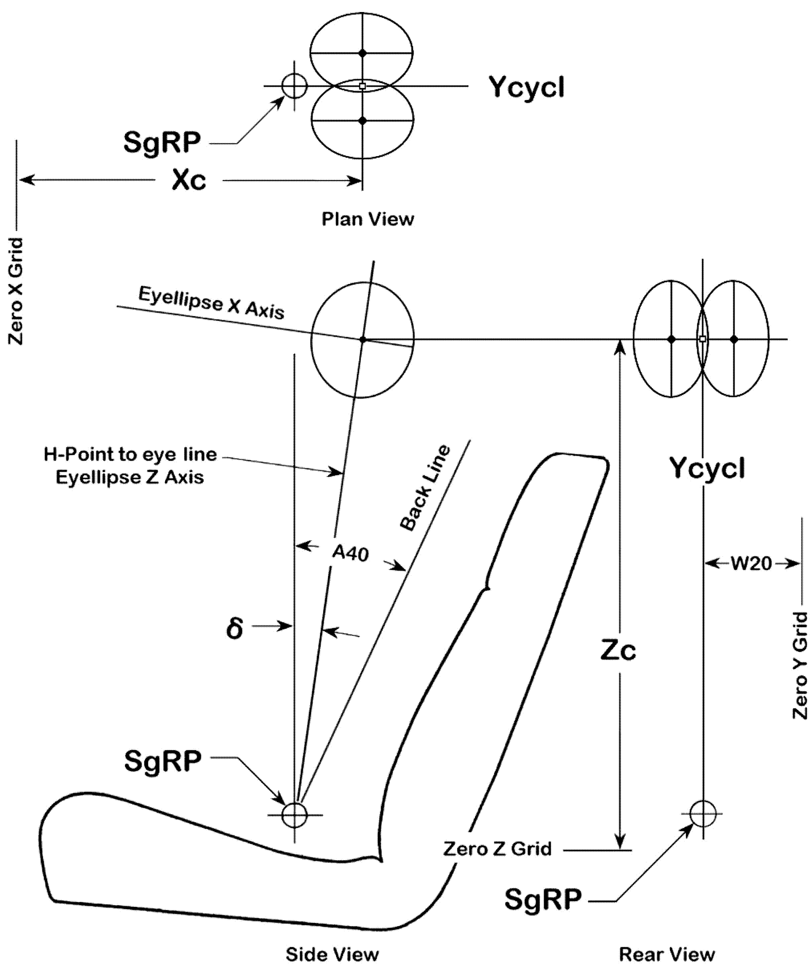

FIGURE B1—FIXED SEAT EYELLIPSE SIDE VIEW AXIS ANGLE AND CENTROID LOCATION

B.2 Axis Angles—The eyellipse is aligned with the vehicle axes in plan view (Z plane) and rear view (X plane).

B.2.1 Side View Axis Angle—Unlike the adjustable seat eyellipse, the longer primary axis of the fixed seat eyellipse is the z-axis. This primary z-axis is tilted back from vertical along a line from the centroid to the H-Point called the “H-Point to eye line”. The angle of the z-axis from vertical, δ, depends on the seat back angle. See Equation B1 and Figure B1.

$$\delta = 0.719(A40) - 9.6 \qquad \text{(Eq. B1)}$$

where

δ is the side view eyellipse angle in degrees (tipped back at the top from vertical) and A40 is the seatback angle. The dimension code for seatback angle depends on the passenger seat position under study. A40-2 refers to passenger second row seating and A40-3 refers to passenger third row seating as defined in SAE J1100.

B.3 Axis Lengths—Axis lengths are pictured in Figure B2 and given in Table B1.

TABLE B1—FIXED SEAT EYELLIPSE AXIS LENGTHS

Percentile	X Axis Lengths	Y Axis Lengths	Z Axis Lengths
95	99.2	104.1	119.6
99	140.4	147.3	164.3

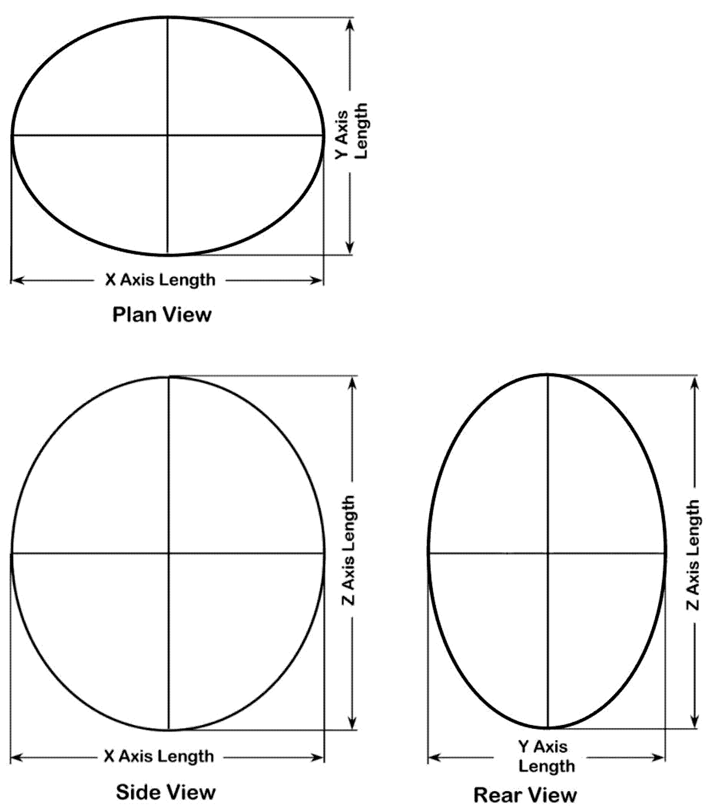

FIGURE B2—FIXED SEAT TANGENT CUTOFF EYELLIPSE FOR ONE EYE – TRUE VIEWS

B.4 Centroid Location—Equations B2, B3, and B4 are used to calculate the eyellipse centroid location. The cyclopean (mid-eye) location, Ycycl, is on the seat centerline at W20 (SgRP). See Figure B1. In side view the centroid is located to vehicle grid using L31 for SgRP x coordinate and H70 for SgRP z coordinate.

$$Xc = L31 + 640\sin\delta \qquad \text{(Eq. B2)}$$

$$Ycycl = W20 \qquad \text{(Eq. B3)}$$

$$Zc = H70 + 640\cos\delta \qquad \text{(Eq. B4)}$$

The dimension codes selected for SgRP Coordinates (to Grid) depend on passenger seat position under study: L31-2, W20-2 and H70-2 refers to second row passenger seating; L31-3, W20-3, and H70-3 refers to third row passenger seating.

B.4.1 Left and Right Centroids—The left and right eyellipse centroids are 65 mm apart, 32.5 mm either side of the mid-eye location.

APPENDIX C

FIXED SEAT TANGENT CUTOFF EYELLIPSES FOR ANY USER POPULATION STATURE DISTRIBUTION AND GENDER MIX [INFORMATIVE]

Fixed seat eyellipses must be calculated from equations given in this appendix when the user population is different from the standard population listed in Table 1, either because the underlying stature distribution is different, the gender mix is different, or a unique cutoff contour is needed.

C.1 Axis Angles—The eyellipse is aligned with the vehicle axes in plan view (Z plane) and rear view (X plane), but it is tilted in side view (Y plane).

C.1.1 Side View Angle—The angle of the z-axis from vertical, δ, depends on the seat back angle. See Equation C1 and Figure B1.

$$\delta = 0.719(A40) - 9.6 \quad \text{(Eq. C1)}$$

where:

δ is the side view eyellipse angle in degrees (tipped back at the top from vertical) and A40 the seatback angle.

C.2 Axis Lengths

C.2.1 Eyellipse z-Axis Length—The following calculations are required to determine the z-axis length.

C.2.1.1 MEAN MALE AND FEMALE H-POINT-TO-EYE DISTANCES—These values are calculated from the mean statures for the selected male and female population.

Equations C2 and C3 are used to calculate the H-Point-to-eye-distance.

$$h_M = 104.3 + 0.317 S_M \quad \text{(Eq. C2)}$$

$$h_F = 104.3 + 0.317 S_F \quad \text{(Eq. C3)}$$

where:

S_M and S_F = mean population stature for males and females, respectively, and
h_M and h_F = mean H-Point-to-eye distance for males and females

C.2.1.2 MEAN MALE AND FEMALE H-POINT-TO-EYE STANDARD DEVIATIONS—Calculate the standard deviation of H-Point-to-eye distance for males and females according to Equations C4 and C5. The mean and standard deviation of H-Point-to-eye distance define the two overlapping normal distributions for males and females. These distributions lie along the primary axis (z) of the fixed-seat eyellipse and embody the way in which driver population anthropometry affects the location and size (in the z axis) of the fixed-seat eyellipse.

$$sd_M = \sqrt{0.317^2 \sigma_{S_M}^2 + 18.67^2} \quad \text{(Eq. C4)}$$

$$sd_F = \sqrt{0.317^2 \sigma_{S_F}^2 + 18.67^2} \quad \text{(Eq. C5)}$$

where:

sd_M, sd_F = standard deviation of H-point-to-eye distance along the eyellipse z-axis for males and females
σ_{S_M}, σ_{S_F} = standard deviation of stature for males and females, respectively.

C.2.1.3 EYELLIPSE Z-AXIS BOUNDARY AND LENGTH—The steps so far are similar to the procedure used to construct the adjustable-seat eyellipse, described in Appendix A. As in that procedure, the primary-axis length (in this case, the eyellipse z axis) is calculated by determining the cutoff values at the upper and lower ends of the distribution. To do this, Equations C6 and C7 must be solved iteratively for CF and CM.

$$1 - q = p_M \Phi((CF - h_M)/sd_M) + (1 - p_M)\Phi((CF - h_F)/sd_F) \quad \text{(Eq. C6)}$$

$$q = p_M \Phi((CM - h_M)/sd_M) + (1 - p_M)\Phi((CM - h_F)/sd_F) \quad \text{(Eq. C7)}$$

where:

p_M is the proportion of males in the population,
CF is the lower boundary of the eyellipse along the z axis,
CM is the upper boundary of the eyellipse along the z axis,
q is the eyellipse cutoff percentile, and
Φ is the cumulative normal distribution.

The length of the primary eyellipse axis (z) is the difference between the upper and lower boundaries of H-Point-to-eye distance, CM and CF.

$$\text{Eyellipse z-axis length} = CM - CF \quad \text{(Eq. C8)}$$

C.2.2 Eyellipse x-Axis Length—The length of the x-axis (perpendicular to eyellipse z-axis in side view) depends on the variability in the H-point-to-eye angle relative to vertical. The side view angle, δ, is the mean H-point-to-eye angle. H-point-to-eye angle is distributed normally with a standard deviation of 2.7 degrees. Thus, boundary angles can be computed using the normal distribution with mean δ and standard deviation 2.7. A radius at each boundary angle with length equal to the mean H-point-to-eye distance will end at the x-axis boundary of the fixed-seat eyellipse. These radii are shown in Figure C1 as r_u and r_l, and the distance between their endpoints is the x-axis length. This length is very close to the length of the arc between the endpoints, a value that can be calculated easily by multiplying the angle between the radii (in radians) by the radius length (the mean H-point-to-eye distance). The procedure described in this paragraph is expressed mathematically in Equation C9 for a q-percentile ellipse.

$$x_\iota = \left(\frac{CM + CF}{2}\right)\left(\frac{\pi}{180}\right)(2.7 * 2\Phi^{-1}(q)) \quad \text{(Eq. C9)}$$

C.2.3 y-Axis Length—The y-axis in the fixed-seat eyellipse is the same as in the adjustable-seat eyellipse. Eye location along the y-axis is modeled as a normal distribution with a fixed standard deviation of 31.65mm, regardless of population anthropometry (Roe, 1975). Thus, Equation C10 gives the y-axis length as a function of eyellipse percentile q.

$$y_\iota = 31.65 \cdot 2\Phi^{-1}(q) \quad \text{(Eq. C10)}$$

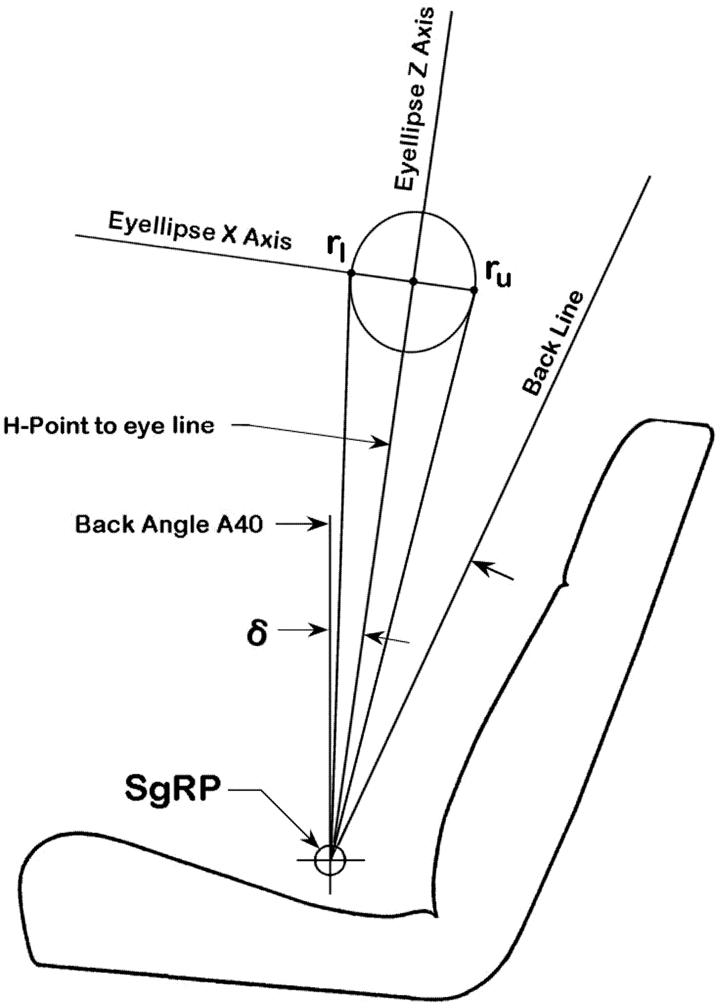

FIGURE C1—FIXED SEAT EYELLIPSE SIDE VIEW (X, Z)-AXIS AND AXIS ANGLE, δ.

C.3 ***Centroid Location—***The centroid of the fixed-seat eyellipse is the mid-point between the two H-Point-to-eye boundary points, along the primary axis and at the occupant centerline. Equations C11 through C13 give the centroid location relative to SgRP in the vehicle axis system.

$$x_c = \frac{(CM + CF)}{2}\sin\delta \quad \text{(Eq. C11)}$$

$$y_c = 0 \quad \text{(Eq. C12)}$$

$$z_c = \frac{(CM + CF)}{2}\cos\delta \quad \text{(Eq. C13)}$$

Equations C6 to C13 define the parameters of the fixed-seat eyellipse for any adult population anthropometry. The shape of the eyellipse is the same across vehicles (for the same adult population) except for small differences in angle as a function of back angle. Whereas the adjustable seat eyellipse is defined relative to the pedal reference point, the fixed-seat eyellipse is expressed relative to SgRP, because the H-point is stationary when the seat and seatback are fixed (see Appendix B).

APPENDIX D

TANGENT CUTOFF EYELLIPSES AND INCLUSIVE EYELLIPSES [INFORMATIVE]

D.1 Tangent Cutoff Eyellipse—Tangent cutoff eyellipses are derived as the perimeter of an envelope formed by an infinite number of planes dividing the eye locations so that P percent of the eyes are on one side of the plane and (100 – P) percent are on the other. With this derivation the 95th percentile eyellipse will not contain 95% of the eye locations inside the ellipse. To illustrate this in two dimensions, consider the side view of the eyellipse shown in Figure 4. If a plane seen as a straight line in side view is drawn tangent to the upper edge of the 95th percentile eyellipse, then 95% of the eyes, whether inside or outside of the eyellipse, will be below the line and 5% of the eye locations will be above the line. Furthermore, if a similar plane is drawn tangent to the lower edge of the 95th percentile eyellipse, then 95% of the eye locations, whether inside or outside the eyellipse, will be above the line and 5% will be below the line.

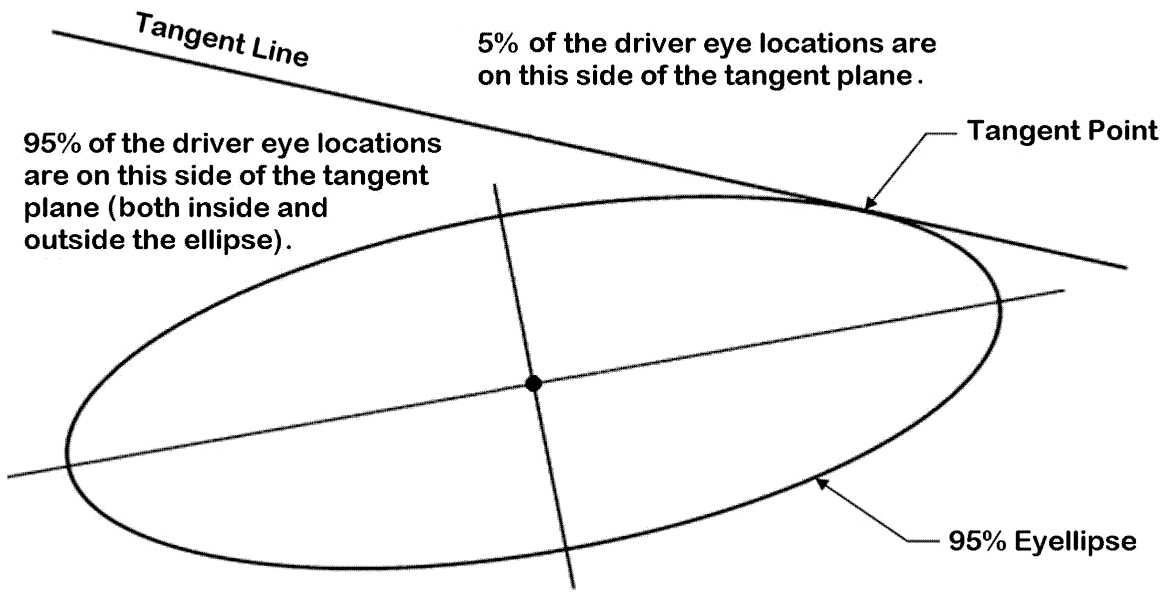

FIGURE D1—TWO DIMENSIONAL TANGENT CUTOFF DESCRIPTION.

For example, if the tangent line shown in Figure D1 is considered as a sight line (or sight plane) to the lowest point on the underside of the windshield header, 95% of the drivers would see at that angle or higher and 5% would see at that angle or lesser (restricted). Any targets in the forward field of view above the sight line would not be seen by 5% of the drivers. If the target is on or below the sight line, at least 95% of the drivers would see the target. For this reason the eyellipse is called a tangent cutoff ellipse. If it is necessary to determine driver accommodation to a specific target above the header obstruction, a progressively smaller percentile eyellipse (tangent cutoff contour) would be constructed such that a tangent from the eyellipse to the target is tangent to the underside of the header.

Tangent cut-off eyellipses presented in previous sections and appendices are used in various SAE J1050 applications to describe sight line accommodation. These are the most common and useful eyellipses for vehicle design.

D.2 Inclusive Eyellipse—There may, however, be some applications for which it is useful to have an ellipse that contains the eye locations of some designated proportion of drivers.

Each tangent cutoff eyellipse is also an inclusion eyellipse, which defines a boundary within which lie a certain percentage of drivers' eyes. The percent of the population included inside any ellipse is always less than the tangent cut-off percentage for that ellipse. For example, a 95% tangent cutoff eyellipse contains 74% of the eye locations within its 2-dimensional boundaries and 56% of the eye locations within its three dimensional boundaries. Table D1 lists a number of inclusive ellipses and their corresponding tangent cutoff eyellipse percentiles.

D.2.1 Axes Lengths for Inclusive Ellipse, Adjustable Seat—Axes lengths for an eyellipse of inclusion are given in the last 3 columns of Table D1 for a USA population containing an equal number of males and females.

TABLE D1—TANGENT CUTOFF EYELLIPSE PERCENTILES AND CORRESPONDING 2-D AND 3-D INCLUSIVE EYELLIPSE PERCENTILES, ADJUSTABLE SEAT

2-D Inclusive (side view)	3-D Inclusive	Tangent Cutoff	X Axis Length(1)	Y Axis Length (1)	Z Axis Length(1)
56.01%	35.02%	90.00%	162.3	47.0	72.8
74.15%	56.07%	95.00%	206.4	60.3	93.4
80.00%	64.09%	96.36%	224.3	65.8	101.9
87.18%	75.00%	97.87%	252.1	74.3	115.1
90.00%	79.69%	98.41%	266.0	78.7	121.8
93.32%	85.60%	99.00%	287.1	85.3	132.1
95.00%	88.80%	99.28%	301.2	89.8	139.0
95.61%	90.00%	99.38%	307.3	91.7	142.0
97.99%	95.00%	99.74%	341.3	102.5	158.7
99.07%	97.50%	99.89%	371.2	112.1	173.5
99.66%	99.00%	99.96%	406.5	123.5	191.2

1. NOTE: Axis lengths (mm) are shown for adjustable seat eyellipses, 50/50 gender mix, USA population.

D.2.2 Axes Lengths for Inclusive Ellipse, Fixed Seat—Axes lengths for an eyellipse of inclusion are given in the last 3 columns of Table D2 for a USA population containing an equal number of males and females.

TABLE D2—TANGENT CUTOFF EYELLIPSE PERCENTILES AND CORRESPONDING 2-D AND 3-D INCLUSIVE EYELLIPSE PERCENTILES, FIXED SEAT

2-D Inclusive (side view)	3-D Inclusive	Tangent Cutoff	X Axis Length(1)	Y Axis Length (1)	Z Axis Length(1)
56.01%	35.02%	90.00%	77.2	81.1	94.9
74.15%	56.07%	95.00%	99.2	104.1	119.6
80.00%	64.09%	96.36%	108.2	113.6	129.6
87.18%	75.00%	97.87%	122.3	128.3	144.9
90.00%	79.69%	98.41%	129.5	135.8	152.8
93.32%	85.60%	99.00%	140.4	147.3	164.3
95.00%	88.80%	99.28%	147.7	154.9	172.2
95.61%	90.00%	99.38%	150.9	158.3	175.5
97.99%	95.00%	99.74%	168.8	176.9	194.1
99.07%	97.50%	99.89%	184.6	193.5	210.4
99.96%	99.00%	99.96%	203.5	213.2	229.7

1. NOTE: Axis lengths (mm)are shown for fixed seat eyellipses, 50/50 gender mix, USA population.

D.3 Procedure for Constructing an Inclusive Ellipse—Axes lengths for inclusive eyellipses representing other driver populations, or different gender mixes, can be determined as follows. From the first 3 columns of Table D1 or D2, find the tangent cutoff eyellipse percentile that corresponds to the desired inclusive eyellipse percentile. Then, calculate the axes lengths for that tangent cutoff ellipse using the procedures described in Appendix A or C.

APPENDIX E

EYELLIPSES FOR CLASS B VEHICLES
[INFORMATIVE]

E.1 Mathematical Description of 3-D Eyellipses for Class B Vehicles—Eyellipses for Class B vehicles have not been changed from prior versions of SAE J941 dating back to 1987. 95th and 99th percentile eyellipses are defined for each of two different ranges of fore/aft seat track travel (TL23). Eyellipses can be constructed in three dimensions using the following information.

E.1.1 Axis Lengths—Dimensions for the length of the 3 axes in true view for the four eyellipses are as shown in Table E1.

TABLE E1—LENGTH OF 3 AXES IN TRUE VIEW FOR THE FOUR EYELLIPSES (mm)

Seat Track Travel (TL23) =	95th Eyellipse 100 to 133 mm	95th Eyellipse >133 mm	99th Eyellipse 100 to 133 mm	99th Eyellipse >133 mm
AXIS				
X(1)	173.8	198.9	242.1	268.2
Y	105.0	105.0	149.0	149.0
Z	86.0	86.0	122.0	122.0

1. NOTE: The x-axis of both 95th and 99th eyellipses is about 25 mm longer for seat track travel in excess of 133 mm. The effect of the longer track travel is to stretch the front of the eyellipse forward in the workspace without changing the location of the rear.

E.1.2 Centroids—The centroid of each eyellipse is located at the midpoint of the 3 axes.

E.1.3 Left and Right Eyes—Eyellipses for the left and right eyes are identical except that their centroids are separated horizontally by 65 mm. A single mid-eye centroid (a cyclopean eye) is located 32.5 mm from the centroid of either eyellipse.

E.1.4 Ellipsoid Surface versus Three Axial Sections—The user may construct either a complete ellipsoidal surface or a 3-D ellipse containing only the 3 axial sections defining plan, side and rear views. Use of the ellipsoidal surface gives the greatest accuracy.

E.2 Locating Procedure for Class B Vehicles—This procedure is applicable to Class B vehicles, which are defined as trucks, buses, or multipurpose vehicles with the following range of driver workspace dimensions as shown in Table E2 (See Figure E1):

TABLE E2—RANGE OF DRIVER WORKSPACE DIMENSIONS—CLASS B VEHICLES

Driver Workspace Dimensions	Range of Values
(H30) SgRP to Heel - Vertical	405 to 530 mm
(TH23) H-Point Rise	0 mm
(TL23) Seat Track Travel	more than 100 mm
(W9) Steering Wheel Diameter	450 to 560 mm
(A40)Torso Angle	11 to 18 degrees

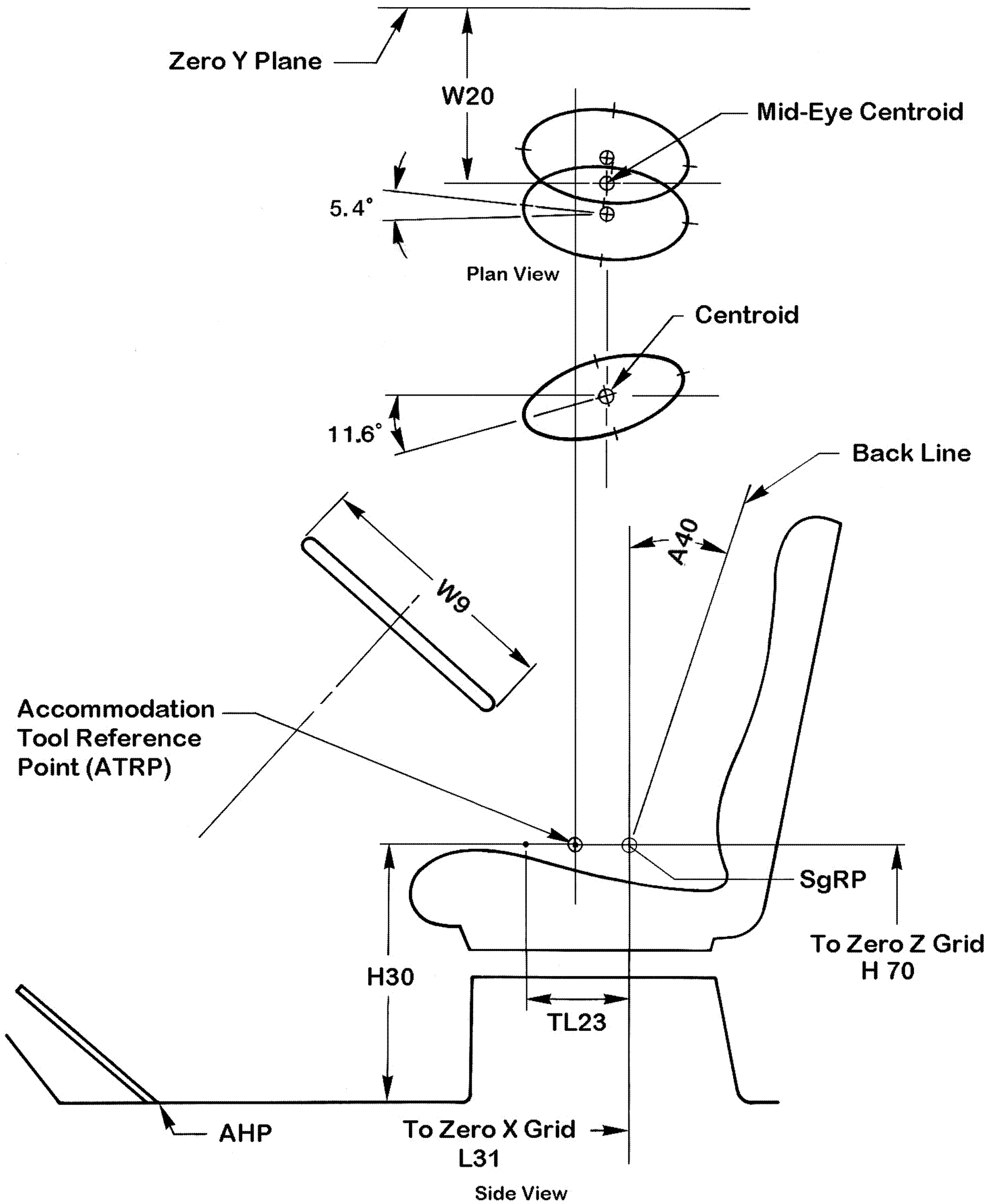

FIGURE E1—EYELLIPSE LOCATION IN CLASS B VEHICLES

E.2.1 Procedure

E.2.1.1 LOCATE ATRP—Determine the Accommodation Tool Reference Point (ATRP) using the procedure for Class B vehicles given in SAE J1516 (1987). The X and Z coordinates of the ATRP are X(ATRP) and Z(ATRP).

E.2.1.2 DETERMINE A40—The design torso angle, A40, is specified by the manufacturer.

E.2.1.3 SELECT AN EYELLIPSE—Determine the seat track travel (TL23) and select the appropriate 95th or 99th eyellipse.

E.2.1.4 LOCATE CENTROID—The eyellipse centroid is located to the vehicle's three-dimensional reference system. The following equations locate the centroid as a function of design torso angle for three different male/female mixes (50/50, 75/25, 90/10 to 95/5) in the driver population. Select the same male/female mix that was used in determining the ATRP. All values are in millimeters except A40 which is in degrees.

a. For a 50/50 male/female ratio:

$$X = X(ATRP) - 175.26 + 12.68*(A40) \quad \text{(Eq. E1)}$$

$$Z = Z(ATRP) + 691.09 - 3.57*(A40) \quad \text{(Eq. E2)}$$

b. For a 75/25 male/female ratio:

$$X = X(ATRP) - 201.05 + 13.65*(A40) \quad \text{(Eq. E3)}$$

$$Z = Z(ATRP) + 699.66 - 3.82*(A40) \quad \text{(Eq. E4)}$$

c. For a 90/10 to 95/5 male/female ratio:

$$X = X(ATRP) - 184.44 + 12.23*(A40) \quad \text{(Eq. E5)}$$

$$Z = Z(ATRP) + 707.52 - 4.17*(A40) \quad \text{(Eq. E6)}$$

In each case the Y coordinate of the left and right eyellipse centroids is given by:

$$YL = W20 - 32.5 \quad \text{(Eq. E7)}$$

$$YR = W20 + 32.5 \quad \text{(Eq. E8)}$$

where:

W20 must be made a negative number for left-hand drive vehicles.

E.2.1.5 ORIENT AXES—Separately rotate each eyellipse about its centroid so the X-axis is inward 5.4 degrees (looking forward) in plan view and down 11.6 degrees (looking forward) in side view.

E.3 P and E Points—These points have not been defined for Class B vehicles.

APPENDIX F

BACKGROUND FOR THIS REVISION OF SAE J941
[INFORMATIVE]

F.1 Historical Information—Past SAE J941 eyellipses were based on data collected in stationary vehicles having fixed (non adjustable) seat backs, seat tracks without vertical adjustment, and no restraint systems (seat belts), which does not represent present vehicle design practice.

The 1992 and earlier SAE J941 Recommended Practices were based on a 1963 study involving over 2300 U.S. drivers performing a straight-ahead viewing task without head turning, sitting in seats having fore/aft adjustment and fixed back angles (SAE Paper 650464 and (1)). Elliptical contours were developed from a statistical analysis of the stereophotogrammetric data, using a male-to-female ratio of one-to-one. These contours were given the name Eyellipse, a contraction of the words eye and ellipse. An eyellipse affords a convenient way to represent driver eye locations in a driver workspace in order to determine what drivers can see. In a subsequent study a procedure was developed to position an eyellipse in the driver workspace for various design torso (back) angles ranging from 5 to 40 degrees (SAE Paper 720200).

To facilitate use of the eyellpses in design, six pairs of eyellipse templates and a locator template were constructed. Each pair of templates (95th and 99th), represented a different amout of seat track travel. The templates contained datum lines to help located the eyellpse in an occupant package layout. With the advent of Computer Aided Design (CAD), the templates were scanned and incorporated by most companies into their CAD procedures.

In 1987 eyellipses were developed for heavy trucks (Class B vehicles). Studies showed that the shape of the existing eyellipses were applicable to heavy trucks, provided the side view angle was inclined more downward and the locating procedure was revised. Rationale for the different locating procedure for Class B vehicles was based on an SAE study of truck driver eye locations in three heavy truck cab configurations having 381 mm of horizontal seat travel (SAE SP 712).

In 1992 a rear view for the eyellipse was added to enable eyellipses to be constructed in 3-D in CAD systems. This rear view had been defined since 1964 but had never been incorporated into SAE J941. Other changes made in 1992 include eliminating the (outboard) lean factor in locating the eyellipse Y-coordinate, reducing the number of eyellipses from 6 to 2 pairs, and the phasing out of the templates.

F.2 This Revision—Eye location data collected in the 1990’s provided evidence that SAE J941 July 1992 could be improved. For this revision, data used in deriving the new eyellipses were collected after participants drove vehicles, wore seat belts, and selected a preferred seat back angle and seat position. A large number of persons were tested in a wide variety of passenger vehicles over a period of several years. Eye position data were also gathered from pairs of identical vehicles, one with and one without vertical seat adjustment. (SAE 980012)

Most of the results are summarized in the foreword to this document. One important additional finding was that adding up to 50 mm of vertical adjustment to driver seats did not affect the shape of the eyellipse. This broadened the application of SAE J941 to include vertically adjusting seats. It is also notable that design back angle (A40) is no longer used in locating an adjustable seat eyellipse. The variability introduced by driver’s back angle has been included in the size of the new eyellipses.

Eyellipses for fixed seats (seats having no horizontal adjustment) had been developed previously but were never included in previous versions of SAE J941. (See SAE Papers 720200 and 750356). These eyellipses were actually derived from adjustable seat data. The new fixed seat eyellipses were derived from eye and posture data collected in both adjustable and fixed seats, as well as from anthropometric considerations. However, only a limited amount of data was collected in fixed seats, none in bench seats. For this reason the Y-axis length from the previous fixed seat eyellipses was retained in this document. More user testing in fixed seats is desirable.

Generalized models and design procedures were developed to construct and locate eyellipses for both adjustable and fixed seats as a function of both vehicle seating package variables and user population characteristics (stature distribution and gender mix). These models were used to develop the main Practice and are given in detail in Appendices A and C.

Rationale—This revision of the eyellipse is the most significant update to SAE J941 since its inception. The new eyellipses differ from the old eyellipses in the following ways:

a. The axis angles in plan view and rear view are parallel to vehicle grid.
b. The side view x-axis angle is tipped down more at the front.
c. For the 95 percentile eyellipse (99th shown in parentheses):

   1. The x-axis length is 7.5 (18.9) mm longer.
   2. The y-axis is 44.6 (63.6) mm shorter.
   3. The z-axis is 7.4 (10.1) mm longer.

d. The centroid location is generally higher and more rearward.
e. The centroid location in side view is a function of packaging geometry (SgRP, steering wheel location, cushion angle, and presence or absence of a clutch pedal).
f. The eyellipse is no longer positioned according to driver design seat back angle.
g. The eyellipse for seat tracks shorter than 133 mm in length has an x-axis length unchanged from the prior SAE J941. The y and z axis lengths, and the centroid location, are based on the new values/ equations given in this document.
h. P and E Points are based on the previous plan view sight lines to mirrors and pillars, but are adjusted to the shape and location of the new eyellipses.

For this revision, data used in deriving the new eyellipses were collected after participants drove vehicles, wore seat belts, and selected a preferred seat back angle and seat position. A large number of persons were tested in a wide variety of passenger vehicles over a period of several years. Eye position data were also gathered from pairs of identical vehicles, one with and one without vertical seat adjustment. (SAE 980012)

Most of the results are summarized in the foreword foreward to this document. One important additional finding was that adding up to 50 mm of vertical adjustment to driver seats did not affect the shape of the eyellipse. This broadened the application of SAE J941 to include vertically adjusting seats. It is also notable that design back angle (A40) is no longer used in locating an adjustable seat eyellipse. The variability introduced by driver's back angle has been included in the size of the new eyellipses.

Eyellipses for fixed seats (seats having no horizontal adjustment) had been developed previously but were never included in previous versions of SAE J941. (See SAE Papers 720200 and 750356). These eyellipses were actually derived from adjustable seat data. The new fixed seat eyellipses were derived from eye and posture data collected in both adjustable and fixed seats, as well as from anthropometric considerations. However, only a limited amount of data was collected in fixed seats, none in bench seats. For this reason the Y-axis length from the previous fixed seat eyellipses was retained in this document. More user testing in fixed seats is desirable.

Generalized models and design procedures were developed to construct and locate eyellipses for both adjustable and fixed seats as a function of both vehicle seating package variables and user population characteristics (stature distribution and gender mix). These models were used to develop the main Practice and are given in detail in Appendices A and C.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Recommended Practice establishes the location of drivers' eyes inside a vehicle. Elliptical (eyellipse) models in three dimensions are used to represent tangent cutoff percentiles of driver eye locations.

Procedures are provided to construct 95 and 99% tangent cutoff eyellipses for a 50/50 gender mix, United States user population.

Neck pivot (P) points are defined in Section 6 to establish specific left and right eye points for direct and indirect viewing tasks described in SAE J1050. These P Points are defined only for the adjustable seat eyellipses defined in Section 4.

This document applies to Class A Vehicles (Passenger Cars, Multipurpose Passenger Vehicles, and Light Trucks) as defined in SAE J1100. It also applies to Class B vehicles (Heavy Trucks), although these eyellipses have not been updated from previous versions of SAE J941.

The appendices are provided for information only and are not a requirement of this document.

Reference Section

SAE J826—Devices for use in Defining and Measuring Vehicle Seats and Seating Space

SAE J941 (1997)—Motor Vehicle Drivers' Eye Locations

SAE J1050—Motor Vehicle Driver and Passenger Head Position

SAE J1100—Motor Vehicle Dimensions

SAE J1516—Accommodation Tool Reference Point

SAE J1517—Driver Selected Seat Position

SAE Paper 650464—Automobile Driver Eye Position, J.F. Meldrum (1965)

SAEPaper 680105—The Eyellipse and Considerations in the Driver's Forward Field of View, W.A. Devlin and R.W. Roe (1968)

SAE Paper 720200—Driver Head and Eye Positions, D.C. Hammond and R.W. Roe (1972)

SAE Paper 750356—Describing the Driver's Workspace Eye, Head, Knee, and Seat Positions, R.W. Roe (1975)

SAE Paper 852317—Describing the Truck Driver Workspace, N.L. Philippart and T.J. Kuechenmeister (1985) (in SAE SP 712)

SAE Paper 980012—Development of an Improved Driver Eye Position Model, M.A. Manary, et al (1998) (in SAE SP-1358)

W.A. Devlin (1975), "Visibility Design Guide," Proposed SAE Recommended Practice (also, ISO/ TC159/ SC4(USA1)6), SAE Driver Vision Committee, Troy, MI

M.S. Sanders (1983), "U.S. Truck Driver Anthropometric and Truck Workspace Data Survey," Final Report submitted to SAE, Warrendale, PA

B.E. Shaw and M.S. Sanders (1984), "Female U.S. Truck Driver Anthropometric and Truck Workspace Data Survey," Final Report submitted to SAE, Warrendale, PA

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