
**Road vehicles — Visibility — Method
for establishment of eyellipses for
driver's eye location**

*Véhicules routiers — Visibilité — Méthode de détermination des
ellipses oculaires correspondant à l'emplacement des yeux des
conducteurs*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 35, *Lighting and visibility*.

This fourth edition cancels and replaces the third edition (ISO 4513:2010), which has been technically revised.

The main changes are as follows:

- added references to the annexes;
- the variables have been modified;
- editorial changes.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document 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 ISO 4513 since its inception. The eyellipses differ from the previous 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 95th 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 driver's torso angle;
- g) the eyellipse for seat tracks shorter than 133 mm in length has an X-axis length unchanged from ISO 4513:2003. The Y- and Z-axis lengths, and the centroid location, are based on the new values and equations given in this document;
- h) neck pivot (P) and eye (E) points are based on the previous plan view sight lines to rear-view mirrors and A-pillars, but are adjusted to the shape and location of the new eyellipses.

New additions, incorporated as annexes, are summarized as follows.

- a) Fixed seat eyellipses for an adult user population at a 50/50 gender mix and 95th and 99th percentile tangent cut-offs are described (see [Annex B](#)). Fixed seat eyellipses and their locating formulae given in [Annexes B](#) and [C](#) are based on data for second row passenger eye locations presented by UMTRI. In addition, a procedure is provided in [Annex B](#) for locating an eyellipse in a second row seat that has adjustable seat track travel or adjustable back angle.
- b) A procedure is given for calculating adjustable and fixed seat eyellipses for any user population stature and gender mix at selected percentile tangent cut-offs (see [Annexes A](#) and [C](#)).

Tables providing comparisons between tangent cut-off eyellipses and inclusive eyellipses are given. An inclusive eyellipse can be constructed using these tables (see [Annex D](#)).

Eyellipses for Class B vehicles are unchanged from ISO 4513:2003 (see [Annex E](#)).

For historical background of ISO 4513 see [Annex F](#).

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Road vehicles — Visibility — Method for establishment of eyellipses for driver's eye location

1 Scope

This document establishes the location of drivers' eyes inside a vehicle. Elliptical (eyellipse) models in three dimensions are used to represent tangent cut-off percentiles of driver's eye locations. Procedures are provided to construct 95th and 99th percentile tangent cut-off eyellipses for a 50/50 gender mix, adult user population.

Neck pivot (P) points are defined 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 adjustable seat eyellipses.

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).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6549, *Road vehicles — Procedure for H- and R-point determination*

SAE J1100, *Motor Vehicle Dimensions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6549, SAE J1100 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

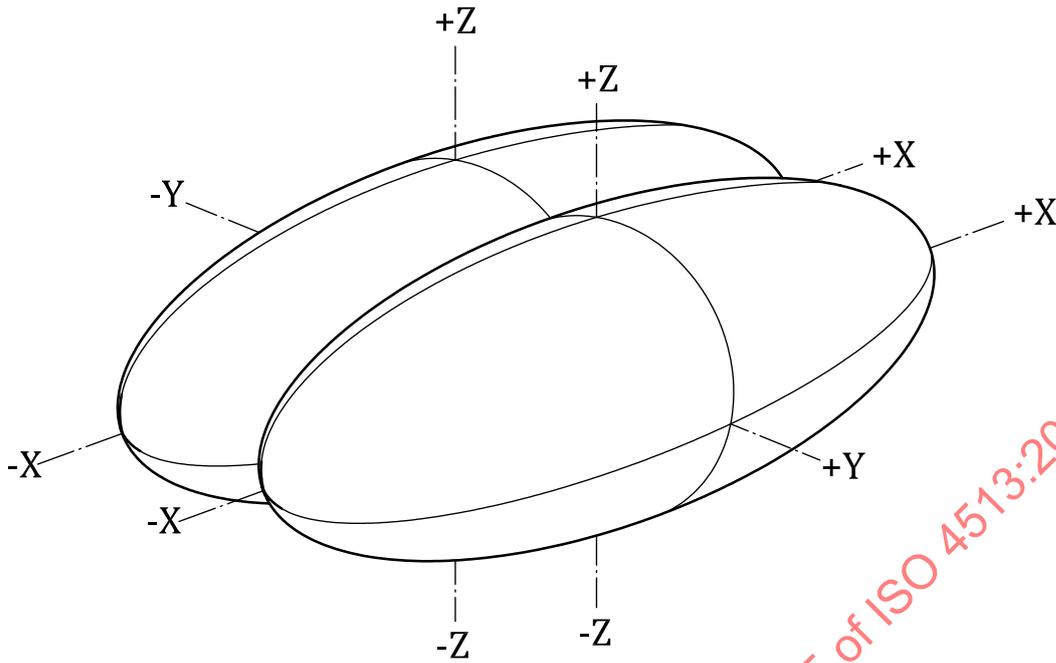
- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

eyellipse

contraction of the words “eye” and “ellipse” used to describe the statistical distribution of eye locations in a three-dimensional space located relative to defined vehicle interior reference points

Note 1 to entry: See [Figure 1](#).



Key
 X, Y, Z ellipse axes

Figure 1 — Typical three-dimensional tangent cut-off eyellipse for the left and right eyes

3.2 mid eye centroid

mid-eye point
 cyclopean eye point
 midpoint between left and right eye points or left and right eyellipse centroids at the centreline of the occupant

3.3 tangent cut-off plane

plane tangent to an eyellipse

Note 1 to entry: When projected at a specified angle or on to a specific target, a tangent cut-off plane can be considered to be a sight plane. In a two-dimensional view, a sight plane can be considered to be a sight line (see [Figure D.1](#)).

3.4 tangent cut-off eyellipse

three-dimensional eyellipse derived as the perimeter of an envelope formed by an infinite number of planes dividing the eye locations so that $P\%$ of the eyes are on one side of the plane and $(100 - P)\%$ are on the other

Note 1 to entry: See [Annex D](#).

3.5 neck pivot point

P point
 point at which a driver's head turns on a horizontal plane

Note 1 to entry: See [Figure 2](#).

3.6

point P1

point 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

Note 1 to entry: See [Figure 2](#).

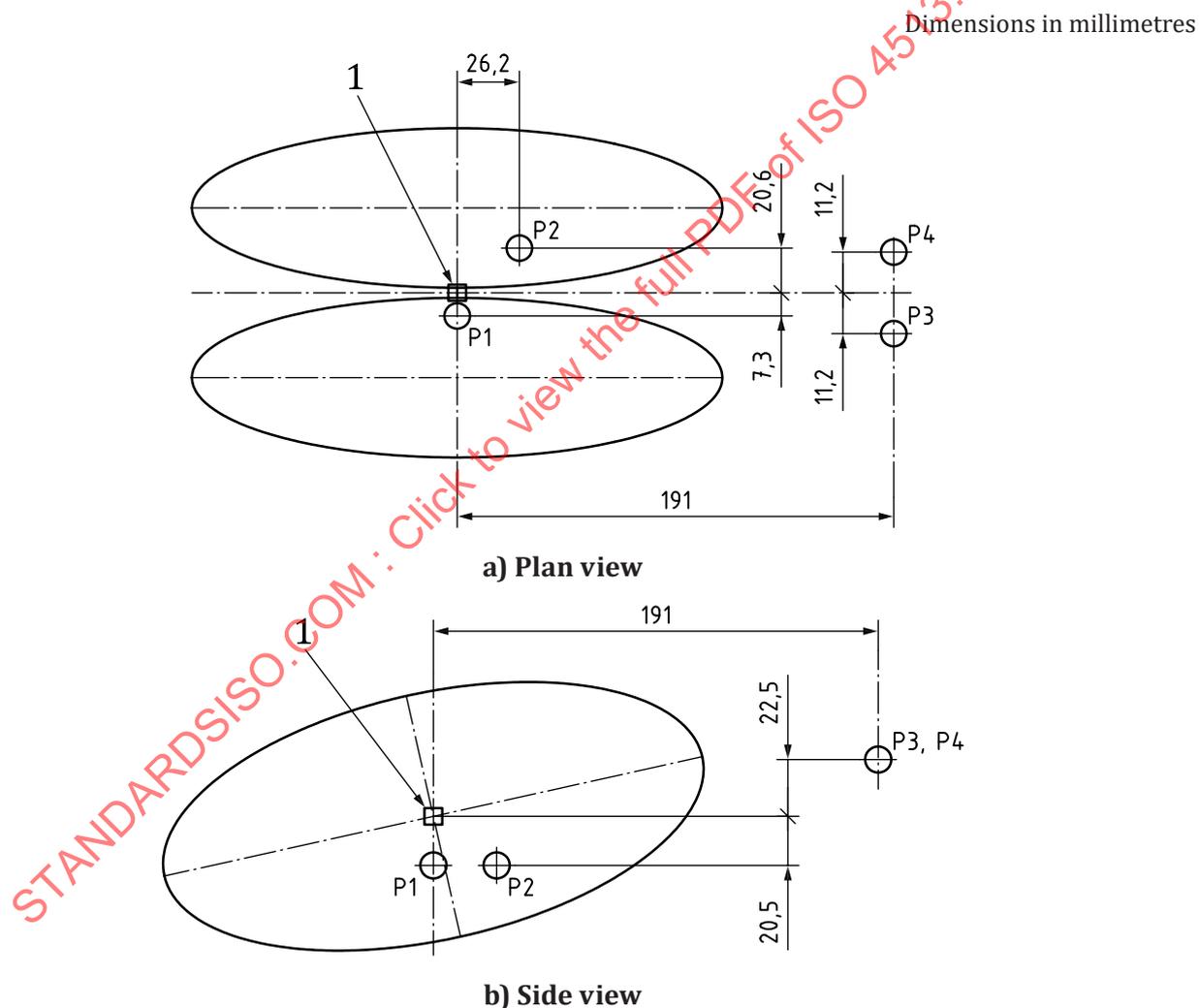
3.7

point P3

point P4

neck (head) pivot points used to position eye points for measuring driver field of view from rear-view mirrors located to the left and right of the driver

Note 1 to entry: See [Figure 2](#).



Key

1 mid-eye centroid

NOTE Eyellipses are shown for reference purposes only.

Figure 2 — P point locations relative to 95th percentile eyellipse mid-eye centroid with seat track travel >133 mm

The 95th and 99th percentile tangent cut-off eyellipses for a 50/50 gender mix are constructed from tables and formulae given in 4.2 to 4.3.2. These eyellipses are applicable to driver and front outboard passenger seat locations.

NOTE 1 See Annex A for an example to determine adjustable seat tangent cut-off eyellipses for any user population stature distribution and gender mix.

NOTE 2 See Annex B for an example to determine fixed seat 95th and 99th percentile tangent cut-off eyellipses for an adult population at a 50/50 gender mix.

NOTE 3 See Annex C for an example to determine fixed seat tangent cut-off eyellipses for any user population stature distribution and gender mix.

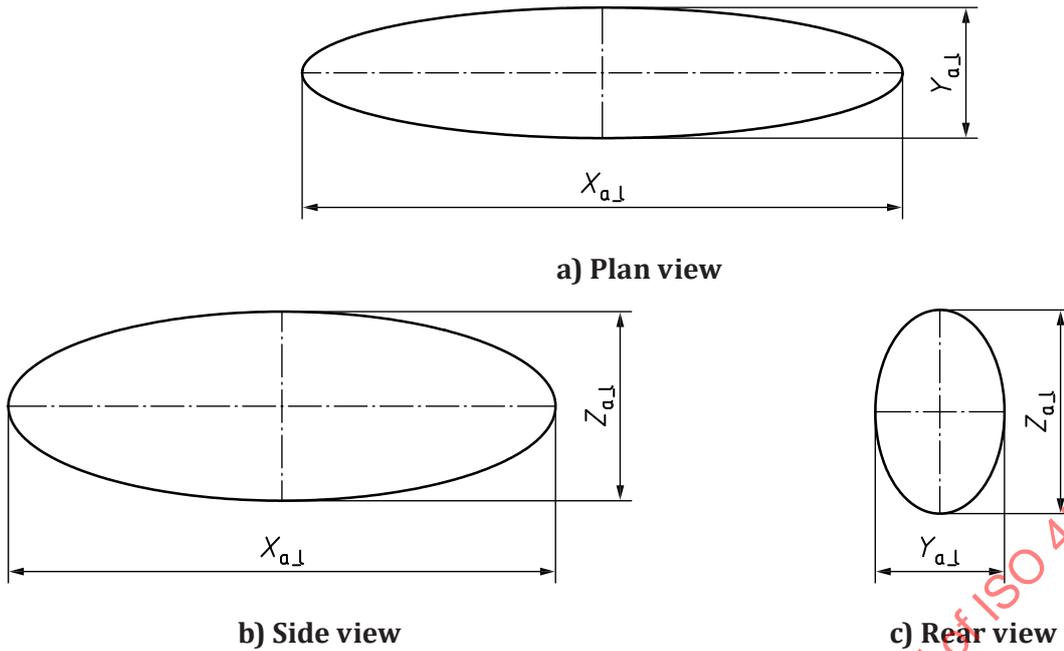
4.2 Axis lengths

Axis lengths are given in Table 2 (see Figure 4).

Table 2 — Left and right eyellipse axis lengths (true view)

Seat track travel (TL23) mm	Percentile	X-axis length mm	Y-axis length mm	Z-axis length mm
>133	95	206,4	60,3	93,4
	99	287,1	85,3	132,1
100 to 133	95	173,8 ^a	60,3	93,4
	99	242,1 ^a	85,3	132,1

^a For seat track travels of 100 mm to 133 mm, the eyellipse X-axis length is unchanged from ISO 4513:2003. No new eye position data were collected for these shortened seat track travels.



- Key**
- $X_{a,l}$ X-axis length
 - $Y_{a,l}$ Y-axis length
 - $X_{a,l}$ X-axis length

Figure 4 — Adjustable seat tangent cut-off eyellipse for one eye, three views

4.3 Axis angles

4.3.1 Rear and plan view 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).

4.3.2 Side view angle, β

In side view, the angle, β , in degrees (positive, tipped down at the front from horizontal), of the eyellipse is:

$$\beta = 12,0 \tag{1}$$

4.4 Centroid locations

4.4.1 Locating formulae

Formulae (2) to (5) are used to calculate the eyellipse centroid location (see Figure 5).

$$X_c = L_1 + 664 + 0,587 L_6 - 0,176 H_{30} - 12,5 t \tag{2}$$

$$Y_{cL} = W_{20} - 32,5 \tag{3}$$

$$Y_{cR} = W_{20} + 32,5 \tag{4}$$

$$Z_c = H_8 + 638 + H_{30} \quad (5)$$

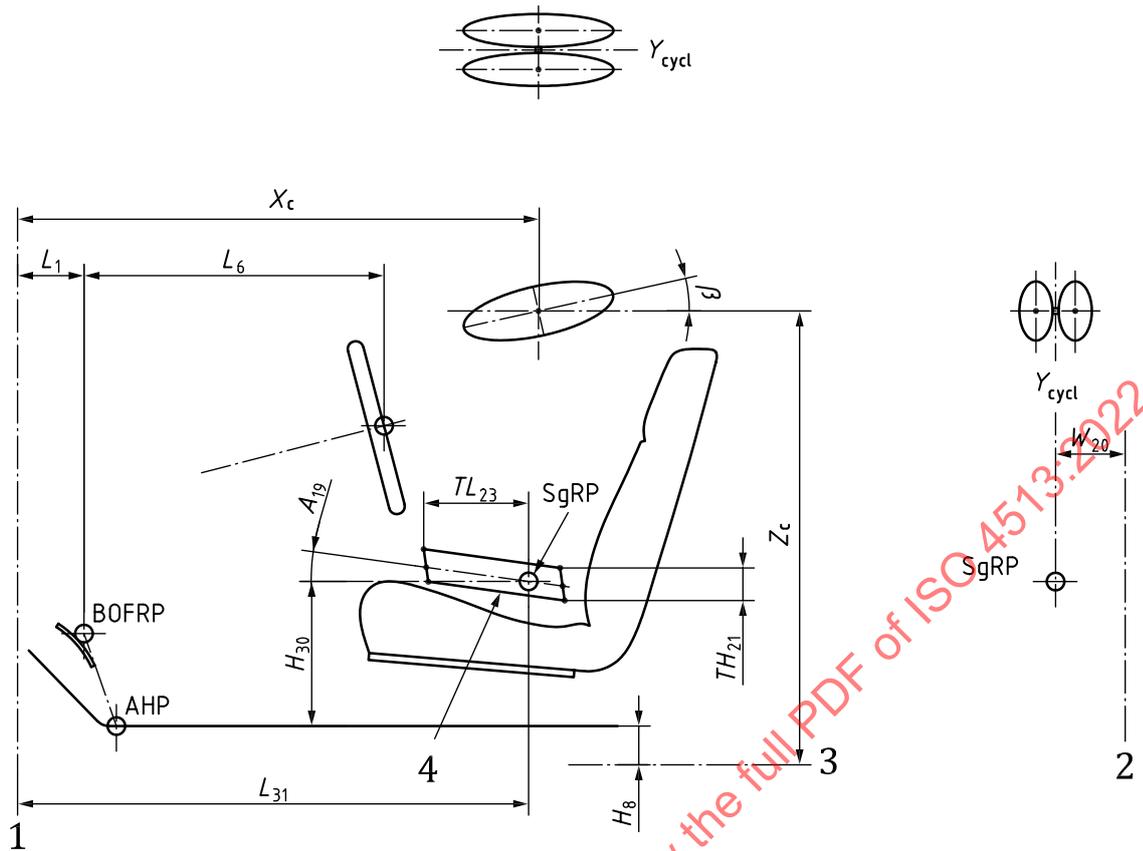
where

- L_1 is the x-coordinate of the BOFRP (L_1);
- L_6 is the x distance from the steering wheel centre to the BOFRP (L_6);
- H_{30} is the z distance of the SgRP from the AHP (H_{30});
- t is the transmission type (1 with clutch pedal, 0 without clutch pedal);
- W_{20} is the y-coordinate of the SgRP (W_{20});
- H_8 is the z-coordinate of the AHP (H_8).

4.4.2 Seats with vertical adjustment

For driver seats having vertical adjustment, [Formulae \(2\) to \(5\)](#) were developed with H30 (and SgRP) positioned at the middle of the vertical adjustment range. Typically, this was 20 mm to 25 mm vertically above the full down H-point travel path ([Figure 5](#)). If manufacturers define their SgRP so it is not 20 mm above the driver's full down H-point travel path, the accuracy in locating the vertical position of the eyellipse using the manufacturer's H30 dimension in [Formula \(5\)](#) is reduced. If the H-point vertical adjustment (TH21) is less than 40 mm, then H30 and the eyellipse Z centroid should be located from a point midway between the full up and full down travel path.

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Key

A_{19}	seat track rise	TL_{23}	seat track travel
AHP	accelerator heel point	W_{20}	y-coordinate of the SgRP
BOFRP	ball of foot reference point	X_c	x-coordinate of the eyellipse centroid location
H_8	z-coordinate of the AHP	Y_{cycl}	mid-eye y-coordinate
H_{30}	z distance of the SgRP from the AHP	Z_c	z-coordinate of the eyellipse centroid location
L_1	x-coordinate of the BOFRP	β	side view angle
L_6	x distance from the steering wheel centre to BOFRP	1	zero X grid
L_{31}	x-coordinate of the SgRP	2	zero Y grid
SgRP	seating reference point	3	zero Z grid
TH_{21}	H-point vertical adjustment	4	H-point travel path

Figure 5 — Eyellipse package factors, side view axis angle and centroid location

4.4.3 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 centreline at W_{20} .

5 Eyellipse locating procedure, Class A vehicles

The steps in the procedure are:

- a) determine seat characteristics A_{19} , W_{20} , H_{30} , TL_{23} ;
- b) determine H_8 and L_6 ;

- c) 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 $t = 0$;
- d) construct identical left and right eyellipses based on the axes given in [Table 2](#);
- e) locate the centroids using [Formulae \(2\) to \(5\)](#);
- f) tilt the front of the eyellipse X-axis down in side view according to [Formula \(1\)](#).

NOTE See [Annex E](#) for description of eyellipses for Class B vehicles.

6 Neck pivot (P) and eye (E) points: locating procedure, Class A vehicles¹⁾

6.1 Background

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 centre 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 eyellipse. P points were not developed for the 99th percentile eyellipse.

6.2 Neck pivot (P) points

Locate these points relative to the cyclopean (mid-eye) eyellipse centroid using values given in [Table 3](#) (see [Figure 2](#)).

The X, Y and Z values in [Table 3](#) may be added to [Formulae \(2\), \(3\), \(4\) and \(5\)](#), respectively, to obtain P point locations relative to the vehicle grid.

Table 3 — Neck pivot points relative to the 95th percentile eyellipse mid-eye centroid

Dimensions in millimetres

Seat track travel (TL23)	Neck pivot point (P points)	X	Y (Left-hand drive)	Y (Right-hand drive)	Z
>133	P1	0	-7,3	+7,3	-20,5
>133	P2	26,2	+20,6	-20,6	-20,5
>133	P3	191,0	-11,2	+11,2	+22,5
>133	P4	191,0	+11,2	-11,2	+22,5
<133	P1	16,3	-7,3	+7,3	-20,5
<133	P2	39,2	+20,6	-20,6	-20,5
<133	P3	175,0	-11,2	+11,2	+22,5
<133	P4	175,0	+11,2	-11,2	+22,5

NOTE Positive values of X are rearward of the centroid, positive values of Y are right of the centroid and positive values of Z are above the centroid.

6.3 Eye (E) points

Position the eye (E) points relative to the P points as shown in [Figure 3](#) and the following formulae:

$$E_x = P_x - 98 \tag{6}$$

1) P points cited in regulations differ from those in [6.1](#) if the regulations are based on ISO 4513:2003 or before. Use the regulatory P points for compliance purposes.

$$E_l = P_y - 32,5 \quad (7)$$

$$E_r = P_y + 32,5 \quad (8)$$

$$E_z = P_z \quad (9)$$

where

P_x is the x-coordinate of the P point;

P_y is the y-coordinate of the P point;

P_z is the z-coordinate of the P point;

E_x is the x-coordinate for the left and right eye point;

E_z is the z-coordinate for the left and right eye point;

E_l is the y-coordinate of the left eye;

E_r is the y-coordinate of the right eye.

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Annex A (informative)

Adjustable seat tangent cut-off eyellipses for any user population stature distribution and gender mix

A.1 General

In this annex, a procedure is given for constructing eyellipses for driver populations that are different from the standard population listed in [Table 1](#), because the underlying stature distribution is different, the gender mix is different, or a different tangent cut-off contour is desired. The user can apply the formulae given in this annex for gender mixes containing 10 % to 75 % females. For larger or smaller percentages of females in the driver population, the eyellipse side view axis angle and centroid Z location are incorrect.

A.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 in side view (Y-plane). In side view the angle of the eyellipse is given in [Formula \(A.1\)](#) (see [Figure 5](#)).

$$\beta = 18,6 - A_{19} \quad (\text{A.1})$$

where A_{19} is the seat track rise angle (A_{19}).

A.3 Reference centroid location

A.3.1 Locating formulae

The reference centroid for the normative part of this document, calculated using [Formulae \(A.2\)](#) to [\(A.4\)](#), is based on a driver population defined by NHANES III anthropometry (see Reference [17]) and consisting of 50 % males and 50 % females (see [Table 1](#)). The mean stature for this reference population is 1 686 mm. [A.6](#) describes how to adjust these formulae for other national driver populations.

$$X_{\text{cref}} = L_1 + 664 + 0,587 L_6 - 0,176 H_{30} - 12,5 t \quad (\text{A.2})$$

$$Y_{\text{cref}} = W_{20} \quad (\text{A.3})$$

$$Z_{\text{cref}} = H_8 + 638 + H_{30} \quad (\text{A.4})$$

where

L_1 is the x-coordinate of the BOFRP (L_1);

L_6 is the x distance from the steering wheel centre to the BOFRP (L_6);

W_{20} is the y-coordinate of the SgRP (W_{20});

H_8 is the z-coordinate of the AHP (H_8);

H_{30} is the z distance of the SgRP from the AHP (H_{30});

t is the transmission type (1 with clutch pedal, 0 without clutch pedal).

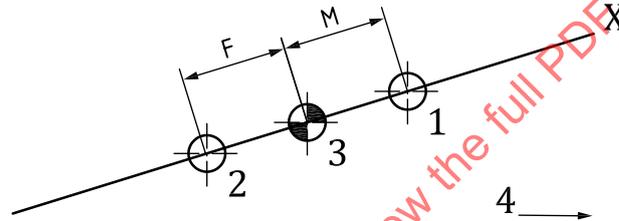
A.3.2 Seats with vertical adjustment

For driver seats having vertical adjustment, [Formulae \(A.2\)](#) to [\(A.4\)](#) were developed with H_{30} defined approximately 20 mm above the driver's full down H-point travel path (see [Figure 5](#)). If manufacturers define their SgRP at a vertical position that is not 20 mm above the full down H-point travel path, the accuracy in locating the vertical position of the eyellipse is reduced. If the H-point vertical adjustment (TH21) is less than 40 mm, then H_{30} and the eyellipse Z centroid should be located from a point midway between the full up and full down travel path.

A.4 Axis lengths

A.4.1 X-axis length

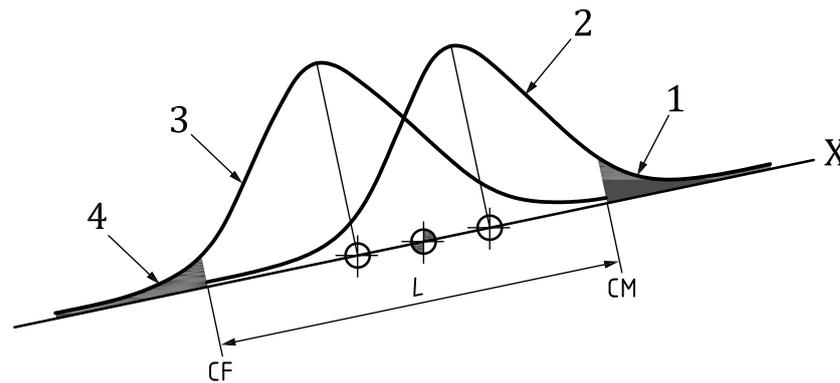
In this subclause the term side view axis length refers to the true length of the eyellipse X-axis, not the horizontal length in side view. [Figures A.1](#) and [A.2](#) illustrate the calculation of side view axis length.



Key

- X eyellipse X-axis
- 1 male centroid
- 2 female centroid
- 3 reference centroid
- 4 rearward

Figure A.1 — Side view location of the male and female eye centroids relative to the reference centroid

**Key**

- L length of eyellipse X-axis
- X eyellipse X-axis
- 1 excluded fraction of males
- 2 distribution of male eye locations
- 3 distribution of female eye locations
- 4 excluded fraction of females

Figure A.2 — Determination of eyellipse X-axis end points and 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 have, on average, 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 have, on average, 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 also differ in average location along the side view axis.

In addition, the variability of the underlying stature distributions should be taken into account. The process of determining eyellipse X-axis length involves constructing the population eye location distribution along that axis and then finding the upper and lower cut-off 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 eye centroid calculated from [Formulae \(A.2\)](#) to [\(A.4\)](#) is treated as the zero point along the side view axis, and the boundaries are calculated as offsets from the reference. First, the centroids of the male and female eye distributions along the side view eyellipse axis, M and F , respectively, are calculated relative to the reference eye centroid using [Formulae \(A.5\)](#) and [\(A.6\)](#).

$$M = 0,473(S_M - S_R) \quad (\text{A.5})$$

$$F = 0,473(S_F - S_R) \quad (\text{A.6})$$

where

S_M is the mean male stature;

S_F is the mean female stature;

S_R is the mean stature of the reference driver population.

The standard deviation of each component distribution is calculated using [Formulae \(A.7\)](#) and [\(A.8\)](#).

$$\sigma_{EM} = \sqrt{0,473^2 \sigma_M^2 + 41,87^2} \quad (A.7)$$

$$\sigma_{EF} = \sqrt{0,473^2 \sigma_F^2 + 41,87^2} \quad (A.8)$$

where

- σ_{EM} is the standard deviation of the male eye location distributions along the side view axis;
- σ_{EF} is the standard deviation of the female eye location distributions along the side view axis;
- σ_M is the standard deviation of the male stature distribution;
- σ_F is the standard deviation of the female stature distribution.

The two means and standard deviations define two overlapping normal distributions along the side view eyellipse X-axis (see [Figure A.2](#)). These may then be used with [Formulae \(A.9\)](#) and [\(A.10\)](#) to determine lower (forward) and upper (rearward) eyellipse boundaries.

$$1 - q = p_M \times \Phi \left(\frac{b_{f,c} - M}{\sigma_{EM}} \right) + (1 - p_M) \times \Phi \left(\frac{b_{f,c} - F}{\sigma_{EF}} \right) \quad (A.9)$$

$$q = p_M \times \Phi \left(\frac{b_{re,c} - M}{\sigma_{EM}} \right) + (1 - p_M) \times \Phi \left(\frac{b_{re,c} - F}{\sigma_{EF}} \right) \quad (A.10)$$

where

- p_M is the proportion of males in the population;
- $b_{f,c}$ is the forward boundary of the eyellipse along the side view axis, relative to the reference centroid;
- $b_{re,c}$ is the rearward boundary of the eyellipse along the side view axis, relative to the reference centroid;
- q is the eyellipse cut-off percentile;
- Φ is the cumulative normal distribution;
- M is the mean male eye centroid along the side view axis, relative to the reference centroid;
- F is the mean female eye centroid along the side view axis, relative to the reference centroid;
- σ_{EM} is the standard deviation of the male eye location distribution along the side view axis;
- σ_{EF} is the standard deviation of the female eye location distribution along the side view axis.

To find the upper and lower boundaries of the eyellipse along the side view axis, [Formulae\(A.9\)](#) and [\(A.10\)](#) should be solved iteratively for $b_{f,c}$ and $b_{re,c}$. Breaking the formula down, the portion inside parentheses that appears twice in each formula 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 [Formula \(A.9\)](#), for example, there is an expression for the proportion of the female population whose eyes lie below the lower cut-off, and an expression for the proportion of the male population whose eyes lie below the lower cut-off. 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 the X-axis length, $X_{a,l}$, which is simply the difference between $b_{re,c}$ and $b_{f,c}$.

$$X_{a,l} = b_{re,c} - b_{f,c} \quad (A.11)$$

where

$b_{f,c}$ is the forward boundary of the eyellipse along the side view axis, relative to the reference centroid;

$b_{re,c}$ is the rearward boundary of the eyellipse along the side view axis, relative to the reference centroid.

A.4.2 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 cut-off percentile. The distributions along these two axes are modelled 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 cut-off points that exclude the appropriate proportion of the population. [Formulae \(A.12\)](#) and [\(A.13\)](#) contain the specific formulae.

$$Y_{a,l} = 18,34 \times [\Phi^{-1}(q) - \Phi^{-1}(1-q)] \quad (A.12)$$

$$Z_{a,l} = 28,39 \times [\Phi^{-1}(q) - \Phi^{-1}(1-q)] \quad (A.13)$$

where

q is the eyellipse cut-off percentile;

Φ^{-1} is the inverse cumulative normal distribution.

A.5 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 should be computed according to [Formulae \(A.14\)](#) to [\(A.16\)](#). These formulae place the final centroid in vehicle grid at the midpoint between the two side view axis cut-off points and along the centreline of occupant.

$$X_c = X_{cref} + \frac{b_{f,c} + b_{re,c}}{2} \times \cos \beta \quad (A.14)$$

$$Y_c = Y_{cref} \quad (A.15)$$

$$Z_c = Z_{cref} + \frac{b_{f,c} + b_{re,c}}{2} \times \sin \beta \quad (A.16)$$

where

$b_{f,c}$ is the forward boundary of the eyellipse along the side view axis, relative to the reference centroid;

$b_{re,c}$ is the rearward boundary of the eyellipse along the side view axis, relative to the reference centroid.

A.6 Eyellipses for selected world populations

Stature values given in [Table A.1](#) may be used to construct eyellipses for the specified populations by using the formulae given in this annex.

CAUTION — These eyellipses have not been verified by field testing.

Table A.1 — Population anthropometry

Dimensions in millimetres

Country	Gender	Mean stature	Standard deviation of stature	Mean seated height
USA (reference)	Males	1 755	74,2	922,1
	Females	1 618	68,7	859,7
Japan	Males	1 672,7	62,4	901,3
	Females	1 544,8	61,2	838,4
Netherlands	Males	1 806,2	80	944
	Females	1 690	70	887

NOTE Data for Japan supplied by Toyota; data for Netherlands supplied by TNO; data for USA from Reference [17].

A.6.1 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 A.2](#).

Table A.2 — Left and right eyellipse axis lengths

Country	Percentile	X-axis length mm	Y-axis length mm	Z-axis length mm
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
Reference (Table 1)	95	206,4	60,3	93,4
	99	287,1	85,3	132,1

NOTE The difference in X-axis lengths among the reference population, Japanese and Dutch populations is very small, indicating that the 95th or 99th percentile eyellipses given in [Table 2](#) are sufficient for most design purposes.

A.6.2 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 likely require an adjustment to the location of their eyellipse centroid. Testing with Japanese drivers is necessary to derive or validate a formula for locating the centroid.

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

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 country's population to seated heights of the reference population, as follows:

$$Z_{\text{cref}} = H_8 + H_{30} + 638 \frac{h_T}{h_R} \tag{A.17}$$

where

- H_8 is the z-coordinate of the AHP (H_8);
- H_{30} is the z distance of the SgRP from the AHP (H_{30});
- h_T is the target population mean seated height;
- h_R is the reference population mean seated height.

Adjust the eyellipse centroid X value from the BOFRP using [Formula \(A.5\)](#) (which is based on the difference between average stature of the target population and average stature of the reference population), as follows:

$$X_{\text{cref}} = L_1 - 12,5t + (664 + 0,587 L_6 - 0,176 H_{30}) + 0,473 (S_T - S_R) \cos \beta \quad (\text{A.18})$$

where

- L_1 is the x-coordinate of the BOFRP (L_1);
- t is the transmission type (1 with clutch pedal, 0 without clutch pedal);
- L_6 is the x distance from the steering wheel centre to the BOFRP (L_6);
- H_{30} is the z distance of the SgRP from the AHP (H_{30});
- S_T is the target population mean stature;
- S_R is the reference population mean stature.

[Table A.3](#) gives the adjustments in centroid location from the reference centroid for a population having an equal mix of males and females, using anthropometry values from [Table A.1](#) and [Formulae \(A.17\)](#) and [\(A.18\)](#).

Table A.3 — Change in eyellipse centroid location (50 % male population)

Dimensions in millimetres

Country	X	Y	Z
Japan	-37	0	-15
Netherlands	29	0	18
NOTE Positive numbers are rearward and up from reference centroid.			

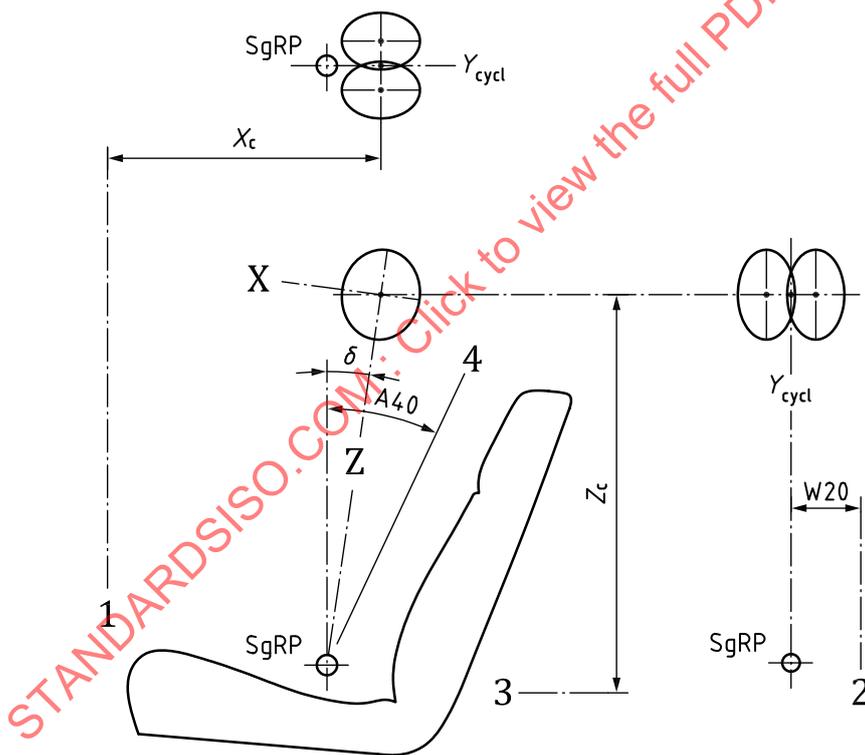
Annex B (informative)

Fixed seat 95th and 99th percentile tangent cut-off eyellipses for an adult population at a 50/50 gender mix

B.1 Background

Fixed seat eyellipses apply to seated positions with no H-point or torso 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 torso angle, A_{40} . Other seat adjustments are assumed fixed at the manufacturer's design specifications.

These eyellipses are based on the user populations described in [Table 1](#). The 95th and 99th percentile eyellipses are constructed from tables and equations described in [B.2](#) and [B.3](#). Fixed seat eyellipses for other percentile tangent cut-offs and gender mixes can be calculated using procedures in [Annex C](#).



Key

X	eyellipse X-axis	1	zero X grid
Z	H-point to eye line (eyellipse Z-axis)	2	zero Y grid
δ	angle of the eyellipse Z-axis from vertical	3	zero Z grid
X_c	x-coordinate of the eyellipse centroid location	4	torso line
Y_{cycl}	mid-eye y coordinate		
Z_c	z-coordinate of the eyellipse centroid location		

Figure B.1 — Fixed seat eyellipse side view axis angle and centroid location

B.2 Axis angles

B.2.1 Plan and rear view axis angles

The eyellipse is aligned with the vehicle axes in plan view (Z-plane) and rear view (X-plane).

B.2.2 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 side view angle of the eyellipse Z-axis, positive, tipped back at the top from vertical, δ , in degrees, depends on the torso angle (see [Formula B.1](#) and [Figure B.1](#)).

$$\delta = 0,698 \times A_{40} - 9,09 \quad (\text{B.1})$$

where A_{40} is the torso angle (A40).

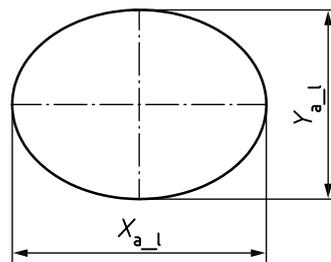
NOTE The dimension code for torso angle depends on the passenger seat position under study. A40-2 refers to passenger second row seating and A40-3 refers to passenger third row seating as defined in SAE J1100.

B.3 Axis lengths

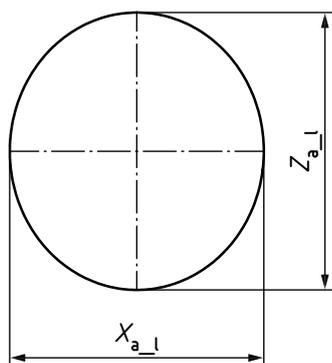
Axis lengths are shown in [Figure B.2](#) and listed in [Table B.1](#).

Table B.1 — Fixed seat eyellipse axis lengths

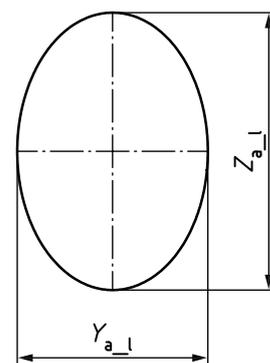
Percentile	X-axis length mm	Y-axis length mm	Z-axis length mm
95	93,5	104,1	130,7
99	132,3	147,3	179,0



a) Plan view



b) Side view



c) Rear view

Key

- $X_{a,l}$ X-axis length
- $Y_{a,l}$ Y-axis length
- $Z_{a,l}$ Z-axis length

Figure B.2 — Fixed seat tangent cut-off eyellipse for one eye — True views

B.4 Centroid location

B.4.1 Locating formulae

Formulae (B.2), (B.3), and (B.4) are used to calculate the eyellipse centroid location. Laterally, the cyclopean (mid-eye) location, Y_{cycl} , is at W_{20} , which normally coincides with the seat centreline (see Figure B.1). In side view the centroid is located to vehicle grid using L_{31} for SgRP x-coordinate and H_{70} for SgRP z-coordinate.

$$X_c = L_{31} + 619 \times \sin \delta \tag{B.2}$$

$$Y_{cycl} = W_{20} \tag{B.3}$$

$$Z_c = H_{70} + 619 \times \cos \delta \tag{B.4}$$

where

- L_{31} is the SgRP x-coordinate (L_{31});
- W_{20} is the SgRP y-coordinate (W_{20});
- H_{70} is the SgRP z-coordinate (H_{70});
- δ is the side view angle of the eyellipse Z-axis, in degrees (positive, tipped back at the top from vertical).

NOTE The dimension codes selected for SgRP coordinates (to grid) depend on passenger seat position under study: L_{31-2} , W_{20-2} and H_{70-2} refer to second row passenger seating; L_{31-3} , W_{20-3} , and H_{70-3} refer to third row passenger seating.

B.4.2 Left and right centroids

The left and right eyellipse centroids are 65 mm apart, 32,5 mm either side of the mid-eye location.

B.5 Seats with limited H-point adjustment

If a second or succeeding row seat has fore and aft H-point adjustment, with a back angle that is either fixed or adjustable, there are no field data available on which to base a procedure for selecting or locating an eyellipse. Until such data are available, select the 95 % fixed seat eyellipse, locate it from the manufacturer's SgRP and torso angle, and then sweep the eyellipse along the range of normal riding fore and aft seat adjustment. The swept volume defines the range of rider eye locations. If the manufacturer's SgRP or torso angle is unknown, use the rearmost, lowest normal riding position and a torso angle of 25°.

Annex C (informative)

Fixed seat tangent cut-off eyellipses for any user population stature distribution and gender mix

C.1 General

Fixed seat eyellipses should be calculated from equations given in this annex when the user population is different from the reference population listed in [Table 1](#), because the underlying stature distribution is different, the gender mix is different, or a unique cut-off contour is needed.

C.2 Axis angles

C.2.1 Plan and rear view 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.2.2 Side view angle

The side view angle of the eyellipse Z-axis (positive, tipped back at the top from vertical), δ , in degrees, depends on the torso angle (see [Figure B.1](#)):

$$\delta = 0,698 \times A_{40} - 9,09 \quad (\text{C.1})$$

where A_{40} is the torso angle (A40).

C.3 Axis lengths

C.3.1 Eyellipse Z-axis length

The following calculations are required to determine the Z-axis length.

C.3.1.1 Mean male and female H-point-to-eye distances

These values are calculated from the mean statures for the selected male and female population. [Formulae \(C.2\)](#) and [\(C.3\)](#) are used to calculate the H-point-to-eye distance.

$$h_M = 67,0 + 0,351 S_M - 1,613 A_{40} \quad (\text{C.2})$$

$$h_F = 67,0 + 0,351 S_F - 1,613 A_{40} \quad (\text{C.3})$$

where

S_M is the mean population stature for males;

S_F is the mean population stature for females;

h_M is the mean H-point-to-eye distance for males;

h_F is the mean H-point-to-eye distance for females;

C.3.1.2 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 [Formulae \(C.4\)](#) and [\(C.5\)](#). The mean and standard deviation of the 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.

$$\sigma_{HM} = \sqrt{0,351^2 \sigma_{S_M}^2 + 384} \quad (C.4)$$

$$\sigma_{HF} = \sqrt{0,351^2 \sigma_{S_F}^2 + 384} \quad (C.5)$$

where

σ_{HM} is the standard deviation of H-point-to-eye distance along the eyellipse Z-axis for males;

σ_{HF} is the standard deviation of H-point-to-eye distance along the eyellipse Z-axis for females;

$\sigma_{S_M}^2$ is the variance of stature for males;

$\sigma_{S_F}^2$ is the variance of stature for females.

C.3.1.3 Eyellipse Z-axis boundary and length

The steps so far are similar to the procedure used to construct the adjustable seat eyellipse, described in [Annex A](#). As in that procedure, the primary axis length (in this case, the eyellipse Z-axis) is calculated by determining the cut-off values at the upper and lower ends of the distribution. To do this, [Formulae \(C.6\)](#) and [\(C.7\)](#) should be solved iteratively for $b_{lo,Z}$ and $b_{u,Z}$.

$$1 - q = p_M \times \Phi \left(\frac{b_{lo,Z} - h_M}{\sigma_{HM}} \right) + (1 - p_M) \times \Phi \left(\frac{b_{lo,Z} - h_F}{\sigma_{HF}} \right) \quad (C.6)$$

$$q = p_M \times \Phi \left(\frac{b_{u,Z} - h_M}{\sigma_{HM}} \right) + (1 - p_M) \times \Phi \left(\frac{b_{u,Z} - h_F}{\sigma_{HF}} \right) \quad (C.7)$$

where

p_M is the proportion of males in the population;

$b_{lo,Z}$ is the lower boundary of the eyellipse along the Z-axis;

$b_{u,Z}$ is the upper boundary of the eyellipse along the Z-axis;

q is the eyellipse cut-off percentile;

Φ is the cumulative normal distribution;

h_M is the mean H-point-to-eye distance for males;

h_F is the mean H-point-to-eye distance for females;

σ_{HM} is the standard deviation of H-point-to-eye distance along the eyellipse Z-axis for males;

σ_{HF} is the standard deviation of H-point-to-eye distance along the eyellipse Z-axis for females.

The length of the primary eyellipse axis (Z) is the difference between the upper and lower boundaries of H-point-to-eye distance, $b_{u,Z}$ and $b_{lo,Z}$.

$$Z_{a,1} = b_{u,Z} - b_{lo,Z} \quad (C.8)$$

where

$b_{lo,Z}$ is the lower boundary of the eyellipse along the Z-axis;

$b_{u,Z}$ is the upper boundary of the eyellipse along the Z-axis.

C.3.2 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 2,63°. Thus, boundary angles can be computed using the normal distribution with mean δ and standard deviation 2,63. A radius at each boundary angle with length equal to the mean H-point-to-eye distance ends at the X-axis boundary of the fixed seat eyellipse. These radii are shown in [Figure C.1](#) 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 subclause is expressed mathematically in [Formula \(C.9\)](#) for a q-percentile ellipse.

$$X_{a,1} = \left(\frac{b_{u,Z} + b_{lo,Z}}{2} \right) \left(\frac{\pi}{180} \right) [2,63 \times 2 \Phi^{-1}(q)] \quad (C.9)$$

where

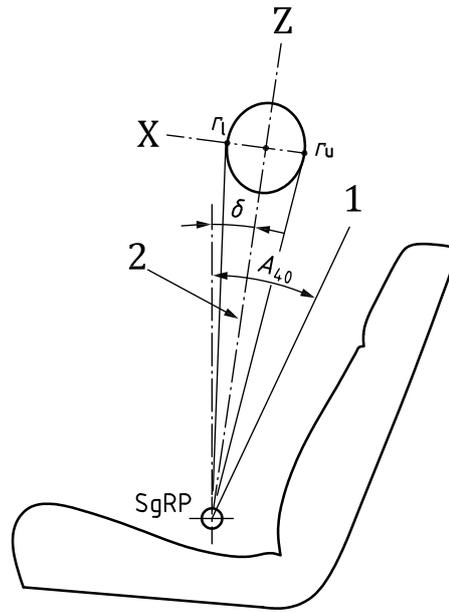
$b_{lo,Z}$ is the lower boundary of the eyellipse along the Z-axis;

$b_{u,Z}$ is the upper boundary of the eyellipse along the Z-axis;

Φ^{-1} is the inverse cumulative normal distribution;

q is the eyellipse cut-off percentile;

π is the ratio of the circumference to the diameter of a circle, the transcendental number 3,141 592 6...



Key

- $A_{4,0}$ torso angle
- r_l, r_u radii defining eyellipse X-axis length
- X eyellipse X-axis
- Z eyellipse Z-axis
- δ angle of eyellipse Z-axis
- 1 torso line
- 2 H-point to eye line

Figure C.1 — Fixed seat eyellipse side view, (X, Z) axis, and axis angle, δ

C.3.3 Eyellipse 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 modelled as a normal distribution with a fixed standard deviation of 31,65 mm, regardless of population anthropometry (see Reference [11]). Thus, [Formula \(C.10\)](#) gives the Y-axis length as a function of eyellipse percentile q .

$$Y_{a,l} = 31,65 \times 2\Phi^{-1}(q) \tag{C.10}$$

where

- Φ^{-1} is the inverse cumulative normal distribution;
- q is the eyellipse cut-off percentile.

C.4 Centroid location

The centroid of the fixed seat eyellipse is the midpoint between the two H-point-to-eye boundary points, along the primary axis and at the occupant centreline. [Formulae \(C.11\)](#) to [\(C.13\)](#) give the centroid location relative to SgRP in the vehicle axis system.

$$X_c = \frac{b_{u,Z} + b_{lo,Z}}{2} \times \sin \delta \tag{C.11}$$

$$Y_c = 0 \quad (C.12)$$

$$Z_c = \frac{b_{u,Z} + b_{l,Z}}{2} \times \cos \delta \quad (C.13)$$

where

$b_{l,Z}$ is the lower boundary of the eyellipse along the Z-axis;

$b_{u,Z}$ is the upper boundary of the eyellipse along the Z-axis;

δ is the side view eyellipse angle, in degrees (positive, tipped back at the top from vertical).

C.5 Summary

[Formulae \(C.6\)](#) to [\(C.13\)](#) 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 torso angle. Whereas the adjustable seat eyellipse is defined relative to the ball of foot reference point (BOFRP), the fixed seat eyellipse is expressed relative to SgRP, because the H-point is stationary when the seat and seatback are fixed (see [Annex B](#)).

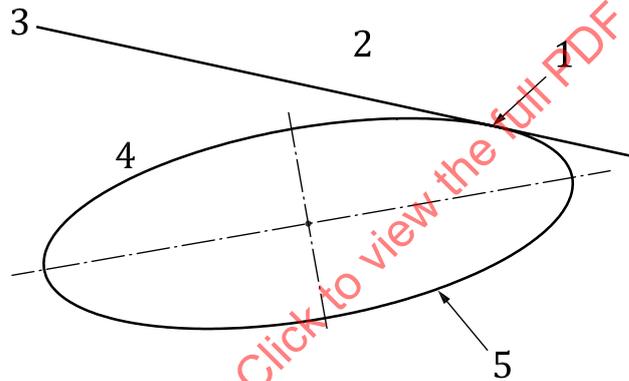
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Annex D (informative)

Tangent cut-off eyellipses and inclusive eyellipses

D.1 Tangent cut-off eyellipse

Tangent cut-off eyellipses are derived as the perimeter of an envelope formed by an infinite number of planes dividing the eye locations so that P % of the eyes are on one side of the plane and $(100 - P)$ % are on the other. 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, are below the line and 5 % of the eye locations are above it. 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, are above the line and 5 % below it.



Key

- 1 tangent point
- 2 5 % of the driver eye locations are on this side of the tangent plane
- 3 tangent line for 2-D; or tangent cut-off plane for 3-D
- 4 95 % of the driver eye locations are on this side of the tangent plane (both inside and outside the ellipse)
- 5 95 % eyellipse

Figure D.1 — Tangent cut-off line/plane description

For example, if the tangent line shown in [Figure D.1](#) 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 cut-off ellipse.

Tangent cut-off eyellipses presented in previous clauses and annexes 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

D.2.1 General

There may, however, be some applications for which it is useful to define an ellipse that encloses or contains the eye locations of some designated proportion of drivers. A 95th percentile tangent cut-off eyellipse does not enclose 95 % of the eye locations within the ellipse.

Each tangent cut-off eyellipse is also an inclusive eyellipse, i.e. it defines a boundary within which lie a certain percentage of drivers' eyes. The percentage of the population included within any ellipse is always less than the tangent cut-off percentage for that ellipse. For example, a 95 % tangent cut-off eyellipse contains 74 % of the eye locations within its two-dimensional boundaries and 56 % of the eye locations within its three-dimensional boundaries. [Table D.1](#) lists a number of inclusive ellipses and their corresponding tangent cut-off eyellipse percentiles.

D.2.2 Axis lengths for inclusive ellipse, adjustable seat

Axis lengths for an inclusive eyellipse are given in the three rightmost columns of [Table D.1](#) for the reference driver population (see [Table 1](#)) containing an equal number of males and females.

Table D.1 — Tangent cut-off eyellipse percentiles and corresponding 2D and 3D inclusive eyellipse percentiles, adjustable seat

2D inclusive (side view) %	3D inclusive %	Tangent cut-off %	X-axis length ^a mm	Y-axis length ^a mm	Z-axis length ^a mm
31,80	13,14	80,00	107,6	30,9	47,8
42,18	21,39	85,00	132,0	38,0	58,8
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

^a Axis lengths are shown for adjustable seat eyellipses, TL23 > 133 mm, 50/50 gender mix, reference driver population.

[Table D.1](#) may also be applied to define tangent cut-off eyellipses smaller than the 95th percentile. As an example, if it is necessary to determine driver accommodation to a specific vision target that is obscured to more than 5 % of drivers (e.g. by the windshield header), a smaller percentile cut-off eyellipse could be found (using [Table D.1](#)) for which a tangent from this eyellipse to the target is tangent to or below the header obstruction.

D.2.3 Axis lengths for inclusive ellipse, fixed seat

Axis lengths for an inclusive eyellipse are given in the three rightmost columns of [Table D.2](#) for the reference driver population (see [Table 1](#)) containing an equal number of males and females.