# INTERNATIONAL STANDARD

# ISO 4513

Third edition
2010-05-15

## 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*

Reference number
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# Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 4513 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 17, *Visibility*.

This third edition cancels and replaces the second edition (ISO 4513:2003), which has been technically revised.

# Introduction

This International Standard 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 International Standard;

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 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 equations 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).

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

## 1 Scope

This International Standard 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 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 International Standard 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 referenced documents are indispensable for the application 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 following terms given in ISO 6549 apply:

a) H-point;

b) seating reference point, SgRP.

For the purposes of this document the following terms given in SAE J1100 apply:

1) ball of foot reference point (BOFRP);

2) accelerator heel point (AHP);

NOTE For applications using the H-point machine described in ISO 6549, the term “operator heel point” is used instead of “accelerator heel point”.

3) Class A and Class B vehicles;

4) H-point travel path, TL23, TH21;

5) A19 — Seat track rise;

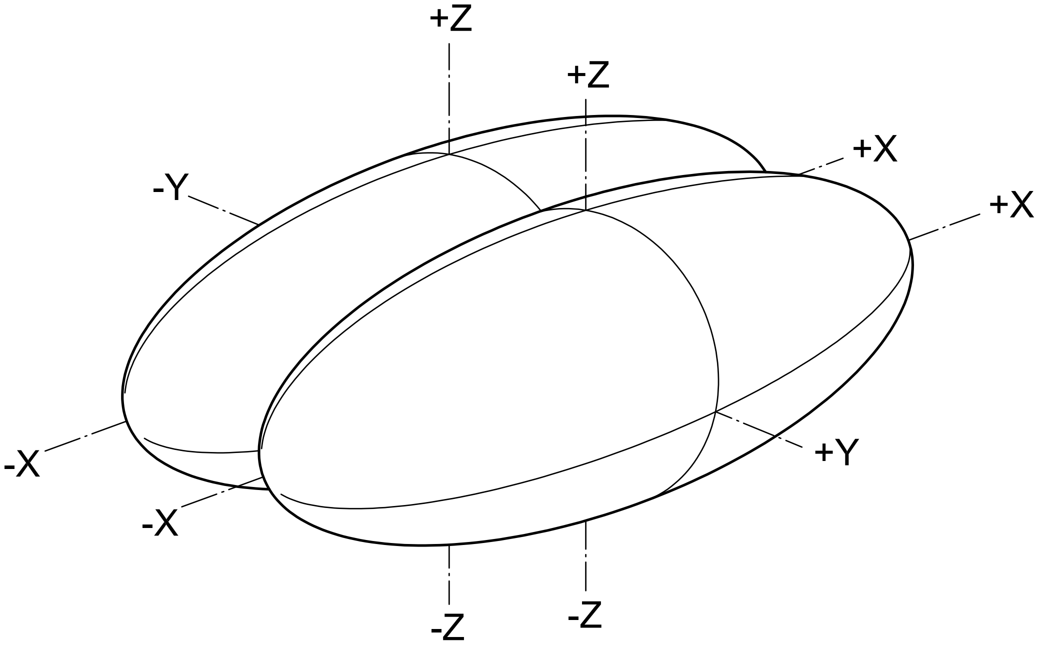
6) H30 — Seat height;

7) L6 — Ball of foot reference point (BOFRP) to steering wheel centre.

For the purposes of this document the following definitions apply.

**3.1**
**eyellipse**
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.




**Key**

X, Y, Z ellipse axes

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

**3.2**
**cyclopean eye point**
**mid-eye point**
midpoint between left and right eye points or left and right eyellipse centroids at centreline of occupant

**3.3**
**tangent cut-off plane**
plane tangent to an eyellipse

NOTE 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

See Annex D.

**3.5**
**neck pivot point**
**P point**
point about which a driver's head turns on a horizontal plane

See Figure 2.

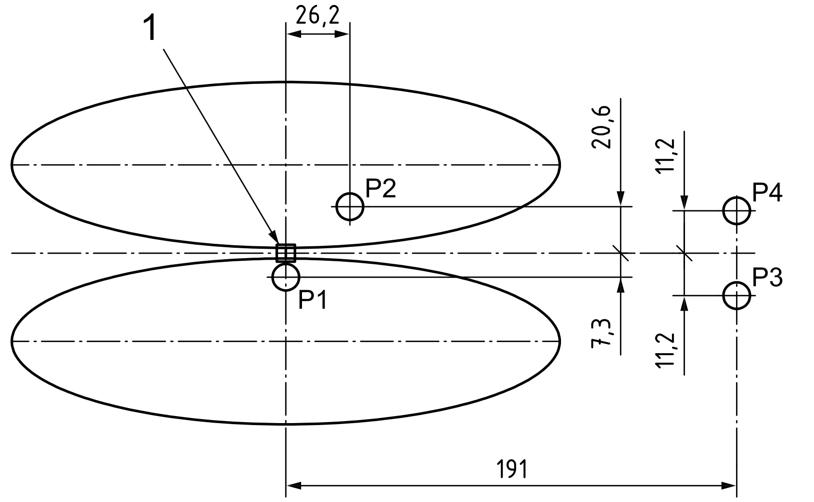
**3.6**
**point P1**
**point P2**
neck (head) pivot points used to position eye points for measuring the driver binocular obstruction due to A-pillars at the left and right side of the vehicle

See Figure 2.

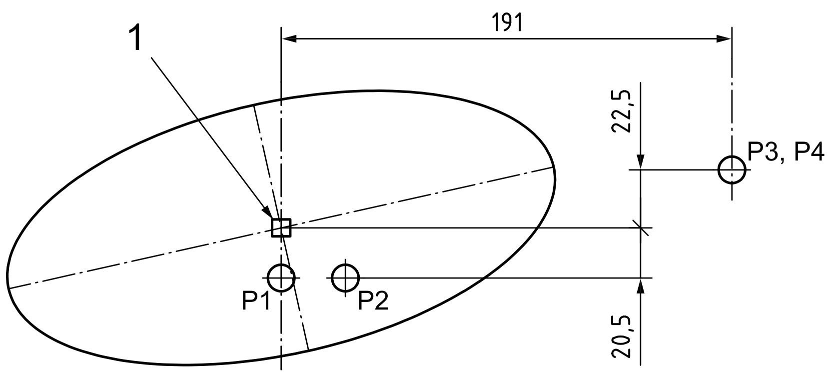
**3.7**
**point P3**
**point P4**
neck (head) pivot points used to position eye points for measuring driver field of view from rearview mirrors located to the left and right of the driver

See Figure 2.

Dimensions in millimetres




**a) Plan view**




**b) Side view**

**Key**

1 mid-eye centroid

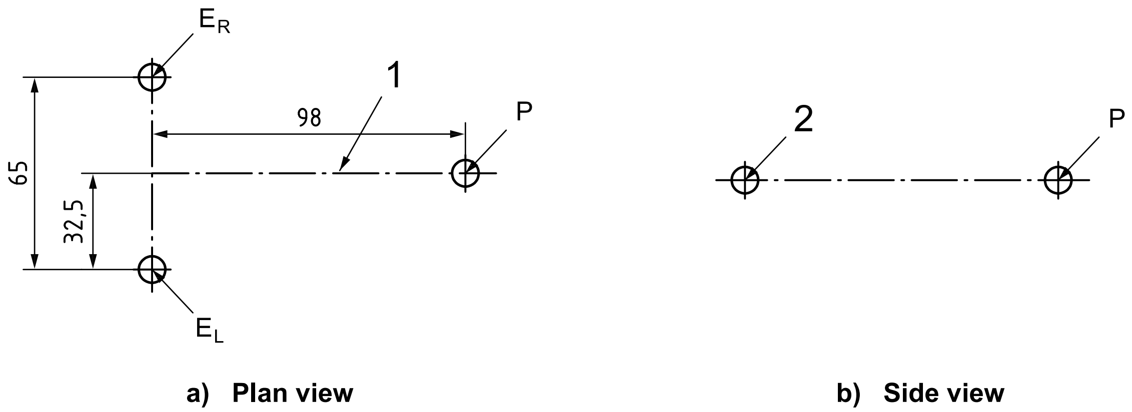
NOTE Eyellipses are shown for reference purposes only.

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

**3.8**
**eye point**
**E point**
point representing an eye of the driver, used in conjunction with a neck pivot point to describe specific viewing tasks

See Figure 3.

Dimensions in millimetres




**Key**

$E_L$ left eye

$E_R$ right eye

P neck pivot point

1 driver head centreline

2 line, viewed end on, between $E_L$ and $E_R$

**Figure 3 — Neck pivot point and associated eye points**

**3.9**
**inclusive eyellipse**
eyellipse that contains a specified percentage of drivers' eyes within its boundaries

## 4 Adjustable seat 95th and 99th percentile tangent cut-off eyellipses for a 50/50 male and female gender mix

### 4.1 Reference anthropometry

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** (see Reference [17])

Dimensions in millimetres

| Gender | Mean stature | Standard deviation of stature |
|---|---|---|
| Male | 1 755 | 74,2 |
| Female | 1 618 | 68,7 |
| NOTE 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 95th and 99th percentile tangent cut-off eyellipses for a 50/50 gender mix are constructed from tables and equations given in 4.2 to 4.3.2. These eyellipses are applicable to driver and front outboard passenger seat locations.

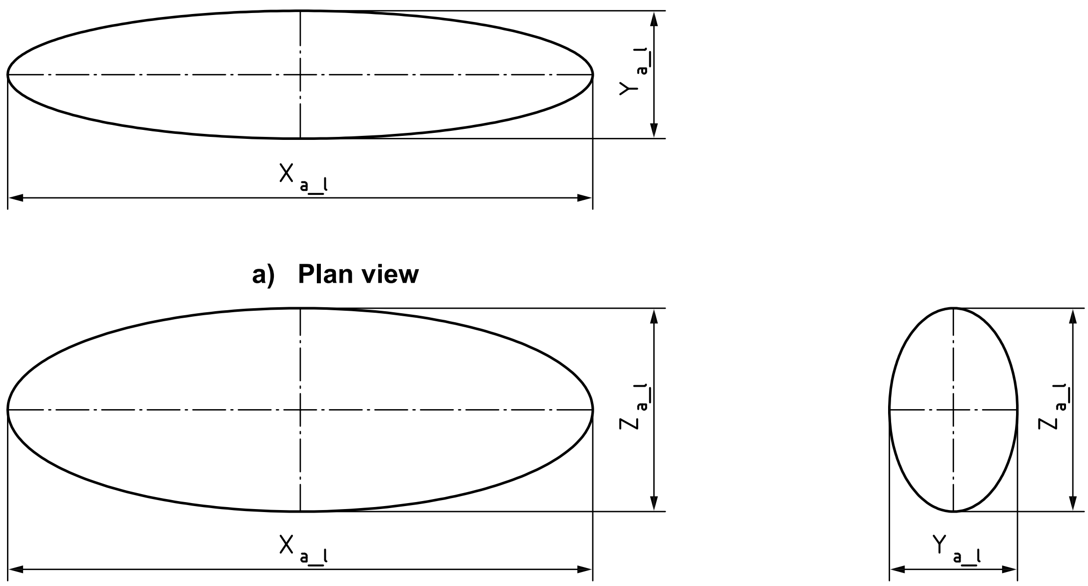
## 4.2 Axis lengths

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

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

| Seat track travel (TL23)<br>mm | Percentile | X-axis length<br>mm | Y-axis length<br>mm | Z-axis length<br>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.




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 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, $\beta$

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

$$\beta = 12{,}0 \quad (1)$$

### 4.4 Centroid locations

#### 4.4.1 Locating equations

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

$$X_c = L1 + 664 + 0{,}587\ L6 - 0{,}176\ H30 - 12{,}5\ t \quad (2)$$

$$Y_{cL} = W20 - 32{,}5 \quad (3)$$

$$Y_{cR} = W20 + 32{,}5 \quad (4)$$

$$Z_c = H8 + 638 + H30 \quad (5)$$

where

L1 is the x-coordinate of the BOFRP;

L6 is the x distance from the steering wheel centre to the BOFRP;

H30 is the z distance of the SgRP from the AHP;

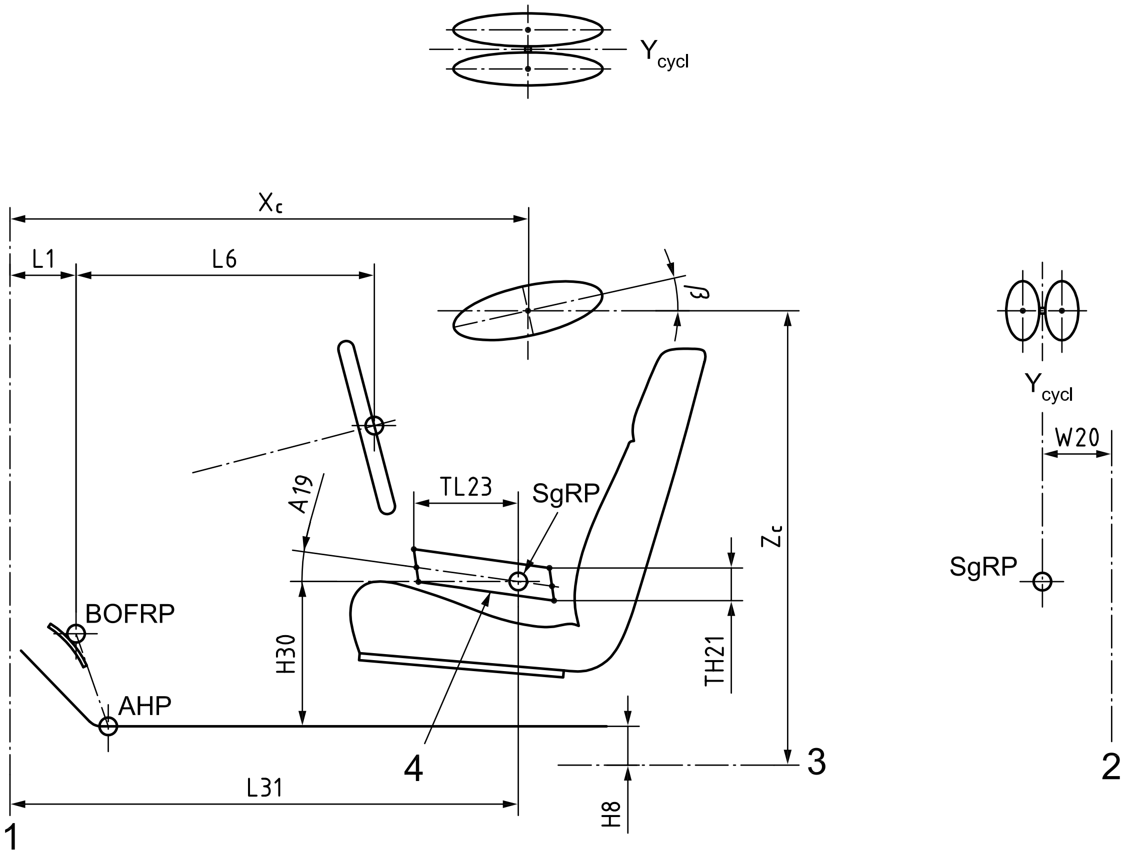
t is the transmission type (1 with clutch pedal, 0 without clutch pedal);

W20 is the y-coordinate of the SgRP;

H8 is the z-coordinate of the AHP.

#### 4.4.2 Seats with vertical adjustment

For driver seats having vertical adjustment, Equations (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 Equation (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.




**Key**

| | | | |
|---|---|---|---|
| A19 | seat track rise | TL23 | seat track travel |
| AHP | accelerator heel point | W20 | y-coordinate of the SgRP |
| BOFRP | ball of foot reference point | $X_c$ | x-coordinate of the eyellipse centroid location |
| H8 | z-coordinate of the AHP | $Y_{cycl}$ | mid-eye y-coordinate |
| H30 | z distance of the SgRP from the AHP | $Z_c$ | z-coordinate of the eyellipse centroid location |
| L1 | x-coordinate of the BOFRP | $\beta$ | side view angle |
| L6 | x distance from the steering wheel centre to BOFRP | 1 | zero X grid |
| L31 | x-coordinate of the SgRP | 2 | zero Y grid |
| SgRP | seating reference point | 3 | zero Z grid |
| TH21 | 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 W20.

## 5 Eyellipse locating procedure, Class A vehicles

The steps in the procedure are:

a) determine seat characteristics A19, W20, H30, TL23;

b) determine H8 and L6;

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 Equations (2) to (5);

f) 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[1)]

## 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 Equations (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. | | | | | |

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.

### 6.3 Eye (E) points

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

$$E_x = P_x - 98 \quad (6)$$

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

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

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

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.

# 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 equations 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 Equation (A.1) (see Figure 5).

$$\beta = 18{,}6 - \text{A19} \quad \text{(A.1)}$$

where A19 is the seat track rise angle.

## A.3 Reference centroid location

### A.3.1 Locating equations

The reference centroid for the normative part of this International Standard, calculated using Equations (A.2) to (A.4), is based on a driver population defined by NHANES III anthropometry (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 equations for other national driver populations.

$$X_{\text{cref}} = \text{L1} + 664 + 0{,}587\ \text{L6} - 0{,}176\ \text{H30} - 12{,}5\ \text{t} \quad \text{(A.2)}$$

$$Y_{\text{cref}} = \text{W20} \quad \text{(A.3)}$$

$$Z_{\text{cref}} = \text{H8} + 638 + \text{H30} \quad \text{(A.4)}$$

where

L1 is the x-coordinate of the BOFRP;

L6 is the x distance from the steering wheel centre to the BOFRP;

W20 is the y-coordinate of the SgRP;

H8 is the z-coordinate of the AHP;

H30 is the z distance of the SgRP from the AHP;

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

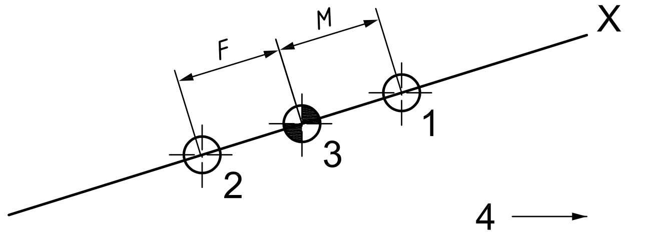
### A.3.2 Seats with vertical adjustment

For driver seats having vertical adjustment, Equations (A.2) to (A.4) were developed with H30 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 H30 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 section 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

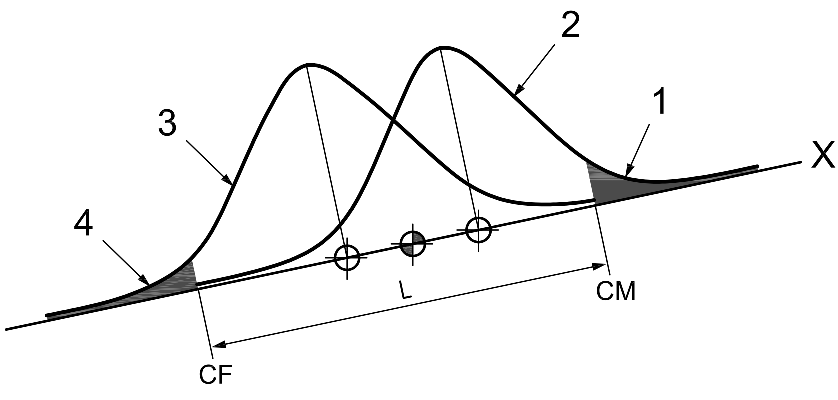
1 male centroid

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 Equations (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 Equations (A.5) and (A.6).

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

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

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 Equations (A.7) and (A.8).

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

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

where

$\sigma_{EM}$ is the standard deviation of the male eye location distributions along the side view axis;

$\sigma_{EF}$ is the standard deviation of the female eye location distributions along the side view axis;

$\sigma_M$ is the standard deviation of the male stature distribution;

$\sigma_F$ 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 Equations (A.9) and (A.10) to determine lower (forward) and upper (rearward) eyellipse boundaries.

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

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

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 cut-off percentile;

$\Phi$ 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;

$\sigma_{EM}$ is the standard deviation of the male eye location distribution along the side view axis;

$\sigma_{EF}$ 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, Equations (A.9) and (A.10) should 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 (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 CM and CF.

$$X_{a\_l} = CM - CF \quad \text{(A.11)}$$

where

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.

### 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. Equations (A.12) and (A.13) contain the specific formulae.

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

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

where

q is the eyellipse cut-off percentile;

$\Phi^{-1}$ 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 Equations (A.14) to (A.16). These equations 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.

$$X_c = X_{cref} + \frac{CF + CM}{2} \times \cos \beta \qquad (A.14)$$

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

$$Z_c = Z_{cref} + \frac{CF + CM}{2} \times \sin \beta \qquad (A.16)$$

where

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.

## 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 equations 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 an equation 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 equation 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:

$$Z_{cref} = H8 + H30 + 638 \frac{h_T}{h_R} \quad (A.17)$$

where

H8 is the z-coordinate of the AHP;

H30 is the z distance of the SgRP from the AHP;

$h_T$ 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 Equation (A.5) (which is based on the difference between average stature of the target population and average stature of the reference population), as follows:

$$X_{cref} = L1 - 12{,}5\ t + (664 + 0{,}587\ L6 - 0{,}176\ H30) + 0{,}473\ (S_T - S_R)\cos\beta \quad (A.18)$$

where

L1 is the x-coordinate of the BOFRP;

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

L6 is the x distance from the steering wheel centre to the BOFRP;

H30 is the z distance of the SgRP from the AHP;

$S_T$ 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 Equations (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. | | | |

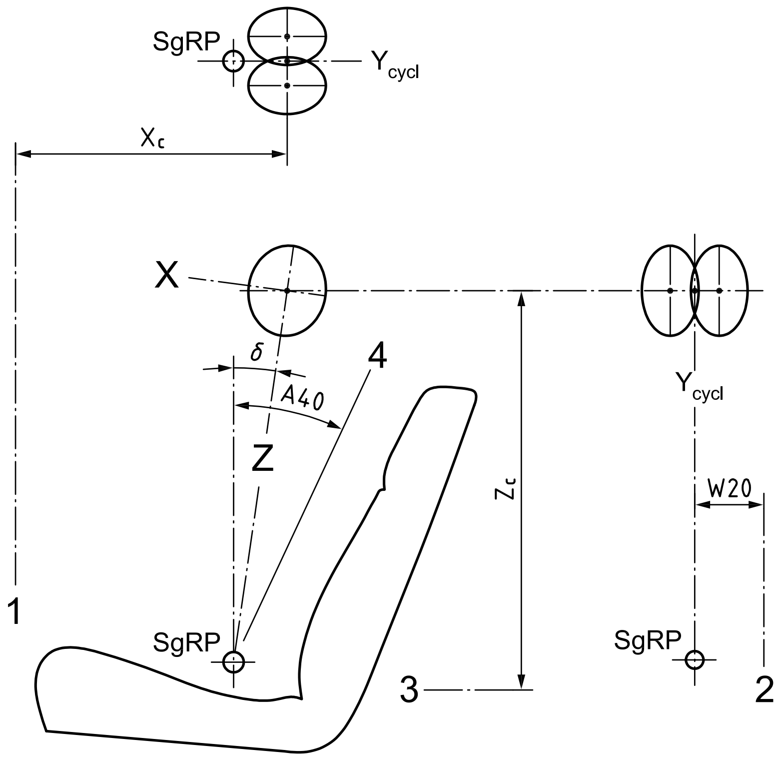
# Annex B
(informative)

# 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, A40. 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 |
| $\delta$ | angle of the eyellipse Z-axis from vertical | 3 | zero Z grid |
| $X_c$ | x-coordinate of the eyellipse centroid location | 4 | torso line |
| $Y_{cycl}$ | y-coordinate of the eyellipse centroid location | | |
| $Z_c$ | 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, $\delta$, in degrees, depends on the torso angle (see Equation B.1 and Figure B.1).

$$\delta = 0,698 \text{ A40} - 9,09 \quad \text{(B.1)}$$

where A40 is the torso angle.

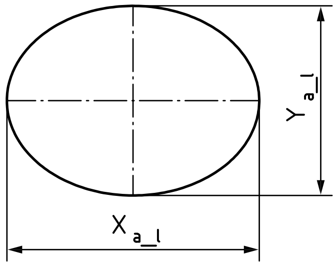
NOTE The dimension code for torso angle depends on the passenger seat position under study. A40-2 refers to passenger second row seating and A40-3 refers to passenger third row seating as defined in SAE J1100.

## B.3 Axis lengths

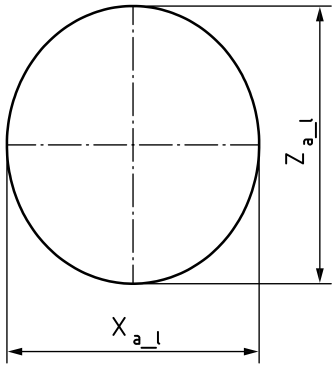
Axis lengths are shown in Figure B.2 and listed in Table B.1.

**Table B.1 — Fixed seat eyellipse axis lengths**

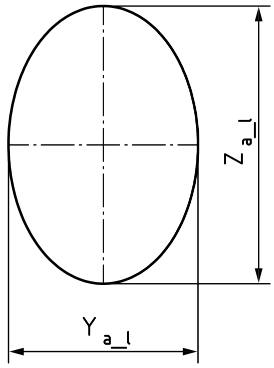
| Percentile | X-axis length<br>mm | Y-axis length<br>mm | Z-axis length<br>mm |
|---|---|---|---|
| 95 | 93,5 | 104,1 | 130,7 |
| 99 | 132,3 | 147,3 | 179,0 |




**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 equations

Equations (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 W20, which normally coincides with the seat centreline (see Figure B.1). In side view the centroid is located to vehicle grid using L31 for SgRP x-coordinate and H70 for SgRP z-coordinate.

$$X_c = L31 + 619 \times \sin \delta \qquad (B.2)$$

$$Y_{cycl} = W20 \qquad (B.3)$$

$$Z_c = H70 + 619 \times \cos \delta \qquad (B.4)$$

where

L31 is the SgRP x-coordinate;

W20 is the SgRP y-coordinate;

H70 is the SgRP z-coordinate;

$\delta$ 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: L31-2, W20-2 and H70-2 refer to second row passenger seating; L31-3, W20-3, and H70-3 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), $\delta$, in degrees, depends on the torso angle (see Figure B.1):

$$\delta = 0{,}698 \times \mathrm{A40} - 9{,}09 \quad \text{(C.1)}$$

where A40 is the torso angle.

## 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. Equations (C.2) and (C.3) are used to calculate the H-point-to-eye distance.

$$h_M = 67{,}0 + 0{,}351\, S_M - 1{,}613\ \mathrm{A40} \quad \text{(C.2)}$$

$$h_F = 67{,}0 + 0{,}351\, S_F - 1{,}613\ \mathrm{A40} \quad \text{(C.3)}$$

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;

A40 is the torso angle.

#### 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 Equations (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

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

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

$\sigma_{S_M}$ is the standard deviation of stature for males;

$\sigma_{S_F}$ is the standard deviation 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, Equations (C.6) and (C.7) should be solved iteratively for ZF and ZM.

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

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

where

$p_M$ is the proportion of males in the population;

ZF is the lower boundary of the eyellipse along the Z-axis;

ZM is the upper boundary of the eyellipse along the Z-axis;

q is the eyellipse cut-off percentile;

$\Phi$ 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;

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

$\sigma_{HF}$ 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, ZM and ZF.

$$Z_{a\_l} = ZM - ZF \qquad (C.8)$$

where

ZF is the lower boundary of the eyellipse along the Z-axis;

ZM 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, $\delta$, 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 $\delta$ 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 Equation (C.9) for a q-percentile ellipse.

$$X_{a\_l} = \left(\frac{ZM + ZF}{2}\right)\left(\frac{\pi}{180}\right)\left[2{,}63 \times 2\Phi^{-1}(q)\right] \qquad (C.9)$$

where

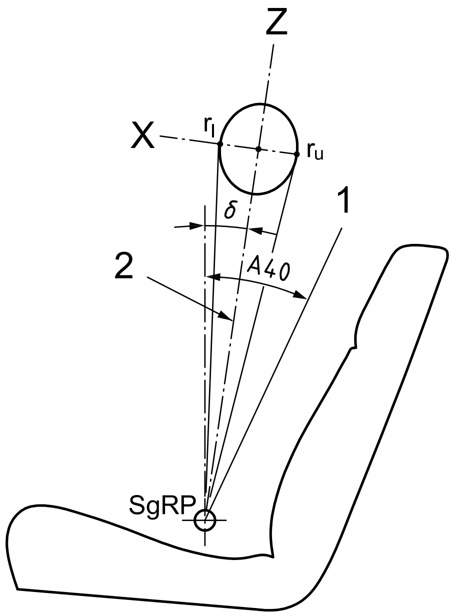
ZF is the lower boundary of the eyellipse along the Z-axis;

ZM is the upper boundary of the eyellipse along the Z-axis;

$\Phi^{-1}$ is the inverse cumulative normal distribution;

q is the eyellipse cut-off percentile;

$\pi$ is the ratio of the circumference to the diameter of a circle, the transcendental number 3,141 592 6…




**Key**

A40 torso angle

$r_u$, $r_l$ radii defining eyellipse X-axis length

X eyellipse X-axis

Z eyellipse Z-axis

$\delta$ 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, $\delta$**

### 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 (Reference [11]). Thus, Equation (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

$\Phi^{-1}$ 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. Equations (C.11) to (C.13) give the centroid location relative to SgRP in the vehicle axis system.

$$X_c = \frac{ZM + ZF}{2} \times \sin\delta \tag{C.11}$$

$$Y_c = 0 \tag{C.12}$$

$$Z_c = \frac{ZM + ZF}{2} \times \cos\delta \tag{C.13}$$

where

ZF is the lower boundary of the eyellipse along the Z-axis;

ZM is the upper boundary of the eyellipse along the Z-axis;

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

## C.5 Summary

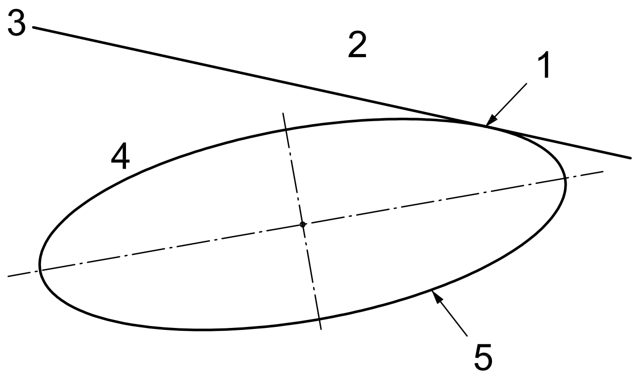
Equations (C.6) to (C.13) define the parameters of the fixed seat eyellipse for any adult population anthropometry. The shape of the eyellipse is the same across vehicles (for the same adult population) except for small differences in angle as a function of torso angle. Whereas the adjustable seat eyellipse 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).

# 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

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 — Two dimensional tangent cut-off 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.

**Table D.2 — Tangent cut-off eyellipse percentiles and corresponding 2D and 3D inclusive eyellipse percentiles, fixed 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 | 47,8 | 53,3 | 69,6 |
| 42,18 | 21,39 | 85,00 | 58,8 | 65,6 | 84,8 |
| 56,01 | 35,02 | 90,00 | 72,8 | 81,1 | 103,6 |
| 74,15 | 56,07 | 95,00 | 93,5 | 104,1 | 130,7 |
| 80,00 | 64,09 | 96,36 | 102,0 | 113,6 | 141,4 |
| 87,18 | 75,00 | 97,87 | 115,3 | 128,3 | 158,1 |
| 90,00 | 79,69 | 98,41 | 122,1 | 135,8 | 166,4 |
| 93,32 | 85,60 | 99,00 | 132,3 | 147,3 | 179,0 |
| 95,00 | 88,80 | 99,28 | 139,2 | 154,9 | 187,4 |
| 95,61 | 90,00 | 99,38 | 142,3 | 158,3 | 191,1 |
| 97,99 | 95,00 | 99,74 | 159,1 | 176,9 | 211,3 |
| 99,07 | 97,50 | 99,89 | 174,1 | 193,5 | 229,1 |
| 99,96 | 99,00 | 99,96 | 191,9 | 213,2 | 250,0 |

[a] Axis lengths are shown for fixed seat eyellipses, 50/50 gender mix, reference driver population.

## D.3 Procedure for constructing an inclusive ellipse

Axis lengths for inclusive eyellipses representing other driver populations, or different gender mixes, can be determined as follows. From the three leftmost columns of Table D.1 or D.2, find the tangent cut-off eyellipse percentile that corresponds to the desired inclusive eyellipse percentile. Then, calculate the axis lengths for that tangent cut-off ellipse using the procedures described in Annexes A or C.

# Annex E
(informative)

# Eyellipses for Class B vehicles

## E.1 Mathematical description of 3D eyellipses for Class B vehicles

Eyellipses for Class B vehicles have not been changed since SAE J941:1987 (see SAE Paper 852317[12]). 95th and 99th percentile eyellipses are defined for each of two different ranges of fore and 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 three axes in true view for the four eyellipses are as listed in Table E.1.

**Table E.1 — Length of three axes in true view for the four eyellipses**

Dimensions in millimetres

| Seat track travel (TL23) = | 95th eyellipse<br>100 mm to 133 mm | 95th eyellipse<br>>133 mm | 99th eyellipse<br>100 mm to 133 mm | 99th eyellipse<br>>133 mm |
|---|---|---|---|---|
| X-axis[a] | 173,8 | 198,9 | 242,1 | 268,2 |
| Y-axis | 105,0 | 105,0 | 149,0 | 149,0 |
| Z-axis | 86,0 | 86,0 | 122,0 | 122,0 |

[a] 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 three axes.

### E.1.3 Left and right eyes

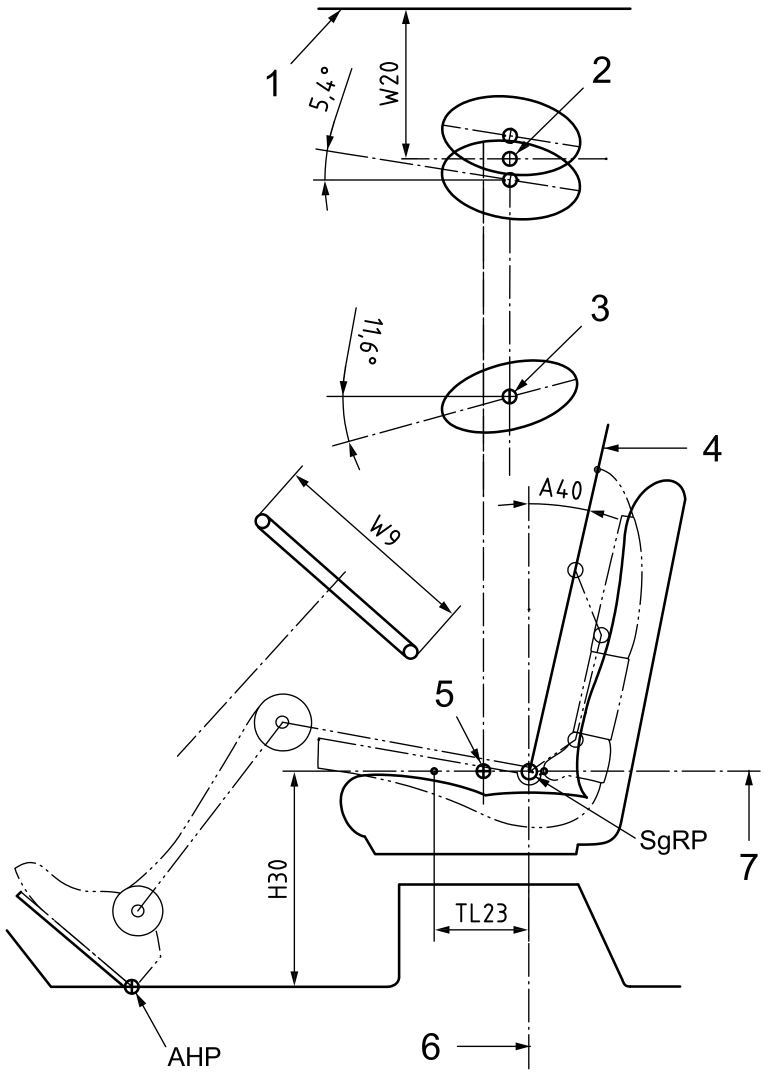
Eyellipses for the left and right eyes are identical except that their centroids are separated horizontally by 65 mm. A single mid-eye centroid (a cyclopean eye) is located 32,5 mm from the centroid of either eyellipse.

### E.1.4 Ellipsoid surface versus three axial sections

The user may construct either a complete ellipsoidal surface or a 3D ellipse containing only the three 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 having the range of driver workspace dimensions given in SAE J1100. Seat height (H30), with values ranging between 405 mm and 530 mm, is the primary workspace dimension defining Class B vehicles (see Figure E.1).




**Key**

A40 torso angle
AHP accelerator heel point
H30 z distance of the SgRP from the AHP
H70 SgRP z-coordinate
L31 x-coordinate of the SgRP
SgRP seating reference point
TL23 seat track travel
W9 steering wheel diameter
W20 y-coordinate of the SgRP
1 zero Y plane
2 mid-eye centroid
3 centroid
4 torso line
5 accommodation tool reference point (ATRP)
6 to zero X grid – L31
7 to zero Z grid – H70

**Figure E.1 — 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. The x- and z-coordinates of the ATRP are X(ATRP) and Z(ATRP).

### E.2.1.2 Determine A40

The 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 within the vehicle's three-dimensional reference system. Equations (E.1) to (E.8) locate the centroid as a function of the torso angle for three different male and female mixes (50/50, 75/25, 90/10 to 95/5) in the driver population. Select the same male and female mix that was used in determining the ATRP. All values are in millimetres except A40 which is in degrees.

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

$$X = X(\text{ATRP}) - 175{,}26 + 12{,}68\ \text{A40} \quad \text{(E.1)}$$

$$Z = Z(\text{ATRP}) + 691{,}09 - 3{,}57\ \text{A40} \quad \text{(E.2)}$$

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

$$X = X(\text{ATRP}) - 201{,}05 + 13{,}65\ \text{A40} \quad \text{(E.3)}$$

$$Z = Z(\text{ATRP}) + 699{,}66 - 3{,}82\ \text{A40} \quad \text{(E.4)}$$

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

$$X = X(\text{ATRP}) - 184{,}44 + 12{,}23\ \text{A40} \quad \text{(E.5)}$$

$$Z = Z(\text{ATRP}) + 707{,}52 - 4{,}17\ \text{A40} \quad \text{(E.6)}$$

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

$$Y_L = \text{W20} - 32{,}5 \quad \text{(E.7)}$$

$$Y_R = \text{W20} + 32{,}5 \quad \text{(E.8)}$$

where

X(ATRP) is the x-coordinate of the ATRP;

Z(ATRP) is the z-coordinate of the ATRP;

A40 is the torso angle;

W20 is the y-coordinate of the SgRP.

NOTE W20 is negative 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° (looking forward) in plan view and down 11,6° (looking forward) in side view.

## E.3 P and E points

These points have not been defined for Class B vehicles.

# Annex F
(informative)

# Background to the revision of this International Standard

## F.1 Historical information

Eyellipses specified in superseded editions of ISO 4513 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.

ISO 4513:2003 and previous editions were based on a 1963 study involving over 2 300 drivers performing a straight-ahead viewing task without head turning, sitting in seats having fore and aft adjustment and fixed back angles (SAE Paper 650464[8]). Elliptical contours were developed from a statistical analysis of the stereophotogrammetric data, using a male to female ratio of 1/1. 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 torso (back) angles ranging from 5° to 40° (SAE Paper 720200[10]).

To facilitate use of the eyellipses in design, six pairs of eyellipse templates and a locator template were constructed. Each pair of templates (95th and 99th) represented a different amount of seat track travel. The templates contained datum lines to help locate the eyellipse 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 Paper 852317[12]).

In 2003, a rear view for the eyellipse was added to enable eyellipses to be constructed in 3D in CAD systems. This rear view had been defined since 1964, but had never been incorporated into ISO 4513. Other changes made include eliminating the (outboard) lean factor in locating the eyellipse y-coordinate, reducing the number of eyellipses from six to two pairs, and the phasing-out of the templates.

## F.2 ISO 4513:2010

Eye location data collected in the 1990s provided evidence that ISO 4513:2003 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[13]).

Most of the results are summarized in the Introduction. The large reduction in width of the eyellipse, from 104,9 mm to 60,3 mm, is attributed to the widespread use of bucket (or split bench) rather than bench seats in most vehicles. Bucket seats generally limit the distance that drivers can position themselves laterally from the centre of the seat.

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 ISO 4513 to include vertically adjusting seats. The reference point for locating the z-coordinate of the eyellipse centroid, for driver seats that provide vertical adjustment, was specified at 20 mm above the full down H-point travel path. This change applied to seats having a vertical adjustment range that exceeded 40 mm.

Another finding was that torso angle, A40, was no longer a predictor variable for locating an adjustable seat eyellipse. Any variability in eye location because of the driver's torso angle was factored into 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 ISO 4513 (see SAE Papers 720200[10] and 750356[11]). These eyellipses were actually derived from adjustable seat data. The new fixed seat eyellipses were derived from eye and posture data collected in fixed rear seats tested with a range of seat back angles in a laboratory study. Because some of the factors that might influence lateral passenger position were not present in the laboratory study, the Y-axis length from the previous fixed seat eyellipses has been retained in ISO 4513:2010. More validation of the fixed seat eyellipses using data from passengers in vehicles 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 normative part of this International Standard and are given in detail in Annexes A and C.

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