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DESIGN GUIDE FOR THE ERGONOMIC ASPECTS OF HELICOPTER CREW SEATING

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Summary

This Design Guide provides an aid to the design of new helicopter crew seats, the improvement of existing seats and the comparison of alternative seats. Methods of measuring seat dimensions, angles and contouring are defined. Recommendations for the dimensions, angles and contouring of the seat pan, backrest, armrests and headrest are based on the principle of matching seat dimensions to the relevant dimensions of the user population. The dimensions suggested are appropriate for British males and females aged between 19 and 45 years. The Design Guide has been formulated so that the suggested dimensions can be replaced by those appropriate to a different user population. Cushion material, cushion coverings, routeing of harnessing, the position of seat controls, eye position, the operation of controls and ingress and egress from the seat are also considered. The Design Guide also contains recommendations for the subjective testing of seat comfort and the dynamic testing of the transmission of vibration through helicopter crew seats.

Contents

1 INTRODUCTION

This Design Guide has been written as an aid to engineers, managers and designers whose task it is to provide crew seating for helicopters. The guide may be used to assist the design of new seats, improve existing seats or compare alternative seats.

2 THE USER POPULATION

The Design Guide has been formulated so that the recommendations can be applied to any given population. This has been achieved by presenting the recommendations in terms of the appropriate percentile values for the relevant dimensions of the population.

In order to illustrate the application of the guide, it is assumed that seating may be designed for a mixed population of male and female helicopter crews drawn from a British population aged between 19 and 45 years. Appendix A lists the relevant percentile values for discrete body dimensions. While the examples are given for this population of users the reader may substitute another population if required.

It is usual for anthropometric data to be quoted for unclothed and unshod individuals, an allowance for clothing should be made to some dimensions. It is advisable to use allowances for clothing and equipment specified for use with particular seats. If this specific information is not available 'standard' allowances do exist but should be used with caution. The anthropometric data used in the Design Guide contains a 'standard' correction for shoe height (Pheasant, 1988).

3 SEAT MEASUREMENTS

3.1 Seat pan

3.1.1 *Introduction*

The seat pan supports approximately 70% of body weight (depending upon posture). The function of the seat pan is to maintain the body in a comfortable posture without causing uncomfortable pressure. The relevant characteristics of the seat pan are size, contouring and cushioning. These characteristics must be able to accommodate the extremes of body type likely to occur in the user population. The properties of the seat pan cushion also affect vibration transmission (see Section 6).

3.1.2 *Measurements*

The following measurements are to be made using a SAE manikin and a pressure monitor, descriptions of both items can be found in Appendix C. The measurements are to be recorded and compared to those recommended in Table 1.

NOTE: For this application the SAE manikin should be used without the lower leg segments in place.

If the seat has an adjustable seat pan angle, backrest angle or lumbar support, the following adjustments must be made, with the SAE manikin in place, before taking the measurements described in Sections 3.1.2.1 to 3.1.2.4:

(a) the seat pan angle should be set at 95°, or as close as possible (seat pan angle can be read directly from the SAE manikin as hip angle);

(b) the backrest angle should be set at 15°, or as close as possible (backrest angle can be read directly from the SAE manikin as back angle);

(c) the lumbar support should be adjusted to give the minimum protuberance from the backrest surface.

3.1.2.1 Measurement of seat pan height

The seat pan height is the vertical distance measured between the surface supporting the heel of the foot and a horizontal plane passing through the H-point (see Figure 1). It is assumed that the feet are operating the pedals. If this dimension is adjustable, then the lowest value and the highest value should be recorded.

3.1.2.2 Measurement of seat pan length

The seat pan length is the horizontal fore-and-aft distance from a vertical plane passing through the H-point to the foremost point on the upper surface of the seat pan cushion (see Figure 1).

3.1.2.3 Measurement of seat pan width

The seat pan width is the horizontal distance between the two most lateral points on either side of the seat pan cushion. This distance is to be measured on the unoccupied seat using a straight surface (such as a wooden metre rule) placed laterally on the seat pan surface directly under the H-point (see Figure 1).

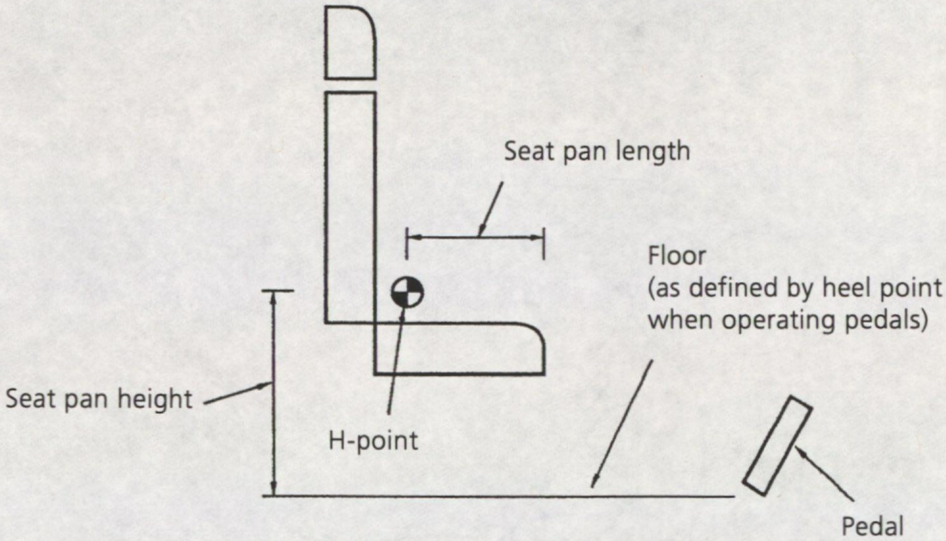
3.1.2.4 Measurement of seat pan angle

It is assumed that the seat pan is tilted in the backwards direction (i.e. the rear of the seat pan is below the front of the seat pan). If this angle is not adjustable, it should be measured using the hip angle on the SAE manikin. If the angle of the seat pan is adjustable, it should be read from the SAE manikin as the hip angle at the highest and lowest adjustments of the seat pan angle.

3.1.2.5 Measurement of seat pan contouring

Pressure measurements are to be made with a subject occupying the seat. The subject should have a height and weight between 25th and 75th percentile values, (i.e. between 1700 and 1790 mm and between 69 and 81 kg respectively). If the seat pan height, the backrest angle, the seat pan angle, or the lumbar support are adjustable, the subject should adjust the seat to provide what is considered to be 'adequate support and comfort' whilst adopting the flying position shown in Figure 2.

Pressure cells should be located in two areas of the seat pan: centred around the ischial tuberosities and at the front edge of the seat pan under the middle of the distal thigh of the occupant (see Figure 1). The maximum pressure values in each area should be compared to those recommended in Table 1.



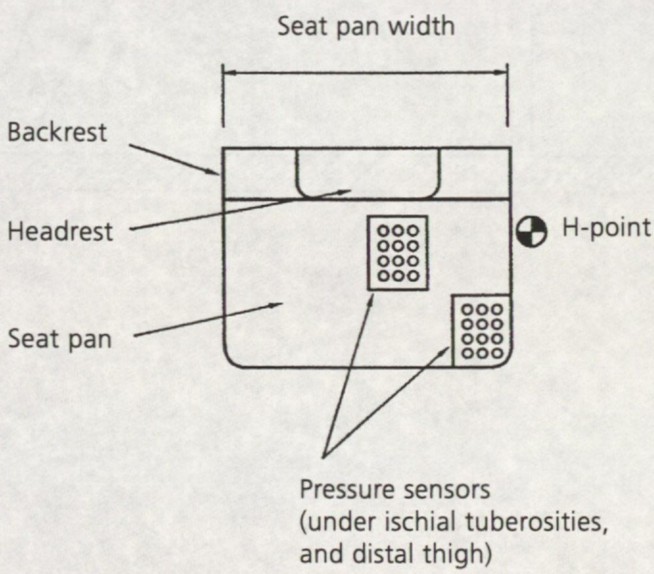


Figure 1 Seat pan measurements

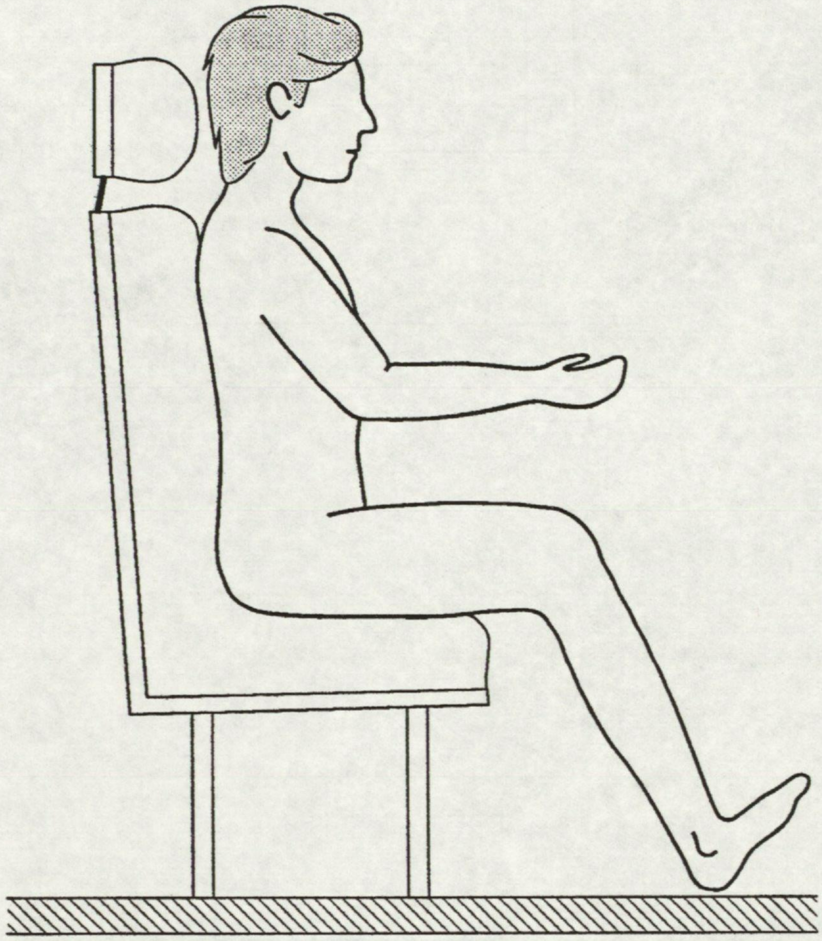


Figure 2 The flying position

3.1.3 *Reporting*

The measurements of the seat pan should be compared with those in Table 1. Comparison can be made with the recommended values based on the considerations in Section 3.1.4.

Table 1 Seat pan measurements and recommendations. (The recommended values are based on the chosen population, details of which can be found in Appendix A)

Dimensions	*Recommended values*			*Percentile criteria*
	Adjustable		*Fixed*	
	Minimum	*Maximum*	*Values*	
Height (mm)	<445	>595	preferably 445, ≯475	5th, 25th
Length (mm)	–	–	preferably 315, ≯335	5th, 25th
Width (mm)	–	–	≮390, preferably ≮425	75th, 95th
Angle (degrees)	<95	>100	≮95, ≯100	–

≮ = not less than ≯ = not greater than

Pressures	*Values between*
At front edge of seat (kPa)	0 to 8
At H-point (kPa)	8 to 14

3.1.4 *Considerations and decisions*

3.1.4.1 Seat pan height

Recommendations for seat pan height are based on the popliteal height of the user population, plus an allowance for shoes. In the case of a non-adjustable seat pan height the height should preferably correspond to the 5th percentile female H-point to floor height. If this suggested height is inappropriate the height may be increased to the 25th percentile female H-point to floor height but should not exceed this value. The suggested heights, together with a correctly chosen seat pan length, can help minimise pressure under the knees of the shorter pilots. Areas of high pressure under the knees can lead to reduced blood supply to the legs and subsequent numbing.

A non-adjustable seat pan height presents several disadvantages. For example, taller pilots may experience 'cramped' leg postures and difficulties in ingress and egress. Locating the eyes at the design eye height may also prove difficult with a non-adjustable seat pan height. These problems may be partially offset by adjustable control positions, fore-and-aft adjustability of the seat and, perhaps, preselection of pilots based on their anthropometric characteristics.

An adjustable seat pan height avoids the problems associated with non-adjustable seat pan heights, especially if combined with fore-and-aft adjustability of the seat. It is recommended that the minimum range of adjustability of the seat pan height should accommodate 5th percentile female to 95th percentile male H-point to floor height.

3.1.4.2 Seat pan length

If the seat pan is too long, shorter legged pilots will be unable to make contact with the backrest, resulting in a flattening of the lumbar lordosis. A long seat pan may also cause uncomfortable pressure behind the knees and under the thighs for shorter legged pilots. The seat pan length must therefore not exceed the 25th percentile, and preferably correspond to the 5th percentile, female H-point to popliteal length.

3.1.4.3 Seat pan width

Adequate seat pan width enables the hips and thighs to be supported without high pressures occurring between the seat pan and the lateral edges of the buttocks and thighs. The seat pan must be sufficiently wide to accommodate not less than the 75th percentile, and preferably not less than the 95th percentile, female hip breadth. Such a seat pan width will also allow for minor movements of the buttocks.

3.1.4.4 Seat pan angle

A seat pan that is tilted backwards encourages contact between the pilot's back and the seat backrest, providing postural support and reduced muscle activity. Problems may arise if the seat pan is angled too steeply backwards. This may make it more difficult to reach the pedals. It may also create excessive pressure under the knees or thighs. If the seat pan is tilted too far forward it will tend to tilt the occupant out of the seat and not allow adequate support from the backrest. The recommended values for both fixed and adjustable seat pan angles are a compromise between allowing pilots to perform their task and providing adequate postural support.

3.1.4.5 Seat pan contouring

The choice of seat pan contouring must be made in conjunction with the selection of cushion material (see Section 3.7). The interaction of contouring and cushion material should avoid high pressures between the seat pan cushion and body areas unsuitable for weight bearing. Pressure values for the distal thigh area and the area surrounding the ischial tuberosities are provided in Table 1.

3.2 **Backrest**

3.2.1 *Introduction*

The backrest provides the main support for the upper body and may include additional lumbar support. The backrest maintains the body in an upright working posture that should be both comfortable and stable. Lumbar support, or other contouring, should not interfere with pilot movements. Similarly, the top of the backrest may need to accommodate shoulder movements and reach clearances.

3.2.2 *Measurements*

The following measurements are to be made using a SAE manikin and a pressure monitor, descriptions of both items can be found in Appendix C. The measurements are to be recorded and compared to those recommended in Table 2.

NOTE: For this application the SAE manikin should be used without the lower leg segments in place.

If the seat has an adjustable seat pan angle, backrest angle or lumbar support, the following adjustments must be made, with the SAE manikin in place, before taking the measurements described in Sections 3.2.2.1 to 3.2.2.2:

(a) the seat pan angle should be set at 95°, or as close as possible, (seat pan angle can be read directly from the SAE manikin as hip angle);

(b) the backrest angle should be set at 15°, or as close as possible, (backrest angle can be read directly from the SAE manikin as back angle);

(c) the lumbar support should be adjusted to give the minimum protuberance from the backrest surface.

3.2.2.1 Measurement of backrest height and width

The backrest width is the horizontal distance between the two most lateral points of the backrest cushion at three specified heights: 400 mm above a horizontal plane passing through the H-point (scapular height), 205 mm above a horizontal plane passing through the H-point (i.e. lumbar height) and at a horizontal plane passing through the H-point (i.e. the level of the hip joint); see Figure 3.

3.2.2.2 Measurement of backrest angle

If backrest angle is not adjustable it should be measured using the back angle on the SAE manikin. If the angle of the backrest is adjustable, it should be read from the SAE manikin as the back angle when the backrest is at its furthest tilt forwards and most reclined tilt backwards.

3.2.2.3 Measurement of backrest contouring

Pressure measurements are to be made with a subject occupying the seat. The subject should have a height and weight between 25th and 75th percentile values (i.e. between 1700 and 1790 mm and between 69 and 81 kg, respectively). If the seat pan height, the backrest angle and the seat pan angle or the lumbar support are adjustable, the subject should adjust the seat to provide what is considered to be 'adequate support and comfort' while adopting the flying position shown in Figure 2.

Pressure cells are positioned along a vertical line 70 mm lateral to the centre-line of the backrest (with the subject positioned centrally), see Figure 3. The line of pressure cells should start at the level of the H-point and extend up the backrest to a point 400 mm above the H-point, or if the backrest is shorter than this point, to the top of the backrest cushion. Pressure values in the buttock, sacral, lumbar and scapular regions of the back can then be measured. The maximum pressures in each area should be compared to those recommended in Table 2.

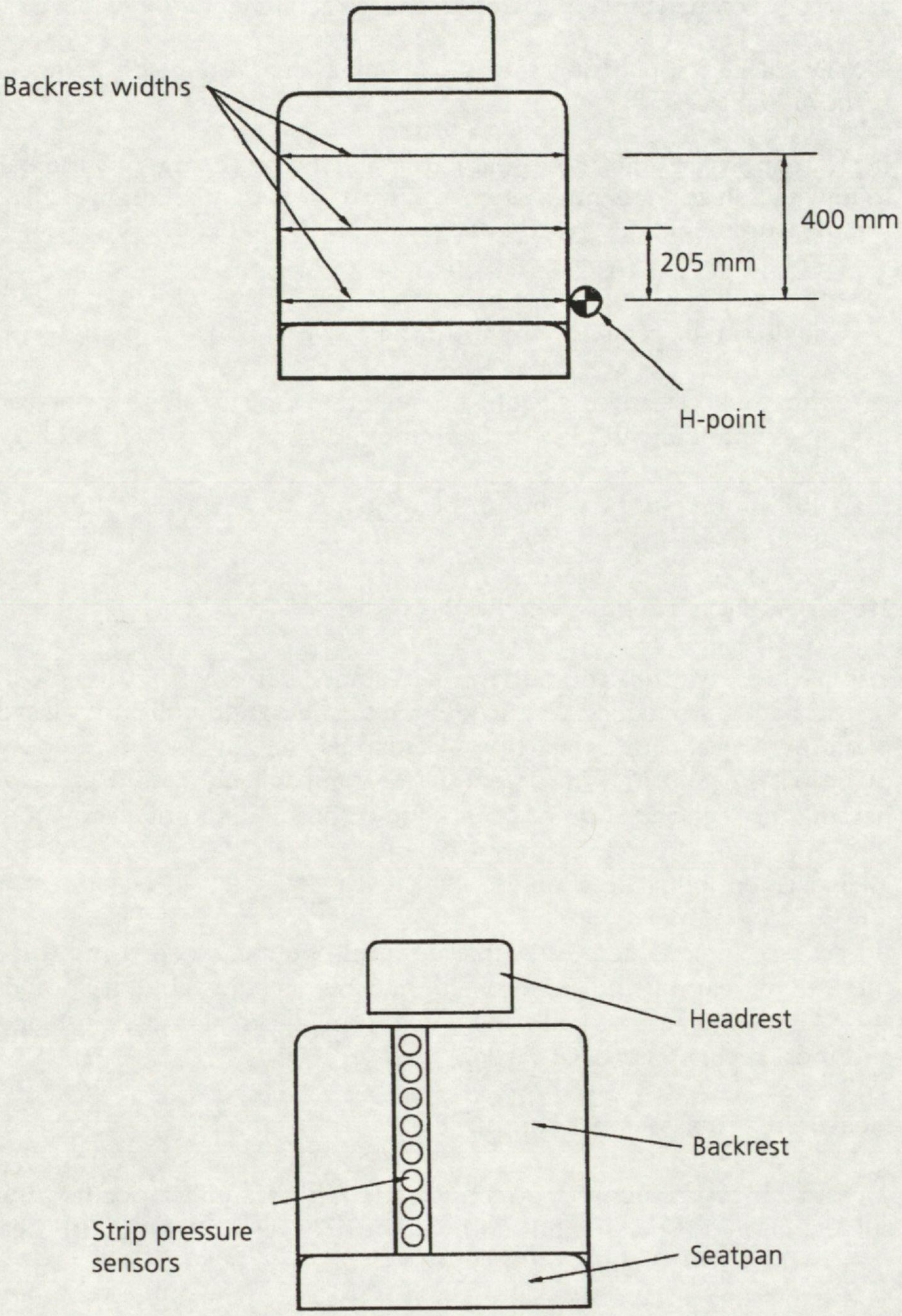


Figure 3 Backrest measurements

3.2.3 *Reporting*

The measurements of the backrest should be compared with those in Table 2. Comparison can be made with the recommended values based on the considerations in Section 3.2.4.

Table 2 Backrest measurements and recommendations. (The recommended values are based on the chosen population, details of which can be found in Appendix A)

Dimensions	*Recommended values*			*Percentile criteria*
	Adjustable		*Fixed*	
	Minimum	*Maximum*	*Values*	
Width at: 400 mm above H-point (mm)	–	–	≮325, ≯345	75th, 95th
205 mm above H-point (mm)	–	–	≮305, preferably ≮330	75th, 95th
H-point (mm)	–	–	≮390, preferably ≮425	75th, 95th
Angle (degrees)	<10	>20	≮10, ≯20	–

≮ = not less than ≯ = not greater than

Pressures	*Values between*
335 mm to 400 mm above H-point (kPa)	2to 5
125 mm to 205 mm above H-point (kPa)	5 to 7
H-point to 120 mm above H-point (kPa)	1 to 6.5
H-point (kPa)	0 to 1

3.2.4.1 Backrest height and width

At the level of the H-point and 205 mm above, the backrest width should be sufficient to accommodate not less than the 75th percentile, and preferably not less than the 95th percentile, hip (female) and waist (male) breadths. At 400 mm above the H-point the backrest width should be sufficient to support the area of the shoulder blades (scapulae) without restricting movement of the shoulders or arms. The width of the backrest at this level should accommodate 75th to 95th percentile male chest breadth.

3.2.4.2 Backrest angle

An adjustable backrest angle offers the pilot the opportunity to alter the seat to suite the task. The suggested range provide angles for optimum working and resting postures. The backrest angle must always be set in conjunction with the seat pan angle, since both act together to influence pilot posture. Smaller backrest angles are required when operating the controls, while larger angles are suitable for resting. Larger backrest angles reduce back muscle activity and reduce pressure in the intervertebral discs.

3.2.4.3 Backrest contouring

The postural support provided by the backrest is dependent on the angle of the backrest, the contouring and the cushion material. For small backrest angles (required when operating controls) it is particularly important that the backrest supports a sitting posture in which the pelvis is tilted to the anterior with the lower or lumbar region of the back in a concave curve (i.e. lordosis). Supporting this posture will minimise back muscle activity and intervertebral disc pressure.

To provide support for a good sitting posture it is necessary for varying amounts of pressure to be present between the backrest and the different regions of the back. The choice of backrest contouring, particularly in the lumbar region, should be made in conjunction with the selection of cushion material. The interaction between contouring and cushion material should provide the pressure values recommended in Table 2.

Contouring can be used for additional support in areas such as the mid-back (lateral support), or the shoulder girdle (via concavities at shoulder blade height). Pressures should still be within the values recommended, and the contouring should not interfere with reach limits.

3.3 **Armrests**

3.3.1 *Introduction*

The two armrests are part of the seat frame and are used when required to support the arms of the pilot during flying, or resting. In supporting the body they should locate it in a stable and comfortable position. It is important that armrests do not interfere with reaching for essential controls and that they can be stowed to facilitate ingress and egress to the seat.

3.3.2 *Measurements*

The following measurements are to be made using a SAE manikin, a description of which can be found in Appendix C. The measurements are to be recorded and compared to those recommended in Table 3. The armrest measurements are illustrated in Figure 4.

NOTE: For this application the SAE manikin should be used without the lower leg segments in place.

If the seat has an adjustable seat pan angle, backrest angle or lumbar support, the following adjustments must be made, with the SAE manikin in place, before taking the measurements described in Sections 3.3.2.1 to 3.3.2.6:

(a) the seat pan angle should be set at 95°, or as close as possible, (seat pan angle can be read directly from the SAE manikin as hip angle);

(b) the backrest angle should be set at 15°, or as close as possible, (backrest angle can be read directly from the SAE manikin as back angle);

(c) the lumbar support should be adjusted to give the minimum protuberance from the backrest surface.

3.3.2.1 Measurement of armrest height

The armrest height is the vertical distance between the upper surface of the armrest and a horizontal plane passing through the H-point. The measurement should be made at a point on the armrest vertically above the H-point.

3.3.2.2 Measurement of armrest length

The armrest length is the horizontal distance of the upper surface of the armrest from a point vertically above the H-point to the foremost point of the armrest. If the front surface of the armrest slopes down, the foremost point is the position where the armrest surface deviates from the line of the armrest.

3.3.2.3 Measurement of armrest width

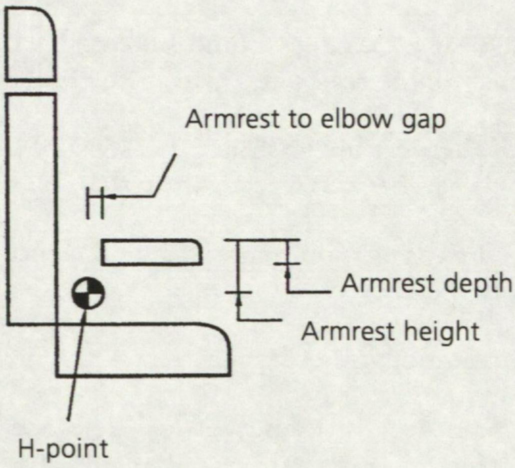
The armrest width is the distance across the armrest upper surface, perpendicular to armrest length. The measurement should be made at a point vertically above the H-point.

3.3.2.4 Measurement of backrest to elbow gap (if one exists)

The backrest to elbow gap is the distance by which the rearmost point of the armrest is in front of a vertical plane. (NOTE: the value may be negative if the rear the armrest is behind the H-point).

3.3.2.5 Measurement of inter-armrest spacing

The inter-armrest spacing is the minimum horizontal distance between the two inner armrest surfaces measured along a lateral line vertically above the H-point.



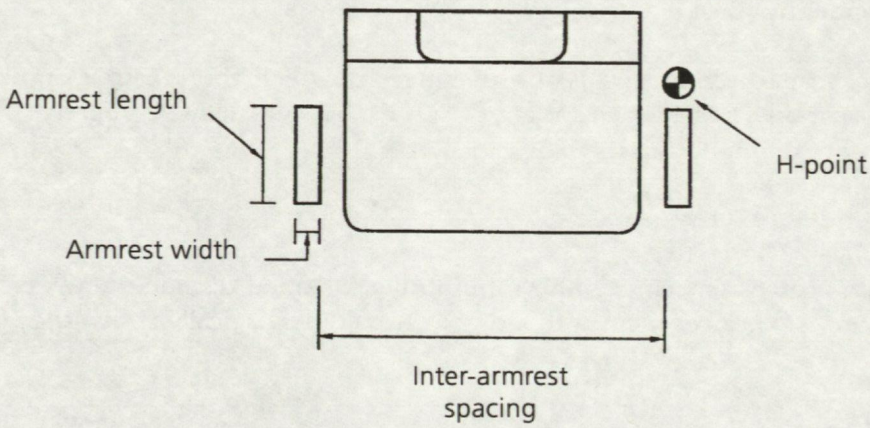


Figure 4 Armrest measurements

3.3.3 *Reporting*

The measurements of the armrests should be compared with those in Table 3. Comparison can be made with the recommended values based on the considerations in Section 3.3.4.

Table 3 Armrest measurements and recommendations. (The recommended values are based on the chosen population, details of which can be found in Appendix A)

Dimensions	*Recommended values*			*Percentile criteria*
	Adjustable		*Fixed*	
	Minimum	*Maximum*	*Values*	
Height (mm)	<125	>215	preferably 125, ≯145	5th, 25th
Length (mm)	–	–	preferably 240, ≯250	5th, 25th
Width (mm)	–	–	≮65	5th
Elbow gap (mm)	–	–	≮50, ≯100	–
Spacing (mm)	–	–	≮425	95th

≮ = not less than ≯ = not greater than

3.3.4 *Considerations and decisions*

3.3.4.1 Armrest height

The optimum armrest height is determined by the need to support the forearms and prevent hunched shoulders which, over time, cause postural discomfort. Sitting elbow height is the most important anthropometric consideration. It is assumed that the armrest height is adjustable so as to be independent of the seat backrest. If the armrest height is not adjustable it is suggested that the armrest height does not exceed the 25th percentile, and preferably corresponds to the 5th percentile, female sitting elbow height, as measured from the H-point, since hunched shoulders are less acceptable than inadequately supported forearms.

3.3.4.2 Armrest length

The task carried out by the pilot will determine the optimum functional length of the armrest. Armrest length only becomes important when (a) a small pilot cannot reach past the foremost point to perform a task (i.e. when the armrest length is greater than the pilot's elbow-wrist length) or (b) when the rearmost point of the armrest causes pressure to be exerted at the elbow (see Section 3.3.4.5). Armrest length should not exceed the 25th percentile and preferably correspond to the 5th percentile female elbow to wrist lengths. The recommended values assume that the elbow is vertically above the H-point.

3.3.4.3 Armrest width

The only limiting factor on armrest width is that the armrest is not too narrow. The recommended value given in Table 3 is a minimum width, based on the 5th percentile values for male forearm width. The maximum width may be determined by the space constraints of the aircraft and inter-armrest spacing.

3.3.4.4 Backrest to elbow gap

The importance of this gap originates from the necessity to avoid pressure on the sensitive ulnar nerve that lies close to the surface of the elbow. The recommended values ensure that a gap remains under the elbow of the pilot.

3.3.4.5 Inter-armrest spacing

It is necessary to consider both ingress and egress to the seat, and the support position of the armrests once a pilot is sitting in the seat. If the spacing is too narrow, the larger pilots will be restricted in both respects. If the spacing is too large, smaller pilots will not receive the support they need for their forearms. The compromise may be to provide armrests that can be stowed so as to eliminate the ingress and egress problem, with either adjustable width or wide fixed-width upper armrest surfaces that can be used by the whole pilot population. The inter-armrest spacing should accommodate not less than the 95th percentile female hip breadths, providing access to the seat for pilots with large hip breadths.

3.4 **Headrest**

3.4.1 *Introduction*

A headrest could provide support for the head and neck. The posture of the pilot will determine how much support is needed. The headrest is also a safety feature, minimising injuries such as whiplash and contusions to the head in the event of an accident. It must be determined at the start of the seat assessment whether pilots will be wearing a helmet.

3.4.2 *Measurements*

The following measurements are to be made using a SAE manikin details of which can be found in Appendix C. The measurements are to be recorded and compared to those recommended in Table 4.

NOTE: For this application the SAE manikin should be used without the lower leg segments in place.

It is assumed that the headrest is attached to the backrest. If the seat has an adjustable seat pan angle, backrest angle or lumbar support, the following adjustments must be made, with the SAE manikin in place, before taking the measurements described in Sections 3.4.2.1 and 3.4.2.2:

(a) the seat pan angle should be set at 95°, or as close as possible, (seat pan angle can be read directly from the SAE manikin as hip angle);

(b) the backrest angle should be set at 15°, or as close as possible, (backrest angle can be read directly from the SAE manikin as back angle);

(c) the lumbar support should be adjusted to give the minimum protuberance from the backrest surface.

3.4.2.1 Measurement of headrest height

Headrest height is the vertical distance between a horizontal plane passing through the H-point to a horizontal plane level with the uppermost cushion surface of the headrest.

3.4.2.2 Measurement of headrest width

Assuming a contoured cushion surface, headrest width is measured as the distance between the two most prominent (i.e. foremost) points on the lateral cushion surfaces.

3.4.3 *Reporting*

The measured dimensions of the headrest should be entered into Table 4. Direct comparison can be made with the recommended values for each dimension, based on the considerations in Section 3.4.4.

Table 4 Headrest measurements and recommendations. (The recommended values are based on the chosen population, details of which can be found in Appendix A)

Measurements	*Recommended values*			*Percentile criteria*
Dimensions	*Adjustable*		*Fixed*	
	Minimum	*Maximum*	*Values*	
Height (mm)	<735	>890	≮785, ≯840	50th ♀, 50th ♂
Width (mm)	–	–	≮160, preferably ≮165	75th, 95th

≮ = not less than ≯ = not greater than

3.4.4 *Considerations and decisions*

3.4.1.1 Headrest height

The headrest must be at the appropriate height to provide the support needed at the time it is needed. It should not force the head forward into an unacceptable posture. Neither should it be so far back that in the event of an accident, excessive neck movement is allowed. In this case it is not appropriate to cater for the larger or smaller ends of the population distribution. For this reason the 50th percentile values of the male and female population have been used as the basis for the recommended height.

3.4.4.2 Headrest width

The width of the headrest must be sufficient to accommodate the 75th percentile, and preferably the 95th percentile, male head widths or helmet widths. If the headrest is too narrow it cannot be considered satisfactory.

3.5 Routeing of harnessing

Crew seats are usually fitted with either a '4-point' or '5-point' harness. An important consideration for this harness is the location of the fixing position of the two shoulder straps. Assuming that these straps are designed to come over the shoulder of the pilot, the critical dimension is either the vertical distance between the strap fixation position on the seat and a horizontal plane passing through the H-point or, if the straps are restrained by the top of the backrest frame, the vertical distance between the top of the backrest frame and a horizontal plane passing through the H-point. This dimension should be no less than the 95th percentile male pilot sitting shoulder height (i.e. 570 mm) as measured from the H-point.

A low harness fixing point may cause compression of the torso and flattening of the lumbar curve, both of which contribute to an inappropriate sitting posture.

3.6 Fittings, buckles and seat controls

Fittings, buckles and seat controls can cause problems if they protrude above the cushion surface of the seat, or are placed such that some pilots cannot reach them.

Harness buckles, including the main 4 or 5-point buckle, must be simple to operate and designed to lie flat wherever they make contact with the body.

Controls for adjusting the seat must be placed such that small pilots can reach them from all seat adjustment positions. The controls must therefore be within the 'reach-to-grip' envelope of a seated 5th percentile pilot.

3.7 Cushion material and cushion coverings

3.7.1 *Static considerations for cushion material*

The selection of a cushion material for both the backrest and the seat pan must be made in conjunction with the selection of contouring in these two areas. The contouring and cushioning of the backrest should encourage and support a lordotic lumbar back posture. The contouring and cushion material of the seat pan must serve two functions: that of providing support, and that of protecting against compression of body tissues.

The contouring and cushion materials should be chosen to produce the pressures recommended in Sections 3.1.2.5 and 3.2.2.3 for the various body areas.

Due to the interaction between contouring and cushion material, either a hard foam with good contouring, or a soft foam with less contouring may produce similar pressure distributions between seat and occupant. A soft foam must not 'bottom-out' (i.e. deform to the extent that an occupant of any size or weight can feel the surface below the foam).

The choice of cushion material must conform to the relevant fire regulations.

3.7.2 *Dynamic consideration for cushion material*

The dynamic properties of the cushions, in both the seat pan and the backrest, must be such that the vibration present during conditions of flight must not be amplified. Section 6 describes a method for testing the dynamic performance of a seat.

The combination of seat frame and cushions must must adhere to the appropriate crashworthiness specifications. These are specific to aircraft types and are therefore beyond the scope of this Design Guide.

(NOTE: Although a soft cushion may provide greater attenuation of helicopter vibration then a firm cushion it may be less satisfactory with regard to crashworthiness.)

3.7.3 *Cushion coverings*

In both the horizontal and the 'nose down' flight attitudes, the covering of the seat cushion must provide enough friction between the upper surface of the cushion and the occupant to prevent the torso from sliding forward away from the backrest. Heavily grained or textured fabrics are usually recommended for this purpose.

The cushion coverings of both the seat pan and the backrest should allow adequate ventilation and evaporation of moisture between the pilot and the seat surface. Natural open weave fabrics are better suited to this task than some synthetic fabrics, which can trap moisture between the pilot and the cushion covering.

4 ADDITIONAL ERGONOMIC FACTORS

4.1 Eye position consideration

4.1.1 *Design eye height*

Whilst sitting in a helicopter crew seat in the flying position it must be possible for the range of pilots between 5th and 95th percentile eye height to locate their head along the design eye line and into the design eye position as defined by current airworthiness requirements and standards.

The required eye position may be achieved with an adjustable seat and/or adjustable controls. The design eye position should be the optimum viewing position for both the external environment and the internal controls and displays.

4.1.2 *View of controls and displays*

A view of the controls and displays must be possible from the flying position. Fore-and-aft adjustability and height adjustability of the crew seat must be such that pilots with eye heights from 5th to 95th percentile values can achieve this position. Those controls and displays that are frequently used, or required in an emergency, must be placed such that the 5th to 95th range of pilots can see them without excessive changes in sitting posture.

The preferred viewing distances for controls and displays depend upon several factors: the size of the individual components of the displays and their importance, the contrast between features and background, the ambient illumination and the interaction between display motion and occupant motion.

The more a seat is adjustable in both height and fore-and-aft location, the easier it becomes to achieve the visual requirements of pilots with 5th to 95th percentile eye height.

4.2 Operation of controls

It must be possible to reach all the necessary flying controls from the normal flying position. For controls at specific locations, seat height adjustment and seat adjustment in the fore-and-aft direction will be needed according to the size of the pilot.

The reach distance is dependent upon the operation to be performed (e.g. 'reach to grip' requires a closer proximity than 'reach to switch').

Adjustment of the seat position should not foul any of the controls or restrict the limb movements of the pilot.

4.3 Ingress and egress

The inter-armrest spacing defined in Section 3 allows for pilots of up to 95th percentile hip breadth to gain access to the seat without encumbrance.

The space around the feet and above the thighs must allow all pilots (i.e. not less than 5th to 95th of the percentile range) to leave the seat easily in the event of an emergency. These areas should not be restricted.

If armrests are not suitable to take the weight of a pilot, grab bars or other support shall be provided within the cockpit to aid movement into and out of seat.

If parts of the seat are moveable, it must be possible to lock them into position.

5 STATIC SEAT COMFORT TESTING

5.1 Introduction

Many subjective techniques exist for the measurement of seat comfort. Two such methods are suggested below. They may be used independently or in combination depending on the information required. These two methods allow comparisons between different seats and can be used to evaluate changes made on a single seat. They cannot give a reliable indication of absolute discomfort for a single seat.

The two methods require the use of no less than eight subjects varying in height and weight between 5th and 95th percentile values. More consistent results may be expected with increased subject numbers. The method of 'extreme group testing' (i.e. choosing subjects representing only the 5th and 95th percentile values for height and weight) is not recommended.

Subjective ratings are dependent on the experimental design. It is suggested that more consistent results may be obtained by presenting all test conditions in one experimental session. The order of presentation of the test conditions must be balanced to avoid order effects.

5.2 Method 1

This method identifies any particular areas of the seat producing discomfort.

In each seat or seat modification to be tested, the subjects must occupy the seat for a period of no less than 10 minutes before any subjective opinion is sought. Subjects must be seated in the position described in Section 3.

The subjects are presented with a diagram illustrating the body divided into several identified areas. An example is shown in Figure 5. The number of areas identified and the areas chosen will be dependent on the seats or seat modifications to be investigated.

Subjects are asked to rate their perceived discomfort in the various body areas and their overall discomfort by choosing a number from the semantic uni-polar scale shown below in Table 5.

Table 5 Discomfort rating scale

Number	*Semantic*
0	Not uncomfortable
1	
2	A little uncomfortable
3	
4	Fairly uncomfortable
5	
6	Uncomfortable
7	
8	Very uncomfortable
9	
10	Extremely uncomfortable

5.3 Method 2

This method provides information as to why a particular area of the seat causes discomfort.

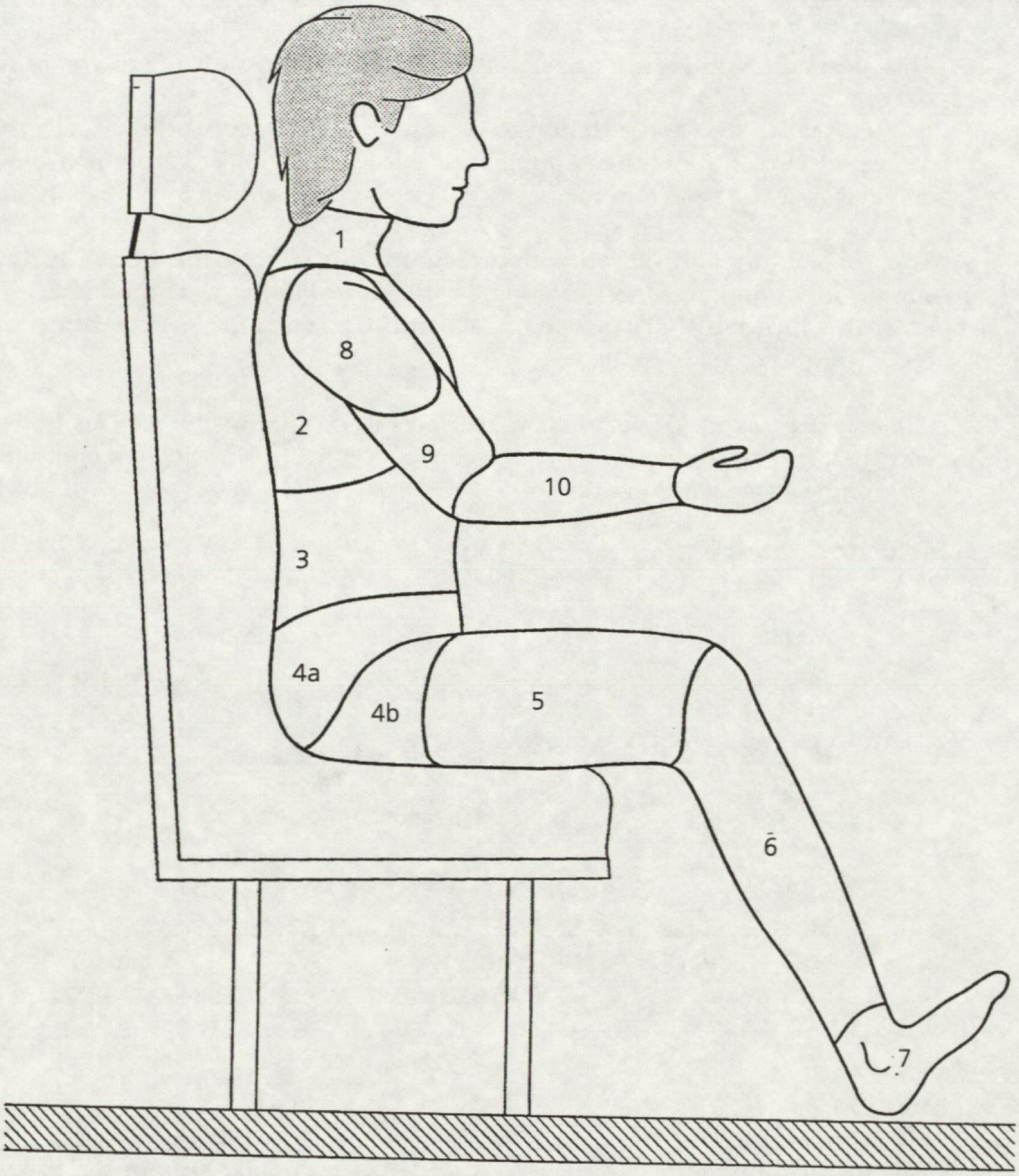
In each seat or seat modification to be tested, the subjects must occupy the seat for a period of no less than 10 minutes before any subjective opinion is sought. Subjects must be seated in the position shown in Figure 2.

Subjects express their opinion of a particular seat feature by placing a mark at the relevant point on a 10 centimetre line.

For example

Is the seat pan length: too short adequate too long

This checklist approach can be used to assess seat dimensions, function and 'fit'



1	Neck	5	Thighs
2	Upper Back	6	Lower Legs
3	Lower Back	7	Feet/Ankles
4	Buttocks	8	Shoulders
	(a) in contact with backrest	9	Upper arm
	(b) in contact with seat pan	10	Lower Arm

Figure 5 The body area map used for comfort rating

6 DYNAMIC RESPONSE OF SEAT

6.1 Introduction

The extent to which helicopter vibration causes discomfort, interferes with activities or impairs health is dependent on the seat dynamics. Seats may amplify or attenuate vibration, depending on their composition and the characteristics of the vibration.

The dominant vibration in helicopters is caused by the rotation of rotors and parts within the gearboxes. The frequencies of rotation are fixed for a particular aircraft but differ between aircraft. The vibration magnitudes depend on flight condition, the condition of the aircraft and many other factors.

The attenuation of vibration provided by a seat depends on the vibration frequency. In consequence, a seat may attenuate more vibration in one aircraft than another. Generally, the greater the proportion of vibration occurring at high frequencies the more the seat will attenuate the vibration.

In this section, a numerical value for the attenuation of vibration required of a seat is defined with reference to Appendix D. The requirements of this section are currently restricted to the transmission of vertical vibration from the floor of the aircraft to the seat pan. The methods defined in Appendix D may also be used with non-vertical vibration and for the transmission of vibration to the backrest.

6.2 Measurements

6.2.1 *Preferred test*

Ideally, a dynamic seat test should be performed either inflight or using a laboratory simulation of vibration recorded during flight in the helicopter. In these cases the seat effective amplitude transmissibility (i.e. SEAT value) should be determined as specified in Appendix D. When reporting the SEAT value the characteristics of the vibration employed in the test must be defined.

6.2.2 *Alternative test*

The SEAT value may be estimated from a knowledge of the helicopter vibration spectrum and measurements of the seat transmissibility.

6.2.2.1 Calculation from measured values

If the helicopter vibration has been measured, the SEAT value may be calculated from the seat transmissibility measured as specified in Sections 7.3 and 8.3 of Appendix D.

6.2.2.2 Calculation without measured values

If the helicopter vibration spectrum is not known it will be necessary to calculate a SEAT value according to Section 8 of Appendix D from an assumed vibration spectrum and the measured seat transmissibility.

The assumed spectrum is based on the assumed magnitudes of vibration at the main rotor frequency, the blade passage frequency of the main rotors and the tail rotor frequency. For any specific type of helicopter, these frequencies are known and the magnitudes of vibration shown in column 3 of Table 6 shall be assumed for each component. If the helicopter type is not known, then the assumed frequencies shown in column 2 of Table 6 shall also be used.

Table 6 Assumed frequencies and magnitudes of vertical helicopter vibration to be used when there are no agreed measured values

Source	*Assumed frequency* Hz*	*Assumed magnitude ms^{-2} rms*
Main rotor frequency	5	0.5
Blade passage frequency of main rotor	15	1.0
Tail rotor frequency	30	1.0

*the known frequencies shall be used, if available

NOTE: It is recognised that the vibration spectrum in helicopters is not well represented by considering only the vibration associated with the main rotor frequency, the blade passage frequency of the main rotor and the tail rotor frequency. The vibration magnitudes associated with these three frequencies may also differ from those shown in Table 6. The values in Table 6 have been selected in recognition that they may be used for a variety of different aircraft with different numbers of rotor blades. Consideration has also been given to the characteristics of seat transmissibility and the frequency weightings used to assess vibration. Use of the assumed values in Table 6 should prevent the selection of a seat which has a dynamic response unsuitable for helicopters. The optimum seat for a specific aircraft can only be selected after consideration of the vibration spectrum to which it will be exposed in that aircraft.

6.3 Reporting

The SEAT value, the vibration spectrum and the method used to derive the SEAT value must be reported (see section 11 of Appendix D).

6.4 Considerations and discussion

A SEAT value of 100% indicates that, although the seat may have amplified the lower frequencies and attenuated higher frequencies, there is no overall useful isolation of vibration. If the SEAT value is greater than 100%, the overall effect of the vibration on the seat has been increased by the seat dynamics. The degree to which the SEAT value is less than 100% indicates the amount of useful isolation provided by the seat. For example, the vibration discomfort experienced on a seat with a SEAT value of 50% will be approximately half the vibration discomfort experienced on a SEAT value of 100%.

The SEAT value for a helicopter seat must be less than 100%. Lower values are desirable.

It is often possible to provide appreciable attenuation of the high frequencies of vibration in helicopters and so reduce the SEAT value to well below 100%. A SEAT value greater than 100%, indicating that the seat is transmitting more vibration than a rigid seat, can almost always be avoided in helicopters.

The SEAT value is usually determined by the dynamic response of the cushion. When selecting cushion materials it is also necessary to consider the support for a good posture (as described in other sections) and crashworthiness.

7 BIBLIOGRAPHY

Grandjean, E (1980). Fitting the task to the man: An ergonomic approach. Taylor and Francis Ltd, London.

Griffin, M J (1990). Handbook of Human Vibration. Academic Press Ltd, London.

Keegan, J J (1953). Alteration of the lumbar curve related to posture and seating. Journal of Bone and Joint Survey, 35, 567-589.

NASA (1978). Anthropometric source book. NASA Defence Publication No. 1024 (US National Aeronautics and Space Administration).

Oborne, D J (1982). Ergonomics at Work. John Wiley and Sons Ltd, Chichester.

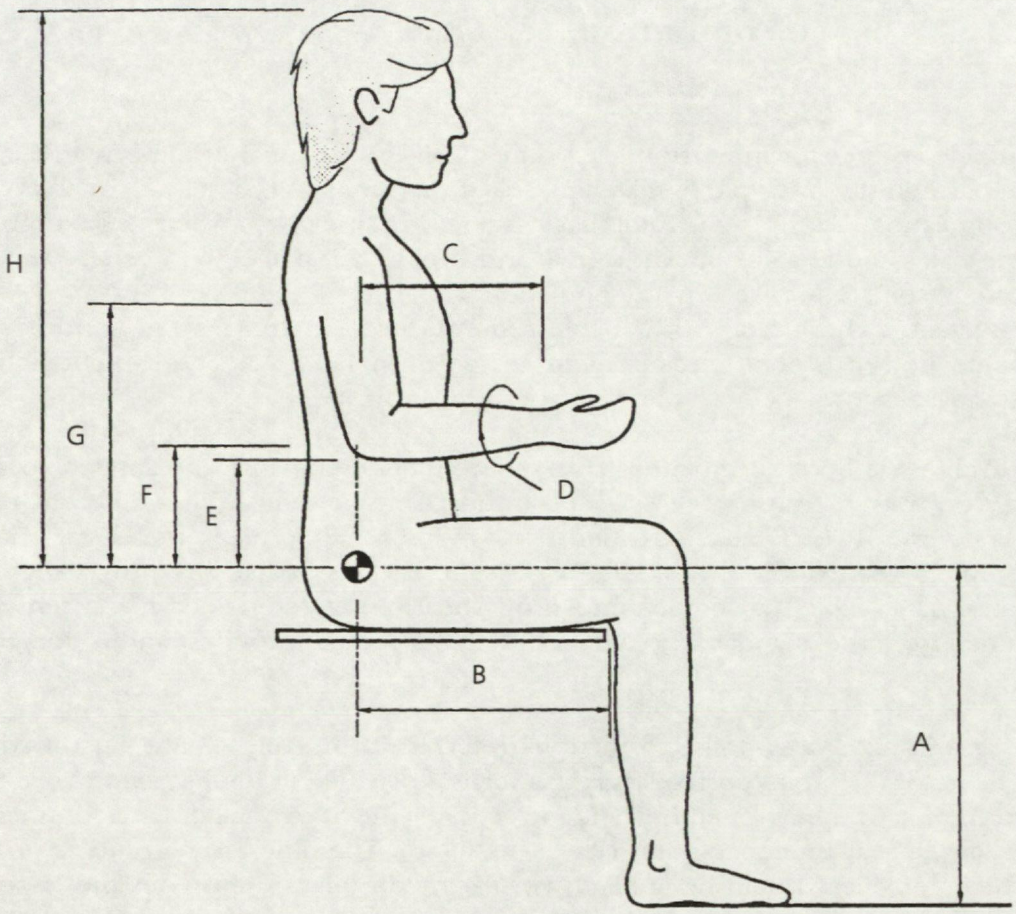
Pheasant, S (1986). Bodyspace: anthropometry, ergonomics and design. Taylor and Francis Ltd, London.

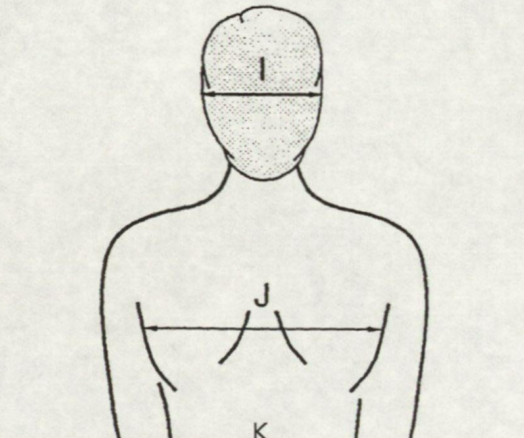
Appendix A Anthropometric Characteristics of the Assumed User Population

The recommended values for the various seat dimensions in Section 3 of the Design Guide are based, in part, on the principle of matching seat dimensions to the relevant dimensions of the user population. The Design Guide has assumed the user population to be a mixed population of males and females drawn from a British population aged between 19 and 45 years (projected estimate for the British population in the year 2000, from Pheasant 1988). Figure A1 illustrates the actual body measurements used in the Design Guide. The percentile values for each body measurement are given in Table A1. The H-point height includes a 'standard' allowance of 25 mm for shoes (Pheasant, 1988).

The Design Guide has been formulated so that recommendations can be applied to any given population by substituting the relevant anthropometric data from a different user population. However, it is not usual to find body measurements using the H-point as a reference point in anthropometric data. To assist in the task of substituting different anthropometric data, Table A2 demonstrates how the H-point referenced measurements may be obtained from the 'standard' body measurements common to most anthropometric data.

The vertical and horizontal H-point corrections referred to in Table A2 are illustrated in Figure A2. The vertical H-point correction is the vertical distance of the hip joint above the Seat Reference Point. The horizontal H-point correction is the horizontal distance of the hip joint in front of the seat reference point (Pheasant, 1988). The different percentiles of the H-point correction values should be applied. For example Table A3 illustrates the H-point correction values for a mixed population of males and females drawn from the British adult population (Pheasant, 1988).





A H-point height
B H-point to popliteal length
C Elbow to wrist length
D $^{1}/_{4}$ forearm circumference
E H-point to elbow height (sitting)
F H-point to lumbar height (sitting)
G H-point to scapular height (sitting)
H H-point to top of head (sitting)
I Head breadth
J Chest breadth (at nipple height)
K Waist breadth
L Hip breadth

Figure A1 Anthropometric measurements used in the Design Guide

Table A1 Anthropometric data used in the Design Guide from British population aged 19–45 years

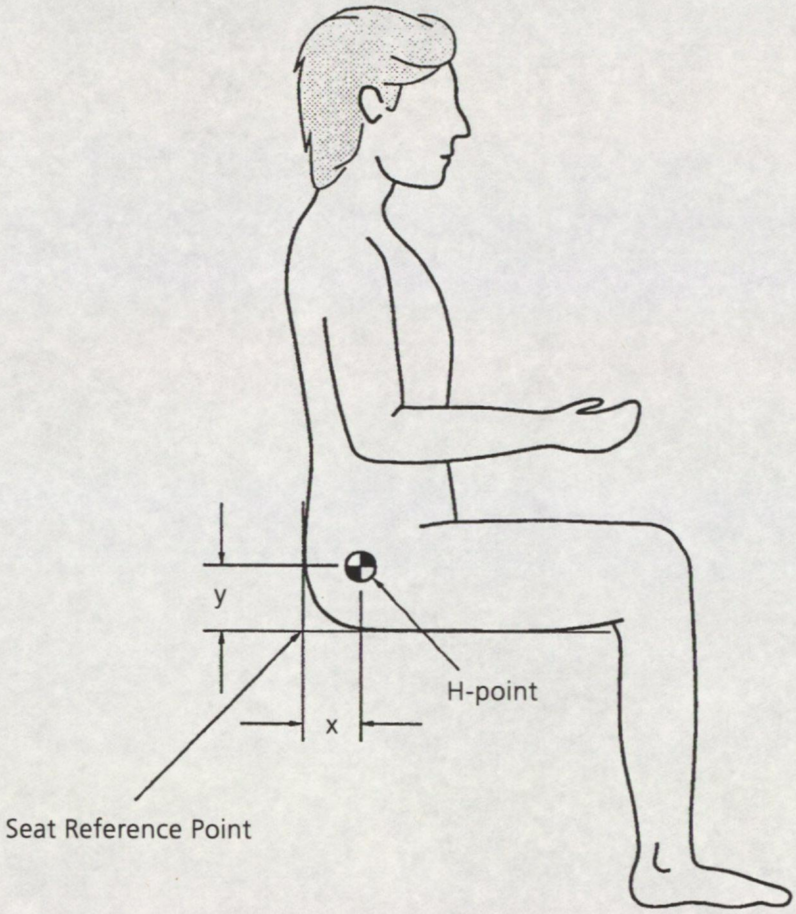
Seat dimension	*Body dimension*	*Male*					*Female*				
		5th	*25th*	*50th*	*75th*	*95th*	*5th*	*25th*	*50th*	*75th*	*95th*
Seat pan	Seat pan										
Height	H-point height	490	525	545	565	595	445	475	495	515	545
Length	H-point to popliteal length	335	360	375	390	420	315	335	350	375	390
Width	Hip breadth	310	335	355	375	405	300	340	365	390	425
Backrest	Backrest										
Width at 400 mm above H-point (i.e. 95th percentile H-point to scapular height (sitting))	Chest breadth	275	295	310	325	345	235	250	265	280	295
Width at 205 mm above H-point (i.e. 95th percentile H-point to lumbar height (sitting))	Waist breadth	250	275	290	305	330	200	215	230	245	260
Width at H-point	Hip breadth	310	335	355	375	405	300	340	365	390	425
Armrest	Armrest										
Height	H-point to elbow height (sitting)	125	150	170	190	215	125	145	165	185	205
Length	Elbow to wrist length	270	280	285	290	305	240	250	255	260	270
Width	1/4 forearm circumference	65	–	70	–	75	45	–	50	–	55
Spacing	Hip breadth	310	335	355	375	405	300	340	365	390	425
Headrest	Headrest										
Height	H-point to top of head	785	820	840	860	890	735	760	785	810	840
Width	Head breadth	145	150	155	160	165	135	140	145	150	155

Table A2 H-point referenced and 'standard' anthropometric measurements

H-point referenced measurement	'Standard' measurement and H-point correction
H-point height	Popliteal height plus vertical H-point correction
H-point to popliteal length	Buttock to popliteal length minus horizontal H-point correction
H-point to elbow height (sitting)	Elbow height (sitting) minus vertical H-point correction
H-point to lumbar height (sitting)	Lumbar height (sitting) minus vertical H-point correction
H-point to scapular height (sitting)	Scapular height (sitting) minus vertical H-point correction
H-point to top of head (sitting)	Statue (sitting) minus vertical H-point correction

Table A3 Percentile values for H-point correction (Adult British population) (Values have been calculated and include rounding errors)

	Males					Females				
	5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
Vertical H-point correction	70	75	75	80	80	65	70	70	75	75
Horizontal H-point correction	110	115	120	125	130	120	125	130	135	140



x Horizontal distance of the H-point or hip joint in front of the Seat Reference Point

y Vertical distance of the H-point or hip joint above the Seat Reference Point

Figure A2 Horizontal and vertical H-point correction measurements

Appendix B Worked Example of the Design Guide

The Design Guide has been used to assess two types of helicopter seat; (1) an existing pilot seat; (2) a prototype pilot seat.

Dimension	*Example seat (existing)*		*Example seat (prototype)*		*Recommended values*			*Percentile criteria*
					Adjustable		*Fixed*	
Seatpan	*min*	*max*	*min*	*max*	*min*	*max*	*Values*	
Height	445	535	410	545	<445	>595	preferable 445, ≯47	5th, 25th
Length	–	350	–	300	–	–	preferable 315, ≯335	5th, 25th
Width	–	415	–	425	–	–	≮390, preferable ≮425	75th, 95th
Angle (degrees)	90	93	94	99	<95	>100	≮95, ≯100	–

Dimension	*Example seat (existing)*		*Example seat (prototype)*		*Recommended values*			*Percentile criteria*
					Adjustable		*Fixed*	
Backrest	*min*	*max*	*min*	*max*	*min*	*max*	*Values*	
Width at: 400 mm above H-point	–	410	–	375	–	–	≮325, ≯345	75th, 95th
205 mm above H-point	–	410	–	385	–	–	≮305, preferable ≮330	75th, 95th
At H-point	–	410	–	0	–	–	≮390, preferable ≮425	75th, 95th
Angle (degrees)	–	15	14	40	<10	>20	≮10,≯20	–

(all values in mm unless stated)

Dimension	Example seat (existing)		Example seat (prototype)		Recommended values			Percentile criteria
					Adjustable		Fixed	
Armrest	min	max	min	max	min	max	Values	
Height	None		45	200	<125	>215	preferably 125, ≯145	5th, 25th
Length	None		–	155	–	–	preferably 240, ≯250	5th, 25th
Width	None		–	70	–	–	≮65	5th
Elbow gap	None		None		–	–	≮50, ≯100	–
Spacing	None		–	470	–	–	≮425	95th

Dimension	Example seat (existing)		Example seat (prototype)		Recommended values			Percentile criteria
					Adjustable		Fixed	
Headrest	min	max	min	max	min	max	Values	
Height	None		None		<735	>890	≮785,≯840	50th ♀, 50th ♂
Width	None		None		–	–	≮160, preferably ≮165	75th to 95th

≮ = not less than ≯= not greater than

(all values in mm unless stated)

Appendix C SAE Manikin and Pressure Monitor

SAE MANIKIN

The SAE Manikin is a three dimensional device used as a standard for defining and measuring vehicle seating accommodation (see Figure C1). It can be adjusted to leg lengths equivalent to those of 10th, 50th or 95th percentile of adult male dimensions. When installed in a seat, the seat penetration is equivalent to that of a 76 kg male.

The H-point is defined as the pivot centre of the torso and thigh. With the manikin installed in the seat the H-point can be used to check the relationship between the human body and the various vehicle structures (e.g. seats, controls).

The SAE Manikin is defined in SAE Standard J826B (1978).

OXFORD PRESSURE MONITOR

The pressure monitor consists of a matrix of pressure cells. The cells have a diameter of 20 mm and can be placed at intervals of 28 mm over a surface. The cells are flexible and designed to cause a minimum of alteration at the interface between the seat surface and the human occupant. After calibration with a mercury sphygmomanometer, the apparatus gives a direct measure of interface pressure in mm Hg. In this Design Guide these values have been converted to kilo Pascals (kPa).

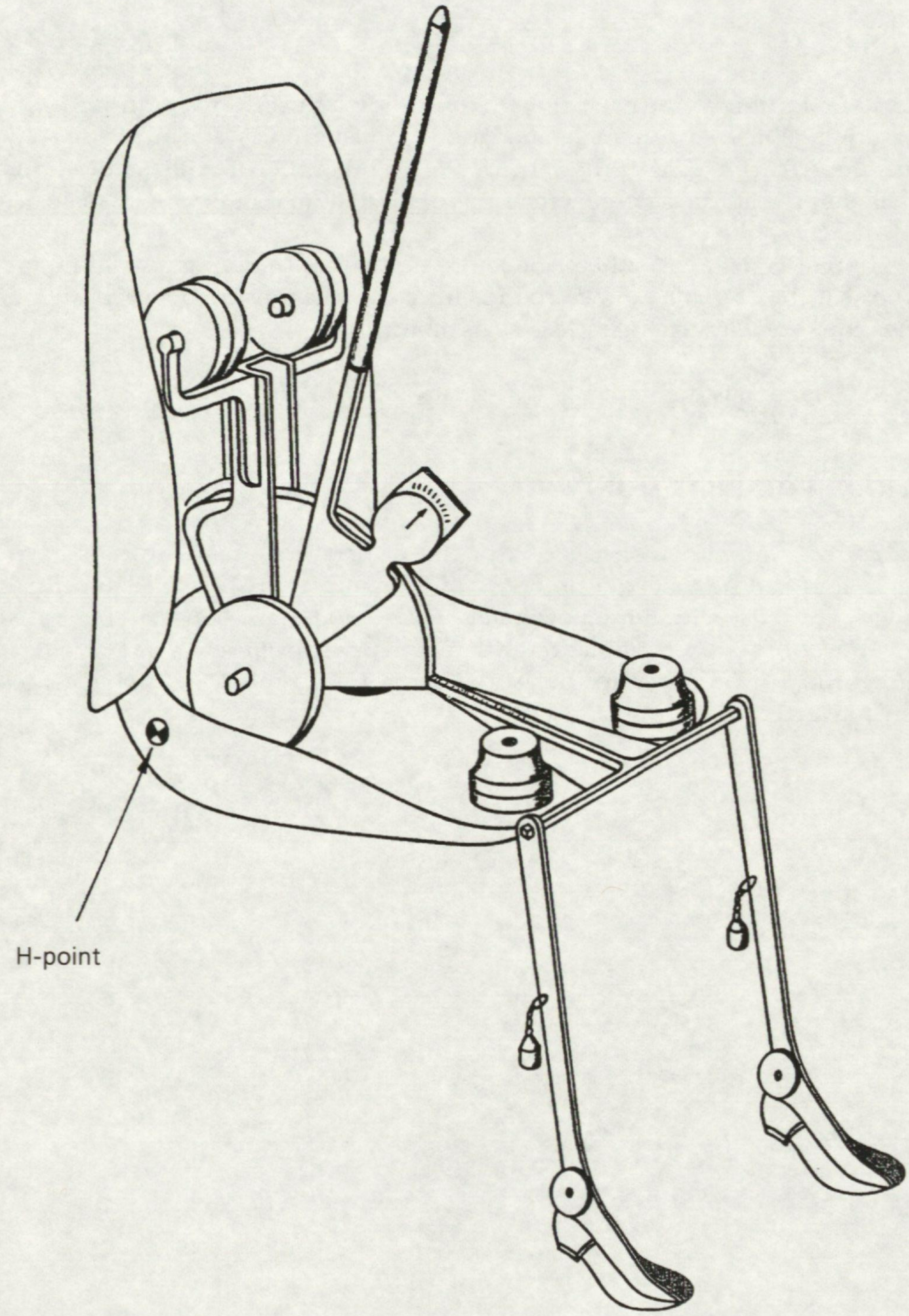


Figure C1 SAE manikin

Appendix D Method For Evaluating the Transmission of Vibration Through Helicopter Seats

1 SCOPE AND FIELD OF APPLICATION

This appendix specifies basic requirements for determining the vibration transmission through a helicopter seat to an occupant of the seat. The methods of measurement and analysis make it possible to compare the test results obtained in different laboratories.

2 GENERAL

The measurement and assessment methods given in this appendix are consistent with the present practice standardised in BS 6841. The measuring equipment and the frequency weighting filters are defined in BS 6841 and BS 7482.

NOTE: The methods have been drafted so as to be consistent with a draft of International Standard ISO 10326–1. However, the vibration evaluation method in BS 6841 (1987) has been substituted for the methods defined in the older ISO 2631 which is currently being revised.

3 INSTRUMENTATION

3.1 Acceleration transducers

The measuring system selected for the evaluation of vibration at the seat mounting and that selected for the evaluation of vibration transmitted to the seat occupant, shall have similar characteristics.

Characteristics of the vibration measuring system, including recording devices, shall conform with Part 3 of BS 7482.

3.2 Transducer mounting

One accelerometer shall be located on the platform [P] at the place where the vibration is transmitted to the seat. The other accelerometer shall be located at the interface between the human body and the seat at either the seat pan [S] and/or the backrest [B] (see Figure D1).

3.2.1 *Transducer mounting on the platform*

The accelerometer on the platform shall be located within a circle with a diameter of 200 mm centred directly below the seat accelerometers. The measuring directions shall be aligned parallel to the movement of the platform. The mounting position should be at a rigid part of the structure so that the accelerometer signal is not influenced by local resonances.

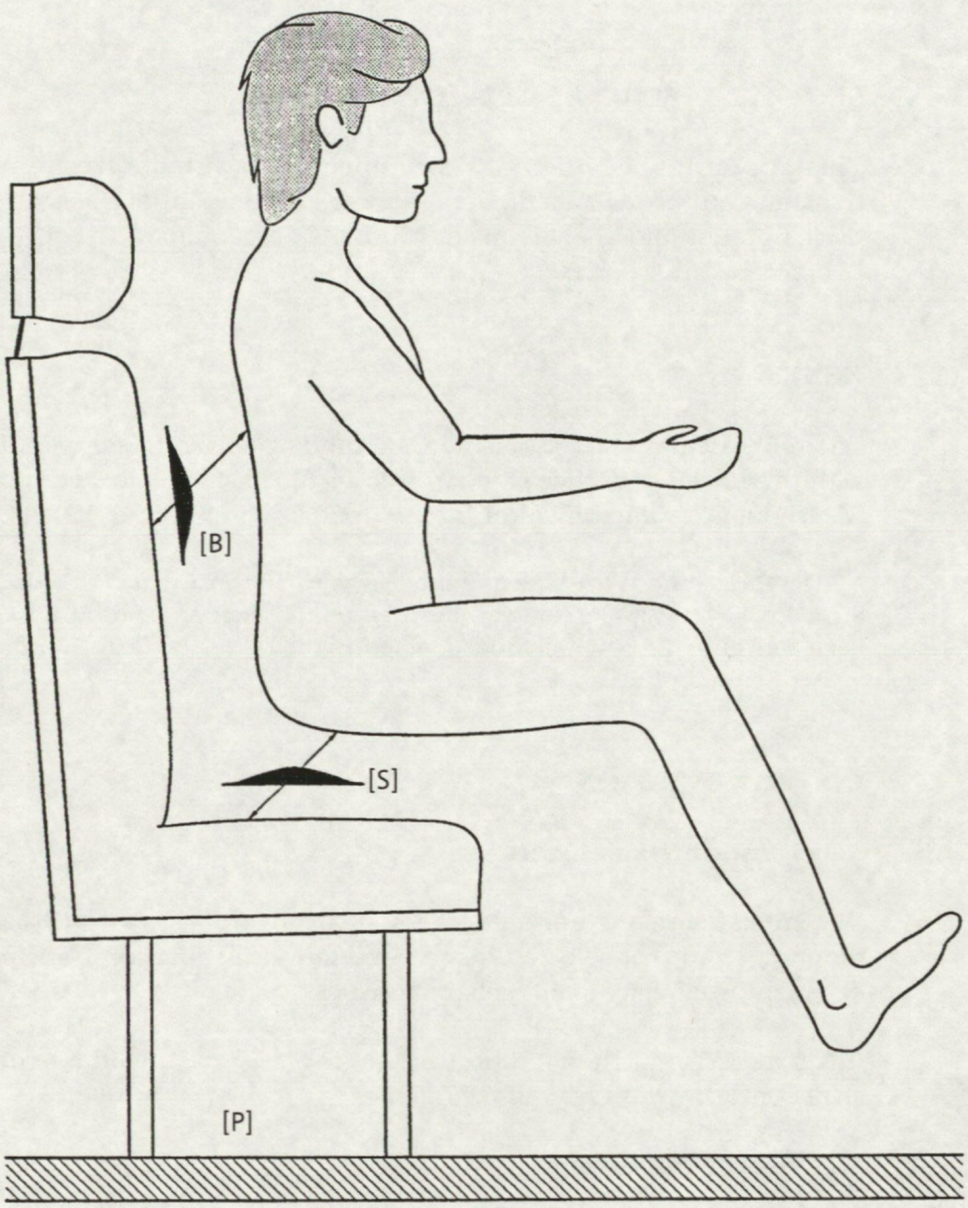


Figure D1 **Location of the accelerometers on the platform [P], on seatpan [S] and on the backrest [B]**

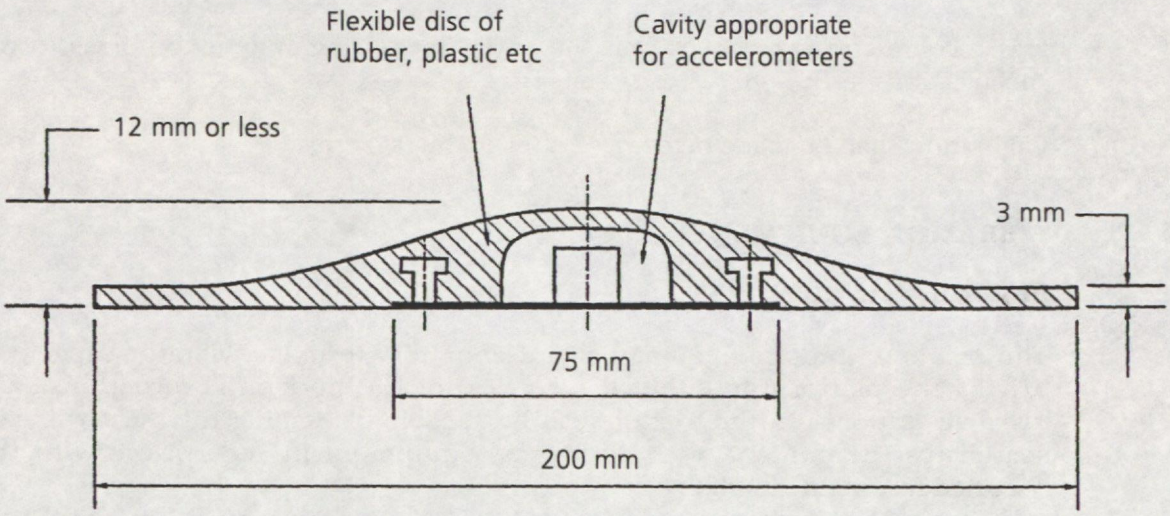


Figure D2 Design of a semi-rigid disc (dimensions in millimetres, not to scale)

3.2.2 *Transducer mounting on the seat pan*

The accelerometers on the seat pan shall be attached in the centre of a mounting disc with a total diameter of 200 mm (± 5 mm), (see Figure D2). This semi-rigid disc of approximately 80 to 90 durometer (A-scale) moulded rubber or plastic material shall have a centre cavity in which to place the accelerometers attached to a thin metal disc of 75 mm (± 5mm) diameter. The disc shall be as thin as possible. The height shall in any case not be more than 12 mm.

The disc shall be placed on the surface of the seat pan and taped to the cushion such that the accelerometers are located midway between the ischial tuberosities of the seat occupant, or within 50 mm of this position.

If measurements are made on the backrest, the accelerometers shall be located in the vertical longitudinal plane through the centre line of the seat. The vertical position of the mount on the backrest shall be such that the upper edge of the mount is at the highest point in contact with the back when the seat occupant sits back against the backrest. The measurement axes shall be aligned parallel to the basicentric coordinate system.

NOTE 1 Besides the semi-rigid disc recommended for soft or highly contoured cushions, a rigid disc with a generally flat surface or an individual form design may be used. The transducer mounting shall be made of low mass materials.

2 For practical reasons it is usually not possible to perfectly align the accelerometers in the disc with the axes of the motion of the platform. A tolerance range within 15 degrees of the appropriate axes is acceptable.

3.3 Frequency weighting

Frequency weighting shall be in accordance with BS 6841 and BS 7482.

3.4 **Calibration**

It is recommended to check that the entire measuring system conforms to the specifications in BS 7482.

Calibration shall be made before and after each test series.

4 VIBRATION EQUIPMENT

4.1 Physical characteristics

The minimum required equipment for laboratory tests is a vibrator capable of driving the platform in either the vertical or the horizontal directions. The dynamic response of the exciter shall be capable of exciting the seat with the seated test person and with additional equipment in accordance with the specified test input vibration.

For the tests involving the simulation of helicopter vibration, or the generation of single or multiple frequency sinusoidal motion, the vibration reproduction must not involve appreciable waveform distortion or background vibration. For the purposes of these tests it is sufficient to show that with sinusoidal vibration at any relevant frequency the acceleration distortion is less than 15%. The background vibration must be less than 15% of the magnitude of the lowest vibration stimulus.

4.2 Control system

If necessary, the frequency response characteristics of the vibration test system shall be compensated so as to correctly reproduce the required vibration. The compensation shall ensure that the power spectral density of the acceleration at the seat mounting base complies with the requirements of the specified test input vibration.

5 SAFETY REQUIREMENTS

Safety requirements should be guided by BS 7085 (1989): 'Guide to safety aspects of experiments in which people are exposed to mechanical vibration and shock'.

6 TEST CONDITIONS

6.1 Test seat

General

The seat to be tested shall be representative of actual or intended production models with regard to design, construction, mechanical and geometrical characteristics and any other factors which may affect the vibration test results.

NOTE: The performance may vary between seats of the same type. Therefore it is recommended to test more than one seat.

If the seat is adjustable, the settings shall be recommended values as defined in Section 3 of the Design Guide.

Before test measurements commence, a person should be seated in the seat for a sufficient time to warm the seat (not less than 5 minutes).

6.2 Test persons

The tests must be conducted with two test persons.

The masses of the test persons must fall in the range between the 25th and 75th percentile mass for the population (i.e. 69 kg to 81 kg). One test person shall have a mass less than the 50th percentile mass (74.5 kg). The other test subject shall have a mass greater than the 50th percentile mass.

The test persons must occupy the seat with feet and arms in a position appropriate to the helicopter cockpit (see Figure 2).

7 TEST INPUT VIBRATION

In order to determine the degree to which the seat will attenuate a specific helicopter vibration a simulated input test is defined (see Sections 7.1 and 7.2).

In order to specify the transmission characteristics of seats with regard to different input frequencies (e.g. for tuning the vibration response of seats) it is recommended to determine the transfer function for the relevant frequency range using a random input spectrum (see Section 7.3).

7.1 Simulated input vibration test

The simulated input vibration shall be specified for a particular helicopter type and may be defined by the time history of a representative signal recorded in the appropriate type of helicopter. Alternatively, it may be defined by the acceleration power spectral density function of a representative recorded signal.

As the dominant components of vibration in helicopters are sinusoidal, it is also sufficient to specify the frequency and rms acceleration corresponding to the principal frequency components. The simulated input vibration may then be synthesised as a multiple-frequency sinusoidal motion with the appropriate spectrum.

When the input vibration is defined by a recorded time history, the frequency range shall be 0.5 to 50 Hz. The recording should be made at the point of entry to the base of a seat in the appropriate helicopter.

Irrespective of how the input vibration is produced, the required frequency weighted rms acceleration on the platform, a_{wp}, shall be specified for each test. This value must be achieved to within an accuracy of ±15%.

7.2 Simulated input test with sinusoidal vibration

For some simulation facilities it may be difficult to generate the multiple frequency motions required for the simulated input test defined in Section 7.1. In this case it is acceptable to conduct the test separately at each frequency in the vibration spectrum. For this test it is important that the vibration magnitudes are set correctly for each frequency of vibration in accord with the measured or assumed spectrum of helicopter vibration.

When testing with sinusoidal motion it is necessary to calculate the overall values of the frequency weighted vibration on the platform, a_{wp}, and on the seat, a_{wS}, that would have occurred if all frequency components had been presented simultaneously.

NOTE: This test requires more testing time: for three frequencies in the spectrum the total test time is increased by a factor of three.

7.3 Transfer function with random vibration input

The vibration transfer function test shall be carried out with two persons as specified in Section 6.2. The transmissibility shall be calculated at frequencies in the range 1 to 50 Hz with a frequency resolution of 0.25 Hz, or less. For this test the power spectrum of the acceleration should be flat (to within 20%) with an overall acceleration of 1.0 ms^{-2} rms.

NOTE: This test is optional.

8 TEST PROCEDURE IN THE LABORATORY

The seat to be tested shall be mounted on the platform of the vibration simulator in accordance with the specified test seat arrangement. The instruments shall be calibrated according to Section 3.4 and the safety shall be checked according to Section 5.

8.1 Simulated input vibration test

A test person shall be positioned in the seat. The vibration simulator shall be operated to produce the appropriate test input vibration. For each subject the test shall be conducted at least three times with the subject leaving the seat between tests.

The test input vibration, during each test run, shall be continuous to provide a sufficient period for data for analysis. In practice this should not be less than 30 seconds.

The test shall be repeated to obtain three consecutive test runs in which the frequency-weighted rms acceleration values, a_w, measured at the seat disc are within 5% of their arithmetic mean. This arithmetic mean shall be recorded as the frequency weighted rms acceleration at the seat, a_{wS}.

The arithmetic mean of the three test values measured at the platform shall be recorded as the frequency-weighted rms acceleration values at the platform, a_{wP}.

The seat effective amplitude transmissibility, SEAT, of the seat, is determined from the ratio of the recorded values as follows:

$$\text{SEAT} = \frac{a_{wS}}{a_{wP}} \times 100$$

8.2 Simulated input test with sinusoidal vibration

The alternative test with sinusoidal vibration should be conducted as specified in Section 8.1 using the input vibration as described in Section 7.2. The test person must leave the seat between repetitions of the same test input.

For this test it is necessary to calculate the frequency weighted rms accelerations that would have occurred if the frequencies of sinusoidal motion had been presented simultaneously. Assume that when the test is conducted with three frequencies of vibration the frequency weighted values on the seat, a_{ws1}, a_{ws2} and a_{ws3} were produced by values of a_{wp1}, a_{wp2} and a_{wp3} on the platform. The SEAT value is then given by:

$$\mathrm{SEAT} = \left[\frac{(a_{ws1})^2 + (a_{ws2})^2 + (a_{ws3})^2}{(a_{wp1})^2 + (a_{wp2})^2 + (a_{wp3})^2} \right]^{1/2} \times 100$$

8.3 Transfer function with random vibration input

The optional determination of the seat transfer function should be conducted using the input vibration described in Section 7.3.

A test person shall be positioned in the seat. The vibration simulator shall be operated to produce the appropriate test input vibration. For each subject, the test shall be conducted at least three times with the subject leaving the seat between tests.

The test input vibration, during each test run, shall be continuous to provide a sufficient period for data for analysis. In practice this should not be less than 30 seconds.

The test shall be repeated to obtain measurements of acceleration on the seat disc and the platform during three consecutive test runs. The subject shall leave the seat between runs.

For each test run the transfer function, H(f), of the seat shall be calculated from the cross spectrum of the acceleration on the seat and the acceleration on the platform, $G_{sp}(f)$, and the power spectrum of the acceleration on the platform, $G_{pp}(f)$:

$$\mathrm{H}(f) = \frac{G_{sp}(f)}{G_{pp}(f)}$$

The mean transmissibility of the seat obtained with each subject shall be determined from the mean of the moduli of the three transfer functions. The mean transmissibilities obtained with the two subjects shall be reported separately.

9 ASSESSMENTS IN HELICOPTERS

The assessment of the seat isolation efficiency in a helicopter during flight is similar to the procedures for the laboratory test with a simulated input vibration (i.e. Section 8.1).

The helicopter must be of the same type for which the seat is intended to be used. The flight conditions (i.e. speed, load etc) shall be selected to represent those most commonly occurring in that helicopter. If required, the measurements may be obtained in several alternative flight conditions.

NOTE: In this case it may not be practical for the seat occupant to leave the seat between measurements. In some cases it may not be possible to obtain measurements with two subjects. Where possible the repetition of the measurements on the same subject, with a second subject and with a different seat of the same type is recommended.

10 ACCEPTANCE

Under the test procedures of this standard, acceptance values can be defined (see Section 6.3 of the Design Guide). Alternatively, seats can be selected on the basis of their SEAT values.

A SEAT value of 100% indicates that, although the seat may have amplified the lower frequencies and attenuated higher frequencies, there is no overall useful isolation of vibration. if the SEAT value is greater than 100%, the overall effect of the vibration on the seat has been increased by the seat dynamics. The degree to which the SEAT value is less than 100% indicates the amount of useful isolation provided by the seat. For example, the vibration discomfort experienced on a seat with a SEAT value of 50% will be approximately half the vibration discomfort experienced on a seat with a SEAT value of 100%.

The SEAT value for a helicopter seat must be less than 100%. Lower values are desirable.

The acceptance value for the simulated input vibration test shall be given as the maximum acceptable SEAT value.

11 TEST REPORT

The test report should contain the following:

(a) Name and address of seat manufacturer.

(b) Model of seat, product and serial number.

(c) Date of test.

(d) Time duration of warm-up period.

(e) Type of measuring disc used: semi-rigid, rigid.

(f) Characteristics of the simulated input vibration test (also distortion and background vibration).

(g) Vibration transmission to the persons at the simulated input vibration test
   - test persons masses in kilograms;
   - seat effective amplitude transmissibilities, SEAT values.

(h) The transfer function with random vibration input.

(i) The name of the person responsible for the test.

(j) Identification of test laboratory.

12 REFERENCES

ISO 2041 (1975) Vibration and shock – Vocabulary.

ISO 5805 (1981) Mechanical vibration and shock affecting man – Vocabulary.

BS 6841 (1987) British Standard Guide to measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock.

BS 7085 (1989) British Standard Guide to safety aspects of experiments in which people are exposed to mechanical vibration and shock.

BS 7482 (1991) British Standard Guide to instrumentation for the measurement of vibration exposure of human beings. Part 3. Specification for instrumentation for measuring vibration exposure to the whole body.