

sitting eye height. One is a group of commercial truck and bus drivers who averaged 29.36 inches in this dimension.¹¹ See Table 2 for the distribution of the series. In the other series 100 male employees of the Civil Aeronautics Administration averaged 29.66 inches with a standard deviation of 1.24 inches. In another male series of 4,000 AAF flying personnel on which sitting eye height, *erect*, was taken, the average was 31.47 inches with a S.D. of 1.27 inches.¹³ For this series, however, a correction factor may be subtracted to adjust for the probable slump in normal sitting eye height. This factor, or difference, between erect and normal seated posture, has been variously determined as follows: (a) two studies at Wright Field showed an average of 1.2 inches;²⁰ (b) 360 commercial truck and bus drivers averaged 1.8 inches;¹¹ (c) 131 civilian pilots showed an average of 2.25 inches.²¹ In general, those with smaller sitting heights will have a smaller than average slump while those with large sitting heights will be above average in slump.

For women, only two small series of *erect* sitting eye height are available; 443 female pilots averaged 30.0 inches, while 151 nurses averaged 29.3 inches.¹⁷ No direct information on slump is available, but it might be tentatively assumed that the average would be slightly less than those observed for males.

b. Arm Reaches. One limiting factor in establishing the dimensions of any working area, including the location of controls, tools, and materials, is the functional arm reach of the operator. It might seem that the static body measurement of anterior arm reach could be used as an indication of the maximum boundaries of the working area for the location of hand controls. However, this dimension defines only the very limited reach area directly in front of the shoulder. Reach to a vertical plane in front of the worker falls off rapidly as the arms are moved to the sides or up and down. Moreover, there is no completely satisfactory way of predicting functional arm reach from anterior arm length or any other single static dimension because of the numerous other variables involved, such as individual differences in sitting heights, shoulder breadths, and variations in the biomechanics of movement at the shoulder. Owing to these difficulties most of the research in this field has been directed toward the study of specific installations for specific populations rather than toward more generally applicable descriptions of biomechanics and human abilities. This is not difficult to understand since the human body is so complex that a formidable number of descriptions would be required in order to provide information for the solution of a significant percentage of industrial situations. It is necessary to develop orderly summaries of the degree of movement, the precision of movement, and the force of movement of the component parts of the body with and without supplementary body support and with various degrees of flexion, extension, rotation, adduction, and abduction.

¹¹ D. I. Patt, Cockpit dimensions in relation to human body size, *TSEAL-3-695-32TT*, ATSC, USAAF, April 29, 1945.

¹³ B. G. King and J. J. Swearingen, Some biological factors in the design of civil aircraft, *J. Aviation Med.*, 19, 414-419 (1948).

The easiest type of functional arm-reach data to obtain is that concerned with only a single horizontal or vertical plane. On horizontal surfaces two "reach" zones may be defined. First, there is a normal reach zone in which work can be done most easily without the use of the upper arm. Second, there is a maximum reach zone, that extends to the points of maximum arm reach. In general, of course, controls, tools, or materials that must be handled often or accurately should be located within the normal reach zone. Secondary items or controls, used only occasionally, may be located beyond the normal reach zone but within maximum reach. Figure 3 shows a drawing of the dimensions of these normal and maximum

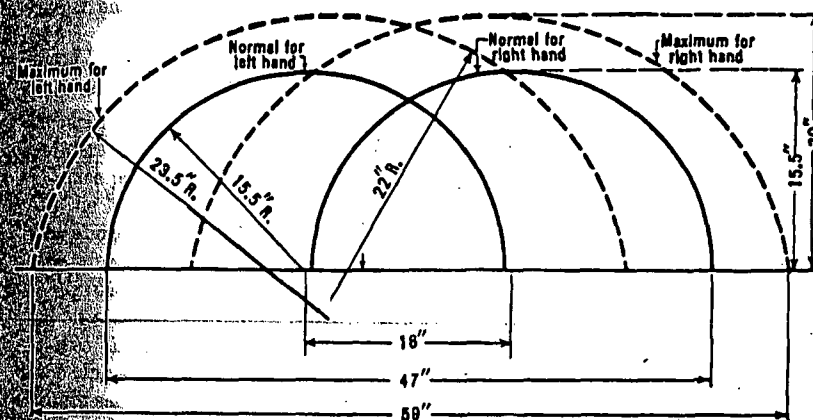


Figure 3. The normal and maximum working areas on a horizontal surface as determined by measurements made on 30 males. The areas are shown for the right and left hands working separately as well as for both hands working together. (Reprinted with permission from Ralph M. Barnes, *Work Methods Manual*, 1944, John Wiley and Sons, Inc.)

working areas as constructed by Barnes. The zones, he believes, should be applicable to about 95 per cent. of the adult working population. For some selected occupational groups, or for segments of the general population larger in body size, these dimensions could be increased. It will be noticed that the reach areas for each arm are semicircular in shape. Work requiring two hands must be located within the overlapping areas of the right and left hands.²²

The maximum reach to a vertical plane in front of the operator will lie directly in front of the shoulder. As the arms are moved to the right and left, or up and down from this point, decreasing portions of the vertical plane will fall

²² R. M. Barnes, *Work Methods Manual*. Wiley, New York, 1944. See also P. C. Squires, Shape of the normal work area, *U. S. Naval Medical Research Laboratory, Report No. 275*, New London, Conn., 1956.