value of one dimension, the corresponding range of values for a second dimension can be determined. The use of such tables can sometimes help to avoid the unnecessary consideration of some of the many individual body measurements that might be pertinent to the design of a piece of equipment. In general, stature correlates reasonably well with body heights and lengths, and weight with breadths, depths, and circumferences.[18] A person of the 5th or of the 95th percentile in height and weight will tend to approximate (but not necessarily duplicate) the 5th or 95th percentiles in his other measurements. Thus, if the height and weight of a group are known, and these measurements are easily taken, *approximations* of some of their other body dimensions may be obtained by referring to correlation tables for this group or even for roughly comparable groups. These have been worked out extensively for the military population by Newman and White. However, it cannot be too strongly emphasized that the correlations are not high enough to permit precise individual prediction, but only group prediction. With intergroup comparisons there is an added factor of error. For these reasons measurements of the dimension involved are always preferable in situations where any degree of precision is required.

3. Dynamic Body Measurements

So far the discussion of anthropometric measurements has centered around the static dimensions of the human body. Although these dimensions are helpful in solving many problems of human sizing in equipment operation, it is evident that a man never operates his machine in the rigid nude positions in which his measurements are taken. For this reason additional material on the dimensions of the human body under dynamic conditions is necessary. To take the most obvious case, clothing can and does alter a man's weight and dimensions considerably. For example, if precise values of weight are required, it is necessary to add allowances for the type of clothing worn while working and for the weight of pocket contents. For men, street clothing may weigh 4 to 8 pounds. While the total increases in the example cited may amount to only about 5 per cent of the nude weight, the specification of a precise reference weight may be important for design purposes; for example, if an engineer adds a percentage safety factor to the strength of a structure based upon a nude reference weight that safety factor would obviously be less than intended. The percentage difference might not be great but situations can be readily visualized where such differences may be of practical importance, for example, when establishing limitations for the number of people occupying an elevator or a vehicle; in conservation of critical materials; or in transport equipment where weight penalties must be reduced to a minimum.[2]

In addition to increasing weight, clothing increases body dimensions, and in

[18] R. A. McFarland, A. Damon, and H. W. Stoudt, *The Application of Human Body Size Data to Vehicular Design*, Special Publication 142, Soc. Automotive Engrs., 1955.

some cases restricts the range and distance of movement as well, as in functional arm reach. With light summer clothing such changes may be negligible, while with heavy winter clothing the differences may be considerable. Other applications in which differences for clothed and unclothed dimensions might be significant would be calculation of area of contact from anthropometric descriptions of the hands and feet, as well as clearance between hand controls, and clearance for pedals or foot-operated controls.

Of greater general importance, however, in the over-all concept of dynamic dimensions is the fact that variations in certain body measurements can influence an employee's ability to perform those movements or actions required for the safe operation of his mechanical equipment. For example, the location of a control for a large man might well be grossly inadequate for a much smaller operator. In cases such as this, one of two courses of action may be taken. Either (*1*) the control must be relocated so as to be equally accessible to both the largest and smallest men, or, if this is not feasible, (*2*) adjustability must be built in at one end of the machine dimension, either at the control itself or at the seat or standing area of the operator.[19]

In considering the whole problem of the functional human dimensions pertinent to the safe design of mechanical equipment, it becomes apparent that the basic data needed, in addition to the static body dimensions in the working position, are of three types: (*1*) the eye level of individuals in the working position, (*2*) the maximum arm reaches, in various vertical and horizontal planes, that can be attained without altering position, and the extension of these reaches attainable by further movements of the trunk or body; (*3*) the leg reaches that can be attained without altering position.[16]

a. Normal Seated Eye Level. This is a basic measurement of considerable importance in the design of working areas of industrial equipment. The eye position of the operator will determine, in part, how much of his surroundings he will be able to see, and how well he will be able to see it. Many working areas have a limited zone in which the operator's eyes will be able to supply him with the necessary visual information most efficiently. The disadvantages of an eye level too low or too high are obvious in the case of vehicular equipment, for example. Where such conditions exist, the designer must see that the spatial relationships of the working area are redesigned so as to permit optimum visibility. This cannot be done, however, unless he first knows at what height above a given seat level the operator's eyes will be located. Although it might seem that seat to eye height would be a fairly straightforward static anthropometric measurement, the problem is complicated by the fact that nearly everyone has a pronounced "slump" when sitting in a comfortable position for operating equipment. However, only two occupational groups have been directly measured for normal

[19] J. H. Ely, R. M. Thomson, and J. Orlansky, "Layout of Workplaces," in *Joint Services Human Engineering Guide to Equipment Design*, Wright-Patterson Air Force Base, Ohio, 1956, Ch. V.