any desired direction by shifting the position of a foot. It is necessary, therefore, that a satisfactory area be provided for him to carry out compensatory shifts of his trunk or foot. If operations must be conducted from the standing position and involve such movements as manual adjustments with extended arm reach, or the removal of one foot from the ground to operate controls, suitable hand or foot rests should be provided. These furnish not only an additional point of postural support, but also eliminate unnecessary energy requirements that would otherwise be needed for support of the extended extremity.

The lack of a stable platform of operations will force the worker to divide his attention between maintaining his posture against unusual disorienting forces and operating his machine. Further, the additional energy utilized for maintaining balance is nonproductive. In consequence, unstable or slippery footing, inadequate seating, and poor body support all adversely influence control operation, reduce efficiency, contribute to muscular and perhaps mental fatigue, and greatly increase the opportunity for injury.

h. Emergency Controls. An emergency control is generally operated by the worker making the error or having the accident. Hence, it should be placed so that it can be operated by other members of the body than the one likely to become caught or injured in the apparatus. Whether the safety stop should be operated by hand or foot or by either is dependent on the task and on certain other factors involved in rapid control operation. Hand-operated controls have some advantages in that the reaction time of the hands is less than that of the feet. Moreover, if the operator is standing, he may have to shift his weight from one foot to the other in order to manipulate a foot control, thereby adding time to the operation.

If the emergency control is to be operated by the hand, it should be positioned within easy reach by either hand when the operator is at or near the normal workplace or near the area where the injury is likely to occur. The same, of course, is true for a foot-operated control. The control should not have to be used accurately and should require only a small amount of force. Since speed of operation is probably the most important factor in determining the success of an emergency control, any arrangement that can only be operated by one particular limb (such as the right foot) is likely to be unsuccessful.[2]

i. Foot Controls. Human engineering data relating to the design of foot controls are less complete than the comparable data on hand controls. In general, however, the problems encountered in the design of foot controls are relatively less complex. Front-to-back seat adjustability can establish satisfactory access to foot controls for people of varying leg lengths, as mentioned above under "Seating Dimensions." The lateral location of pedals frequently can be more critical, however, especially in vehicular or other types of equipment where frequent use of several pedals is essential both to the operation of the machine and to the safety of the operator. When foot controls are crowded, many operational difficulties are often present, especially with heavier footgear, such as the unintentional application of one pedal while attempting to depress the other, or undue delay in removing the foot from one pedal in order to avoid striking the edge or underside of a second pedal. The optimum lateral spacing will vary widely depending on the size and type of shoes or boots normally used on the job. Clearances should not be made unnecessarily large, however, especially between pedals to be used in rapid sequence, since this may increase application time.

One of the aims of foot-pedal design is to lower the energy demands on the operator. This can be accomplished in part by a lever-arm ratio requiring relatively small amounts of work. The machine layout may sometimes place the leg in unnatural positions or may require the driver to make complex compensatory movements in order to move the foot from one pedal to another, thus resulting in unnecessary fatigue. For this reason there should be no structural interference with the movement of the leg or legs during operation of the controls. In order to avoid unnecessary leg motion, the height of a foot pedal in the rest position should never exceed 10 inches above the floor, 8 inches being preferable. In all cases there should be a reasonably large contact area between the sole of the foot and the pedal in order to prevent slippage, and for pressure of long duration, contact with the whole foot is desirable.[88] However, since the arch of the foot can exert a greater force than the toe, the foot should be applied to the pedal so that the distance from the heel to the pedal axis is about 4 inches.[89] This fact is confirmed by the research of Clark and Weddell, who state that maximum force with minimum fatigue is attained when the bones of the lower leg are in a direct line with the pedal axis. This point of contact is toward the front of the heel. It was found, in addition, that the optimum leg position, of those tested, for exerting maximum pressure without strain was with the thigh horizontal and the knee at a 45° angle from the vertical. If the thigh is elevated from the seat a greater pressure can be exerted. Should adjustability be desirable and feasible in the pedal stalk itself, there are some data to indicate that about $8^1/_2$ inches of adjustability will be necessary in order to accommodate persons (males) of different body size.[90]

3. Standardization of Equipment

One of the major factors that may cause a worker to deviate from the best method of doing a job is the variable nature of the controls and equipment provided for him.[91,92] Frequently the individual is called upon to employ different models of some type of device in order to effect a given end. The arrangement of

[88] H. Koch, Fussbediente Arbeitsmachinen und Ermudung, *Arbeitsschutz*, 3, 52–59 (1941).

[89] E. A. Muller, Die gunstige Anordung im sitzen betatigter Fuszhebel, *Arbeitsphysiologie*, 9, 123–127 (1936).

[90] L. G. Clark and G. M. Weddell, The pressure which can be exerted by the foot of a seated operator with the leg in various positions, *R. N. P. 44/163*, Royal Naval Personnel Research Committee, Med. Research Council, Cambridge University, England, 1944.

[91] P. M. Fitts, Psychological requirements in aviation equipment design. *J. Aviation Med.*, 17, 270–275 (1946).

[92] P. M. Fitts, Psychology and aircraft design. *Mech. Eng.*, 69, No. 2, 135 (1947).