

level might not only be located inaccurately without visual aid but might also result in fatigue if operated frequently. Placement at about elbow height is probably best for those controls that are to be operated continuously.

Point of origin, reaching distance, and terminal point all influence the accuracy with which movements can be made.⁷⁶ In general, it appears that controls in forward areas should be located at least 6 to 8 inches apart if reasonable certainty of not grasping the wrong control when "reaching blind" is desired. Work areas should be "cleared up" so that unnecessary objects or controls, or moving or dangerous parts, are eliminated. Such a program could result in a reduction in the number of cases of inadvertent operation of controls, the erroneous operation of one control for another, the inability to locate a control quickly enough due to confusion, or accidental entanglements with the machinery.

b. *Direction of Movement.* Analysis of errors has indicated the importance of taking into account the relationships between the movement of the display desired (whether a pointer, a drillpress head, or a crane boom) and the direction of motion required by the control to produce that movement. This is particularly true when sudden and discrete movements of the controls are required. It is important that a control handle should move so that the resulting display movement is in the "expected" direction in order to minimize the possibility of accidental movement of the control in the wrong direction (see Figure 10).²

In order to define these "expected" directions, it was observed how operators moved a rotary control in order to center a linear display when different spatial arrangements existed between the display and the control.⁷⁷ Operators consistently responded as though they expected the movement of the indicator to be in the same direction as that portion of the knob adjacent to the indicator. It was found that arrangements in which both the control and the indicator were in the same perpendicular plane facing the operator brought about more consistent responses than arrangements in which control and indicator were not in the same plane.

Other studies have confirmed the above finding that when individual responses are required, fewer errors occur if the movement of a control lever produces a response in the "expected" direction.^{78,79} In other words, fewer errors are made when

⁷⁶ P. M. Fitts and C. Crannell, Location discrimination: II. Effect of twelve days of practice on the accuracy of reaching movements to twenty-four different areas, *Memorandum Rept. No. MCREXD-694-41*, Air Materiel Command, USAF, n.d.

⁷⁷ M. J. Warrick, "Direction of Movement in the Use of Control Knobs to Position Visual Indicators," in P. M. Fitts, ed., *Psychological Research on Equipment Design, Rept. No. 19*, USAF-Aviation-Psychology Program, U. S. Government Printing Office, Washington, 1947, Ch. 9.

⁷⁸ M. A. Vince, *Direction of Movement of Machine Controls*, Flying Personnel Research Committee, Med. Research Council Unit in Applied Psychol., Cambridge University, England, 1946.

⁷⁹ M. J. Warrick and W. F. Grether, The effect of pointer alignment on check reading of engine instrument panels, *Memorandum Rept. No. MCREXD-694-17*, Air Materiel Command, USAF, June 4, 1948.

an upward movement of the control produces an upward movement of the display and a downward movement of the control produces a downward movement of the display. The second best relationship was found to be a forward movement of the

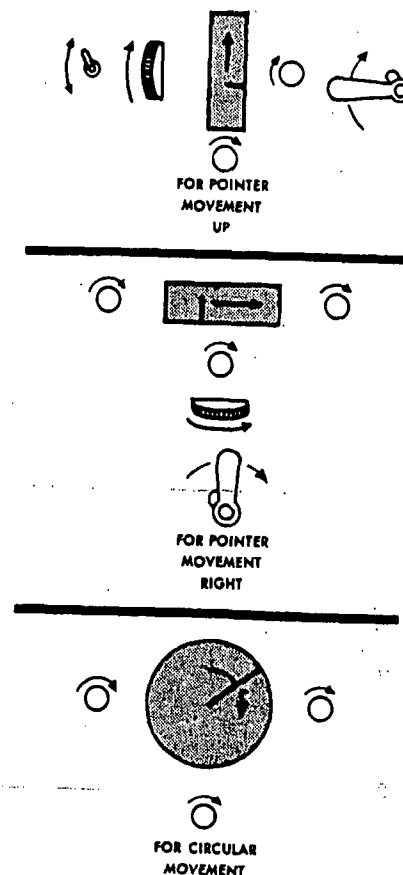


Figure 10—Expected relationships between controls and displays. The proper direction of movement for knobs, cranks, and toggle switches is indicated above for corresponding pointer movement upward, to the right, and in a circular direction. (From Woodson.⁸⁰)

control to move the display up with a backward movement to move the display down. Display-control relationships have also been found to result in fewer errors