A DISPLACEMENT-SENSING, CONSTANT-TORQUE RESPONSE LEVER

ROBERT M. HERRICK AND PAUL KARNOW

U. S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA.

This report describes a response-lever mechanism that was designed specifically to study the intensive properties of lever-pressing behavior of rats in an orbiting satellite. The applications of the lever, however, are not restricted to behavioral studies in outer space.

The characteristics of the lever mechanism are illustrated in Fig. 1. First, the mechanism senses the angular displacement of the lever arm during each lever press. Second, the

Fig. 1. Schematic representation of characteristics of displacement-sensing, constant-torque response lever. (See text for interpretation of symbols.)

system functions as though a constant force, F_K , maintains a constant clockwise torque in opposition to the counterclockwise torque created by the force, F_{rat} , which is applied by the rat. Third, exposure of the whole lever mechanism to an additional force, F_A (such as the force of gravitational attraction), does not change the torque required to rotate the lever arm.

The electrical system consists of a pair of electrically connected brushes in a sleeve in one end of the lever arm, and nine pairs of contacts, flush-mounted in two insulating plates. The nine contacts in one plate are electrically continuous, and the nine in the other are electrically isolated. When the lever arm rests against the upper stop, current flows

into the large "home" contact. When the T-bar is pressed, current is carried, in succession, to the other eight contacts.

The system maintaining a constant clockwise torque consists of two *Ne-ga-tor* springs that spool from two small drums onto a large drum to which the lever arm is secured. When the T-bar is pressed, the large drum rotates against a constant opposition created by the springs. (Details of how these springs produce this constant opposing torque may be found in *Ne-ga-tor* Spring Bulletins of the Hunter Spring Company of Lansdale, Pennsylvania.)

Preventing additional forces from changing the torque characteristics is achieved (a) by mass-balancing, at the fulcrum, the T-bar side of the lever arm against the brush assembly side, and (b) by using two *Ne-ga-tor* springs so that the effects of an extraneous force on the springs are equal and opposite.

Fig. 2. Photographs of response-lever mechanism. Top photo: top outer casing removed and one plate lifted off. Lower photos: Lever arm—*Ne-ga-tor* spring assembly on left; plates and lower outer casing on right.

To evaluate the response-lever characteristics, three calibration procedures were followed. (1.) Use was made of a dividing head

(a milling machine accessory) to measure contact size and spacing. The arc generated by the T-bar while moving from one contact to the next was within $\pm 0.2^\circ$ of the desired 5° (or 4.43 mm). (2.) A specially constructed device measured the force applied perpendicularly to the T-bar as a function of angular displacement. The force was about 30,000 dynes, with a variation of 2 or 3% throughout the total 48° excursion of the T-bar. (3.) The force required to move the T-bar was measured during centrifugation of the lever mechanism. The variation in the force during exposures to radial accelerations between 2.5 and 28 g was about 1 to 2%. (Further details of the response lever and the calibration procedures are given in References.)

Figures 3, 4, and 5 suggest some of the analyses possible with data obtained with the lever.

Fig. 3. Sample record of the time course of a single lever-press.

Fig. 4. Sample record of the sequence in which 100 lever-presses were emitted.

In these figures, use is made of a "lever position code." The Home Position represents the interval of arc of the T-bar (adjustable 5 to 8°) from its resting position against the upper stop to a point just before the brush touches the first small contact. Lever Position 1 represents the next 5° of arc of the T-bar, and each successively numbered lever position

Fig. 5. Sample record of frequency of lever presses to each lever position, in percentages.

represents an additional 5° of arc. Figure 3 presents the time course of a single lever-press made by a human. Figure 4 gives the maximum displacement of the T-bar for each of one-hundred successive lever-presses by a rat. A reinforcement was given only when the T-bar was pressed to Lever Position 5, or 6, or 7 and then returned to the Home Position. Figure 5 shows a distribution of lever presses when only the presses to Position 5 were reinforced.

REFERENCES

Herrick, R. M., and Karnow, P. A displacement-sensing constant-torque response lever designed for use in satellites. U. S. Naval Air Development Center, MA-6105, 1961.
U. S. Patent No. 2, 971, 273 (issued 14 Feb 1961) and U. S. Patent No. 2, 972, 198 (issued 21 Feb 1961).