HOW ENGINEERS USE BASIC SCIENTIFIC FACTS—ILLUSTRATED BY A CONCRETE EXAMPLE

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ABSTRACT

There was a requirement for a small, sensitive electric switch, suitable for operation by slow motion, where small energy is available. Operation by thermal expansion is one example of such slow motion. The requirement was for a switch capable of controlling a ½ h.p. alternating current motor at full line voltage without the use of relays. It must also make positive contact and have low resistance on low energy switching, as in thermocouple circuits. It was apparent that to control a load of ½ h.p. at potentials up to 460 volts required snap action, yet the microscopically slow motion (on the order of 2.5 x 10^{-4} cm. per minute) and a total energy of only a few hundredths of a g. cm., ruled out the use of wide contact separation. Hence, the first consideration was the criteria of breaking an alternating current circuit without wide contact separation. It was impractical to consider working with a gap within the mean free path of an ion, but experience indicated that in contact openings on the order of .02 to .05 cm., ionization is less than with wider gaps, and that silver contacts separated by this distance, at suitable speed will satisfactorily interrupt circuits carrying 1200 watts at potentials up to 600 volts. The successful use of such short gaps for power switching had long been overlooked, although the general principles have been recognized in automotive ignition breakers for many years.

To meet commercial requirements, such a switch must provide a sharp, clean break to avoid radio interference, as well as to prevent contact destruction. The toggle mechanism to produce such a snap action break must also provide a velocity of contact separation on the order of 4 centimeters per second, as it has been learned that interrupting 60 cycle alternating current loads at lower velocity than this offers the probability of the rekindling of the arc if the zero phase is passed at the time the contacts are only minutely separated. On higher speeds, the probability is of an arc of higher voltage, due to greater mean length, and, consequently, greater wattage. Hence this critical speed produces the minimum mean energy dissipation in the arc. The mass of the moving parts and the air damping must also be considered from the standpoint of minimizing the bounce of contacts on the make, as the arcs occurring during the period of bounce are destructive to contacts and detract from the precision of the operation when

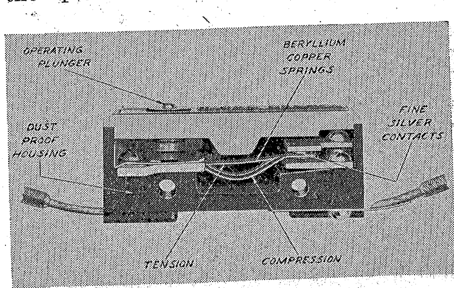

Fig. 1

switches are used as timing means where a few milli seconds tolerance is of consequence.

Most of these elements may appear to be pure engineering problems, yet it was found helpful to review the theoretical physics of spring moduli and the criteria of stability in considering the relationship of parts of a toggle mechanism which will approach the performance specified.

In its commercial form, the switch is made from a single piece of heat treated beryllium copper .2 mm. thick. The spring is cut to have one central member 4 cm. long and two side members, joined to the central element at one end, each 2.2 cm. long, the whole being 1.3 cm. wide. The long central member is mounted in cantilever manner and the two short side legs seated in V's so placed as to give them a bow form. The free end carries a silver contact cooperating with fixed contacts. Fig. 1 illustrates

such a switch mounted in a Bakelite block (shown cut open), with an operating plunger bearing against the long tension member at such a point as to produce a snap movement of the contact end. This type is self returning, but by use of wider separation of fixed contacts, it may be made of a sustained contact type. Such switches are made to operate with a plunger movement on the order of 2.5 x 10^{-4} cm. and a total energy of as little as .05 g. cm. Variations in design are made as it is apparent that a switch useful on the new 200 inch telescope in California will be specified in a different manner from one which must resist the vibration and centrifugal forces present in the hub of an aeroplane propeller, and an incubator thermostat switch will differ from one used on a ponderous machine tool.

The switch was designed primarily for use on alternating current, but by use of special circuits, several hundred watts D.C. may be switched.

The commercial success which this switching device has attained has fully justified the time and expense put into the careful scientific study of the basic principles involved.