pass through an epoxy seal and thence through a straight coupling into a U tube from which they emerge via a second T and another short epoxy seal to the room. All tubing is 3M and standard fittings are used. Silicon oil is pumped into the U tube under pressure (usually only 1 kbar) and frozen in a liquid nitrogen Dewar. The purpose of this solid plug is to stop any gas leaking past the first epoxy. The seal is designed for maximum safety.

Thus far, this seal has been used without a single leak or problem. In principle, the seal should not leak at any pressure up to the rupture pressure of the tubing, or blowout of the last epoxy seal, because, if necessary, one may equalize the gas pressure and oil pressure on opposite sides of the first epoxy seal. (This does not appear to be at all necessary and consequently one should be able to contain much higher pressures than the blowout pressure since the first seal is subjected to the differential pressure). The basic achievement of the seal is to transform the problem of making a low temperature gas seal into that of a room temperature liquid seal, a vastly easier problem.

In Fig. 3 is shown the piston seal and another type of plug seal used with solid helium to 10 kbar in the piston-cylinder apparatus. In addition to sealing against solid helium the piston must be leak tight against fluid helium below its freezing pressure. To meet this requirement a threaded stem is provided on the cap for a pretensioning nut. An indium gasket serves as the low pressure seal and as a lubricant during the piston stroke; indium seems to be very satisfactory in this application and much easier to work with than potassium washers which have been used in similar systems.[11] The antiextrusion rings are chiefly responsible for the high pressure seal. The fixed plug seal design features a single unsupported wedge of a hard material (in effect, a single antiextrusion ring) in a sandwich of washers. This seal was very successful with solid helium, and requires remarkably little pretightening. Since the ring twists when compressed, an accurately machined fit to the bomb is not required.

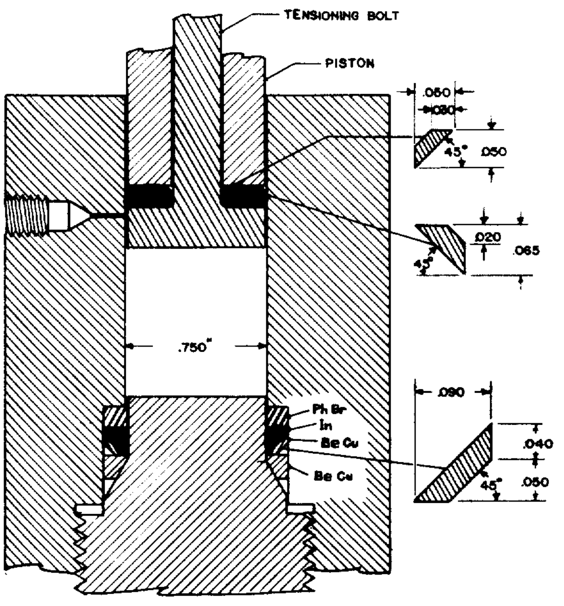

FIG. 3. Seals for 10 kbar piston-cylinder apparatus. Washers are of phosphor bronze, half-hard beryllium copper, and indium; piston antiextrusion rings are of half-hard beryllium copper, and all remaining parts are of hardened beryllium copper.

---

* Research supported by the National Science Foundation.

[1] American Durafilm Company, Inc., Newton Lower Falls, Massachusetts. We are grateful to Donald H. Newhall of Harwood Engineering Company, Walpole, Massachusetts for drawing our attention to this product.

[2] R. H. Cornish and A. L. Ruoff, Rev. Sci. Instr. 32, 639 (1961).

[3] F. Lazarre, J. Phys. Radium 14, 213 (1953).

[4] D. Gugan, J. Sci. Instr. 33, 160 (1956).

[5] K. S. Balain and C. J. Bergeron, Rev. Sci. Instr. 30, 1058 (1959).

[6] L. G. Blosser and H. S. Young, Rev. Sci. Instr. 33, 1007 (1962).

[7] L. A. Davis, R. B. Gordon, J. K. Tien, and J. R. Vaisnys, Rev. Sci. Instr. 35, 368 (1964).

[8] R. J. Vaisnys and P. W. Montgomery, Rev. Sci. Instr. 35, 985 (1964).

[9] Furane Plastics, 4516 Brazil Street, Los Angeles, California.

[10] Emerson & Cuming, Inc., Canton, Massachusetts.

[11] C. A. Swenson, Phys. Rev. 112, 31 (1958).

Gas-Triggered Pinch Discharge Switch*

R. G. JAHN, W. VON JASKOWSKY, AND A. J. CASINI

Guggenheim Laboratories for the Aerospace Propulsion Sciences, Department of Aerospace and Mechanical Sciences, Princeton University, Princeton, New Jersey

(Received 16 July 1964; and in final form, 11 September 1964)

THE advantages of gas-triggered discharges confined by ablating insulator surfaces for low inductance switching of large current pulses have been discussed in a previous note.[1] This note also described the design and performance of a particular inverse pinch switch which successfully incorporated these features. A similar switch has subsequently been constructed which discharges in a direct pinch mode and displays significantly better performance than its predecessor. The device is shown schematically in Fig. 1.

The electrodes are plane, circular disks of aluminum, 14 cm in diameter, separated 4 cm by two concentric Plexiglas insulators which define an annular discharge gap 2.5 cm wide. A group of twelve 6.3-mm radial holes are drilled through the inner insulator, via which the discharge gap is first evacuated, and then triggered by a pulse of gas. The concentric return conductor is separated from the electrode edges and outer Plexiglas cylinder by a Teflon sleeve which extends into the external coaxial leads to the load and to the source.

In its present application, this device switches a 15-μF, 10-kV capacitor bank across another discharge chamber[2] which draws some 3×10^5 A peak current at about 500 kc. The operational sequence consists of the evacuation of the switch gap to a pressure considerably below the Paschen limit for argon ($\approx$0.5 mm Hg-mm), the sub-

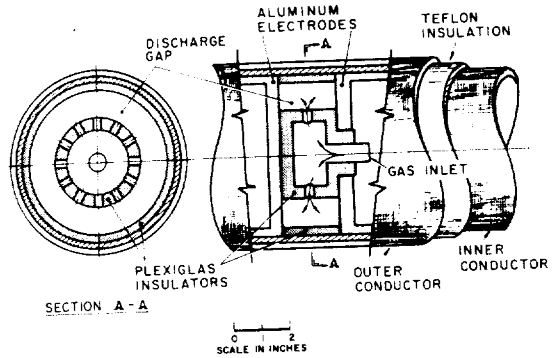

FIG. 1. Schematic diagram of pinch discharge switch.

sequent charging of the capacitor bank to the desired voltage, and finally the symmetrical injection of a small amount of argon through the radial ports in the inner insulator into the discharge gap. As the gas density rises past the Paschen limit, a diffuse breakdown precipitates over the entire gap ring. In this type of operation the switch stabilizes at an inductance of about 3×10^{-9} H, and at a resistance of about 5×10^{-3} Ω, and displays a minimum of initiation noise and electrode damage. It is found to sustain several hundred discharges before requiring dissembly for cleaning and buffing of the electrode surfaces.

The two critical dimensions in the device are the length and the annular width of the discharge gap. The former was established by empirical experiments as the minimum length which would permit sufficiently low gas density at breakdown to sustain the diffuse discharge mode. Shorter gap lengths, which predicted higher gas densities at breakdown, displayed a tendency to concentrated arc filaments.

The width of the annular gap was determined as a compromise between minimizing the inward constriction or "pinching" of the discharge, which would tend to increase the inductance, and the necessity to provide adequate gap width for the discharge to develop the desired cylindrical symmetry. Magnetic probe experiments in similar discharge chambers without the inner insulator show that the breakdown current tends to assemble itself into a cylindrically symmetric pulse, about 2 cm in radial width, near the outer insulator[2] (Fig. 2). If too large a diameter inner insulator is inserted into such a chamber, thereby establishing an annular discharge gap smaller than this preferred initial current pulse width, the discharge is found to use only a small angular fraction of the gap, concentrating in a higher inductance, higher resistance configuration at some azimuthal position. The initial current pulse width, and hence the minimum gap width, is presumably associated with the effective skin depth of the discharge plasma, and thus would be mildly frequency dependent. Although this frequency dependence has not yet been explored in detail, it is anticipated that the influence of the channel width on the azimuthal symmetry of the discharge will persist in other applications of this type of switch.

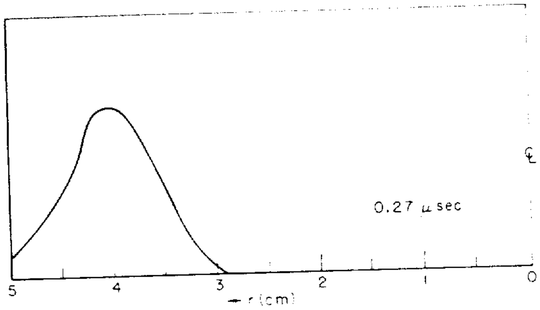

FIG. 2. Current density distribution in 10-cm-diam pinch discharge in 20 μ argon.

---

* Supported by NASA Grant NsG-306-63.

[1] R. G. Jahn, W. von Jaskowsky, and A. J. Casini, Rev. Sci. Instr. 34, 1439 (1963).

[2] R. G. Jahn and W. von Jaskowsky, Am. Inst. Aeronautics Astronautics J. 2, 1749, (1964).

Combustion Bomb with a Window*

DAN PAVONE AND CHARLES E. HOLLEY, JR.
University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

(Received 28 July 1964; and in final form, 25 September 1964)

THE desirability of visual observation of combustion reactions in calorimetric research was first stated by Ziehl and Roth[1] in 1948. They briefly described the construction of a combustion bomb having a glass window mounted in a side arm perpendicular to the axis of the combustion chamber, and the utilization of motion picture photography to record and study combustion reactions. More recently, Nuttall, Frisch, and Hubbard[2] have reported on the construction of a transparent bomb based upon the use of a thick-wall Pyrex glass cylinder for the combustion chamber. These authors also enumerate the advantages to be gained in determining optimum conditions of combustion by visual observation of the effect of variation of combustion conditions on combustion temperature, rate of burning, fusion of the sample and combustion products, spattering, and the resulting completeness of combustion.

Figure 1 shows an isometric cross section of the apparatus we have designed and found to be convenient for the study of combustion reactions. It is designed to be used at pressures up to 70 kg/cm^2. The combustion chamber (A), 7 cm i.d.$\times$11.4 cm high, and the side arm (B), 5.7 cm i.d.$\times$5 cm long, are constructed of type 321 stainless steel tubing with a wall thickness of 3 mm and are welded to the base and closure fittings, also of stainless steel, by tungsten-inert gas arc welding. The axis of the side arm is at an angle of 60° from the vertical axis of the bomb. The lid (C) and the closure nuts (D and E) are made of