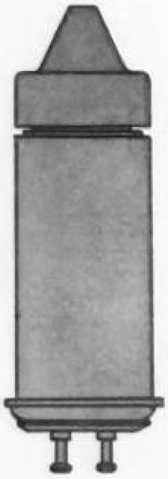
# COMPONENTS DESIGN

# HIGH VOLTAGE CONTROL



Electro-optical device consisting of a light bulb and a photosensitive cell contained in a light-proof case affords isolation up to 25,000 volts between light bulb (control) and photoconducting cell (signal) circuits.

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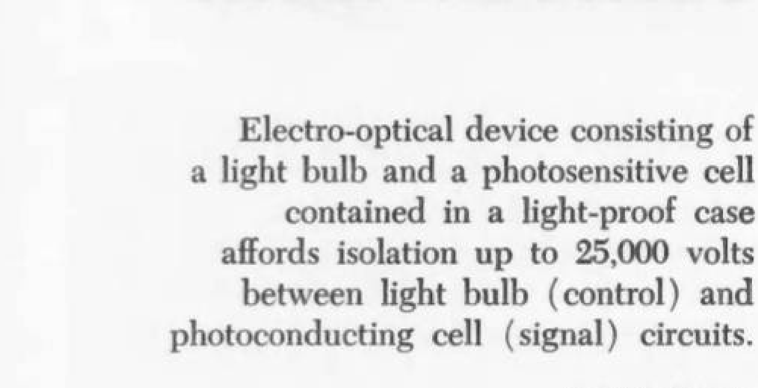

Fig 1 Four-terminal electro-optical device consists of a light source and a photoconducting cell enclosed in an opaque tube. Variation in the light source causes variation in the cell's conductivity. Common applications of the Raysistor include use as relays, choppers, or electrically controllable potentiometers or rheostats. In relay applications, the absence of moving contacts eliminates the problems of contact wear and pitting and provides life capability of over two billion operations. In potentiometer applications, noise and scratch of a moving contact in the signal circuit are absent. As a chopper, the Raysistor avoids the problems associated with moving contacts. Less than 0.5 microvolt emf is induced in the photocell due to modulation of the light source.

In July of last year, Raytheon announced a four-terminal electro-optical device called a Raysistor, designed to replace relays, switches, and potentiometers for low-noise commutation, switching, and circuit control. A voltage applied to two of the terminals controls the passage of a signal at the other two terminals. The control circuit consists of a light source which, when fully excited, lowers the resistance of a photoconductor in the signal circuit by a factor of about $10^6$, thus allowing an ac or dc signal to pass. When the intensity of the light source is varied, the Raysistor acts as a potentiometer or rheostat. Figure 1 describes the physical characterisctics of the basic Raysistor design.

### NEW HIGH-VOLTAGE DESIGN

A major factor in the performance of the Raysistor is the electrical and mechanical isolation of the control circuit from the signal circuit. Electrical control energy is converted to light energy to release charge carriers in a completely separate circuit. Raytheon engineers recognized that this principle could be used to provide extremely high voltage isolation between circuits. Applications of such a device would be for control of high-voltage power supplies, bias control of high-voltage regulator tubes, and metering of any circuit at a potential with respect to ground (with a meter at ground potential).

Starting with the basic Raysistor, Raytheon set up a development program to provide isolation up to 25,000 volts between the signal circuit and the control circuit. Figure 2 shows a production model of a high-voltage Raysistor that fulfills the program objectives. Figure 3 shows the performance of a typical unit.

Principal problems of the design were:

- *To find a dielectric material that would be a water-clear optical medium for maximum transmission of the control light, and that would not break down under high-potential gradients so as to permit spark flash-over be-*

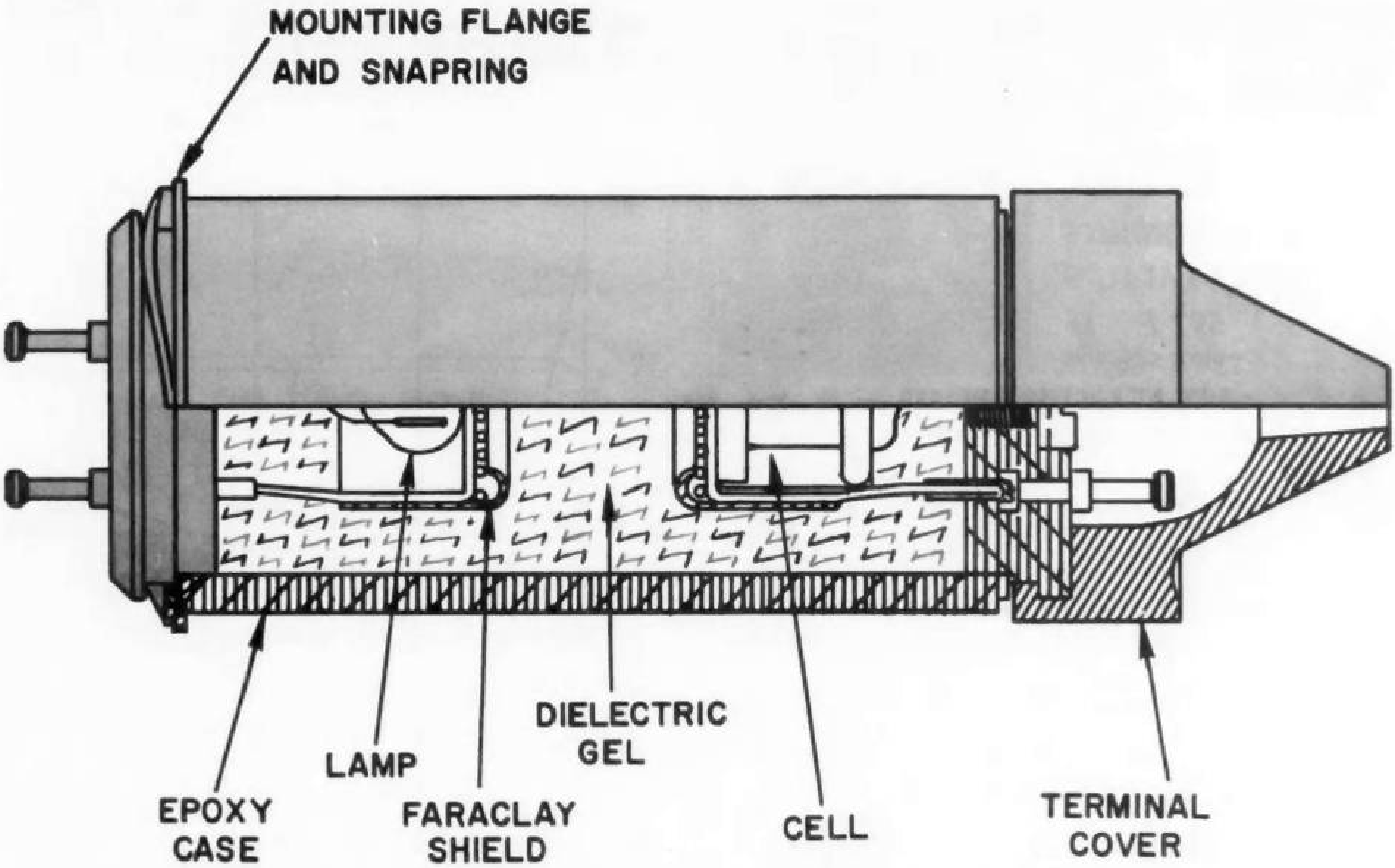

Fig 2 High-voltage Raysistor, encapsulated in a high-dielectric transparent fluid, operates with 25,000 volts differential between the control circuit and the signal circuit. Tentative specifications: control circuit is an incandescent lamp with supply voltage of 6.0 vdc or peak ac and control current of 0 to 200 ma; signal circuit is a photoresistor with on resistance 100 ohms, off resistance $4 \times 10^{9}$ ohms, maximum power dissipation 250 mw, and maximum voltage 300 vdc or peak ac.

*tween the control and signal circuits.*

- *To prevent corona due to ionization of gases. Corona has two harmful effects: glow of the gases activates the photoconductor, causing error in the output; and the ionization products often lead to cumulative breakdown of the dielectric materials.*

THE DIELECTRIC MATERIAL

A survey of dielectric materials and experimentation with many types indicated availability of a gel that provides the necessary optical and dielectric properties as well as the desired temperature characteristics.

Stiffer, unyielding materials were found to be unsatisfactory because they tended to transmit forces caused by temperature variations to the embedded parts, and even to stress-crack themselves at low temperatures. The dielectric gel also provides a high degree of shock and vibration protection to the circuit components suspended within it.

To prevent formation of air bubbles which would tend to ionize in a high electric field, causing corona glow or spark flashover, the gel is introduced into the assembly under vacuum and is heat cured so that it adheres to all surfaces contacted, preventing any air gaps at the interfaces. The gel maintains contact with all surfaces indefinitely. Its properties are stable over a wide temperature range and over a much longer time than the life of any equipment in which the Raysistor would be used. The intimate surface contact of the gel, together with good thermal conductivity (uncommon in electric insulators), provides good heat transfer, allowing the photocell to be rated for a much higher power dissipation than would be possible in air.

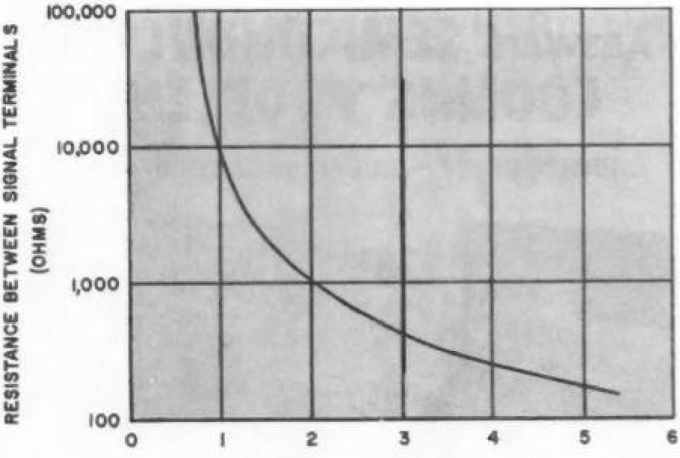

Fig 3 Transfer function of type CK1108 High-Voltage Raysistor. A wide range of specifications is available for potentiometer or control link applications. The curve shows a signal resistance variation of 10,000 to 1, with a 10-to-1 range of control voltage. Models with full control voltages as low as 1.1 volts are available for use with transistors.

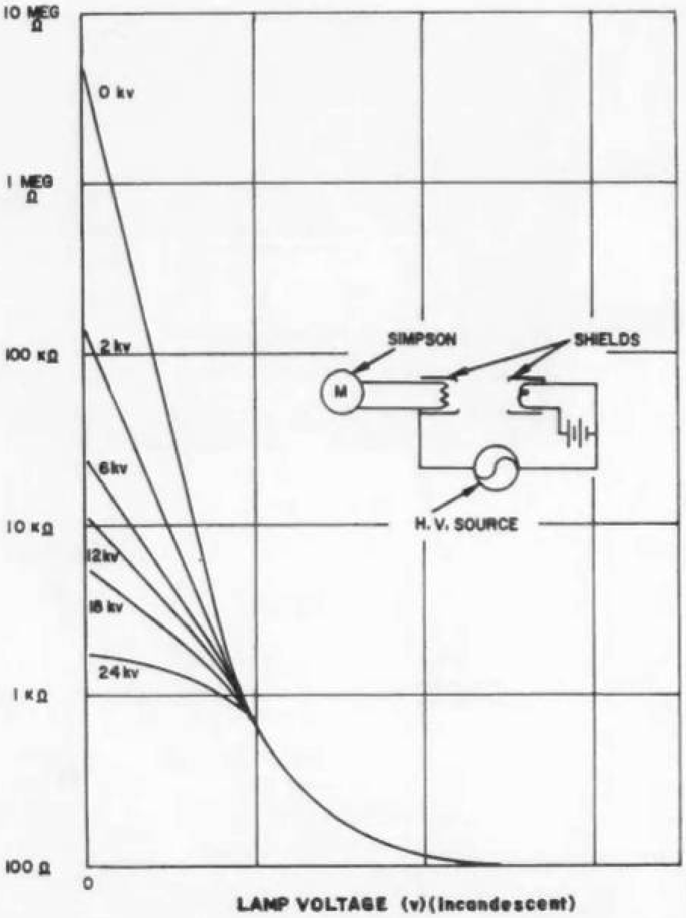

**Fig 4 Performance of the high-voltage Raysistor without wire-mesh closures over the openings in the corona shields. Penetration of the electric field into the enclosures causes gas in the cell or bulb to ionize. This effect is apparent from the change in cell-resistance-vs-lamp-current curves as voltage from the high-voltage source is increased.**

### CORONA SHIELDS

Ionization of gases within the light bulb and the photocell is prevented by surrounding the bulb and photocell with corona shields. The two shields, which are identical, are cylinders with one open end rolled into a torroidal shape to minimize corona formation points. Across the opening in the torroid is a wire-mesh screen to prevent penetration of the high electric field into the shield enclosure, so that both the bulb and the cell are maintained in a field-free space.

Early tests without the wire mesh showed definite changes in the lamp current vs cell resistance curves as the high voltage was increased (see Fig 4). These changes were attributed to ionization of gases in the bulb or the cell caused by penetration of the field into the enclosure. Figure 5 shows how the wire mesh screen eliminates field penetration and improves performance. The shield assembly also serves as a true Faraday shield, minimizing capacitive coupling between the lamp and the signal circuits. This prevents ac voltage appearing across the lamp and signal circuits from being coupled into the signal circuit.

### OPAQUE ENCLOSURE

Since the resistance-vs-light-intensity curve of the photocell is logarithmic, a very small amount of light has a pronounced effect on photocell resistance. An absolutely light-tight enclosure for the unit was therefore required to protect the photocell from interfering light. In addition to being absolutely opaque, the enclosure had to be dimensionally stable and non-hygroscopic and have very high dielectric strength. This combination of properties was hard to find. Most dielectric materials assumed to be opaque were found to be unsatisfactory under test. The problem was solved by a special filled epoxy formation which meets all requirements.

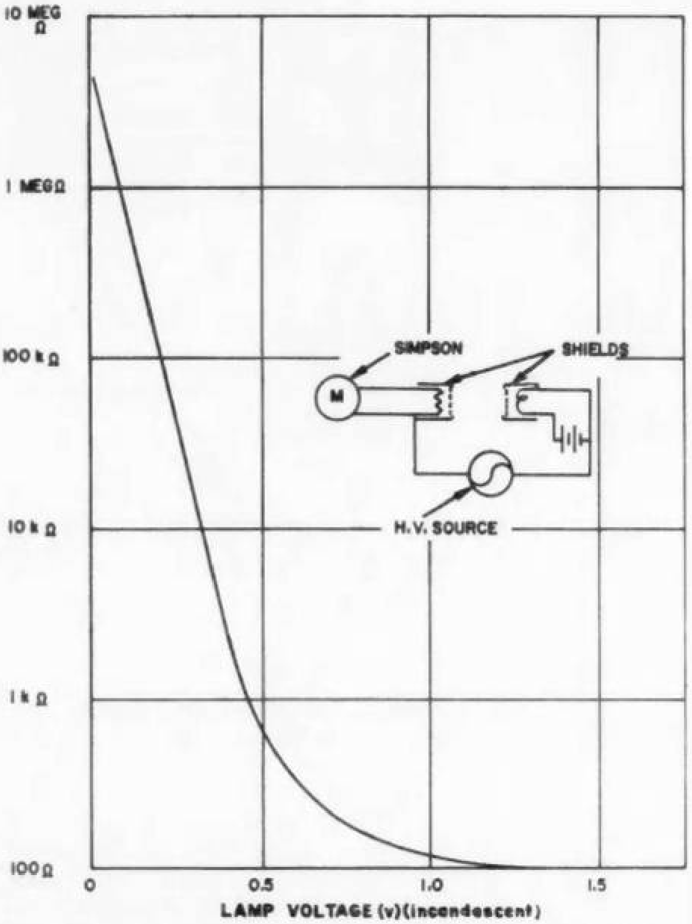

**Fig 5 Performance of the high-voltage Raysistor with wire-mesh closures over the openings in the corona shields. The screens prevent formation of electric fields inside the enclosures, preventing any variation in performance as voltage from the high-voltage source is increased.**