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Split-Ring Marx Generator Grading

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ABSTRACT

A technique which utilizes split rings for Marx generator grading is described. While conventional grading rings are electrically continuous and operate at a single potential on each ring, the split rings are divided into two sections by insulating spacers. Some advantages and applications of this technique are discussed.

SPLIT-RING MARX GENERATOR GRADING

Introduction

A split-ring technique for Marx generator grading has been developed at AFWL which provides certain advantages over conventional methods. While conventional grading rings are electrically continuous and operate at a single potential on each ring, the split rings are divided into two sections separated by insulating spacers (Fig 1). One section is electrically connected to the top of its associated stage switch, and the other section is connected to the bottom of that switch. Thus, one full stage voltage appears between the sections during charging, but after switch closure (during erection) the sections equalize in voltage.

Construction

The ring sections (Fig 1, Piece No 1) can be fabricated from any material suitable for conventional rings, e.g., electrical conduit, aluminum tubing, or copper pipe. The shape can either be rectangular, as shown, or circular depending upon the particular Marx design. The cross sectional dimensions are chosen to provide adequate spacing between the rings and the Marx core.

The section spacers (Piece No 2, Figs 1 and 2) can be fabricated from any high-dielectric strength material; and can either be molded as one piece or formed by gluing several pieces together, taking necessary care in the positioning of glue seams. In the prototype "Molecule" Marx, for example, the spacers are made by gluing two rubber cane tips to a polyethylene disc. The spacers must provide a snug, friction-fit around the grading ring. Piece No 3 in Fig 2 is simply a metal plug inserted

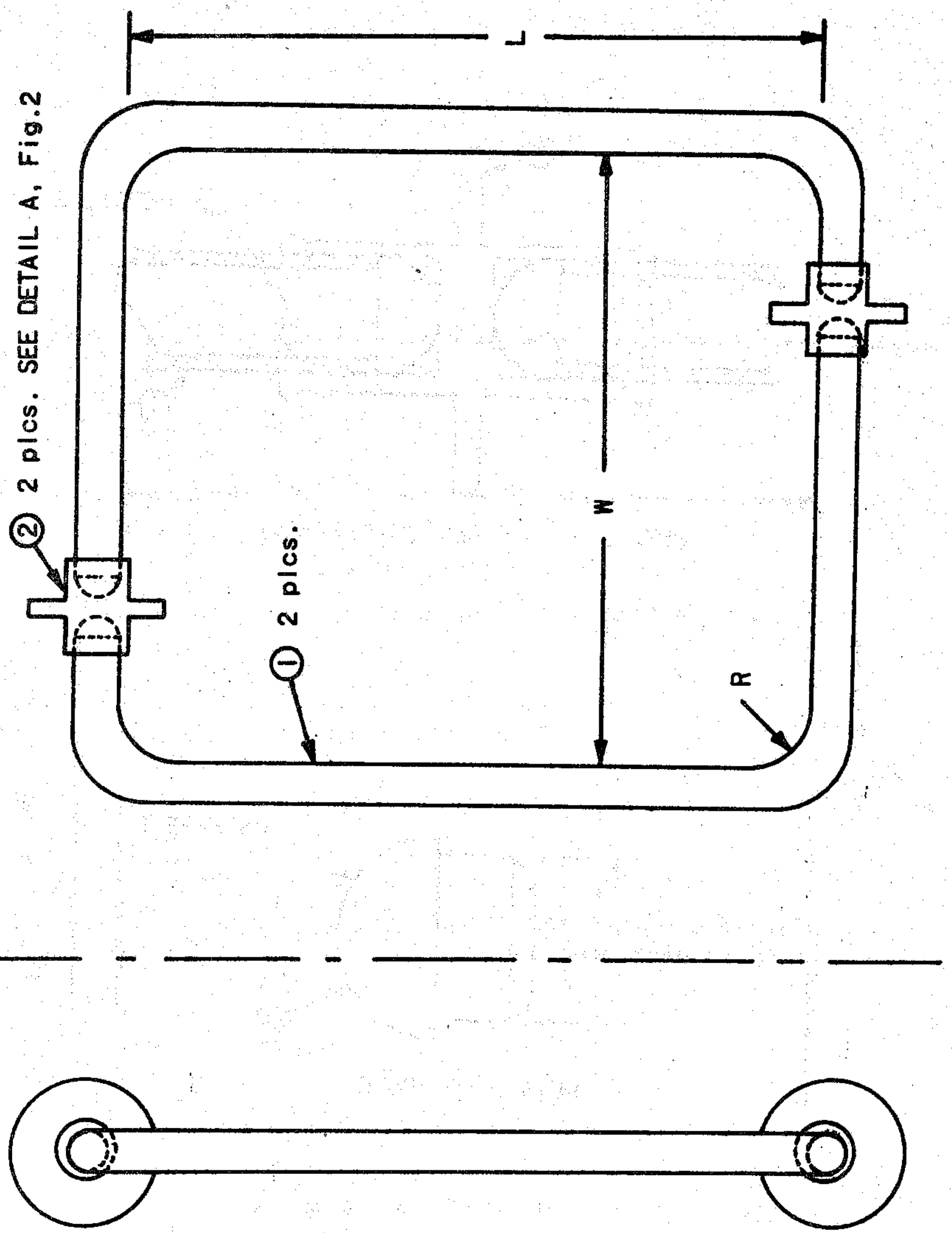
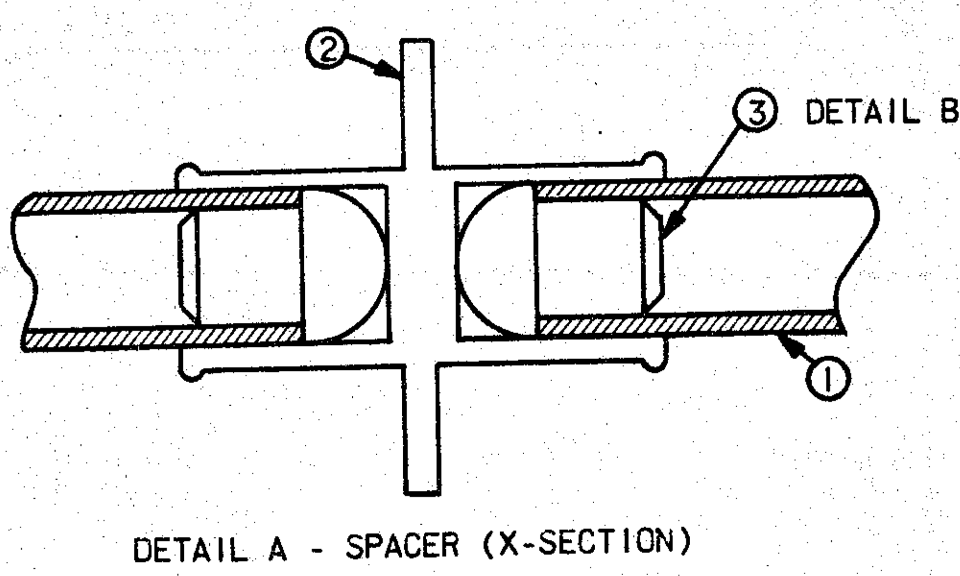


Fig. 1 Grading Ring Profile



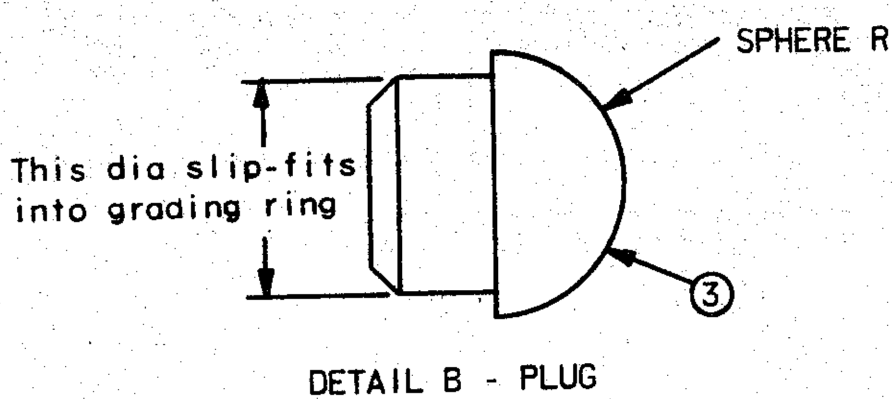


Fig. 2 Details of Plug and Spacer

to terminate the tubing in a round end to shield the sharp edges which could cause an arc through the spacer. The rings are supported on the Marx structure in any desired position by dielectric rods. Electrical connections to the rings are made by appropriate techniques such as soldering, clamping, or with threaded inserts such as "Molynuts" or "Rivnuts."

Application

There are several conveniences which the split-ring grading technique provides to the Marx designer. In addition to providing the same field grading of conventional rings, the split-rings provide attachment points for charging resistors. One specific technique illustrated in Fig 3 is suitable for liquid resistors, wirewounds, ceramic resistors, film resistors and conductive elastomers. Each resistor string is fitted with metal end terminals which mate onto banana plugs attached to the rings. The stage capacitors may then be either hard-wired to the grading rings or connected through another resistor string. This sideways resistor connection is preferable because it damps erection transients which might otherwise overvoltage the inter-ring capacitance and produce an arc between grading rings. However, the sideways resistance must be small compared to the main stage charging resistance so that proper grading of the Marx is maintained after erection.

The split-ring technique also provides assistance in the quest of that golden fleece sometimes called the "Self-Healing Marx". Pulsar Associates, Inc. is presently investigating two promising concepts for stage fuses utilizing split grading rings. These fuses would sense a failed capacitor during charging and disconnect it from the

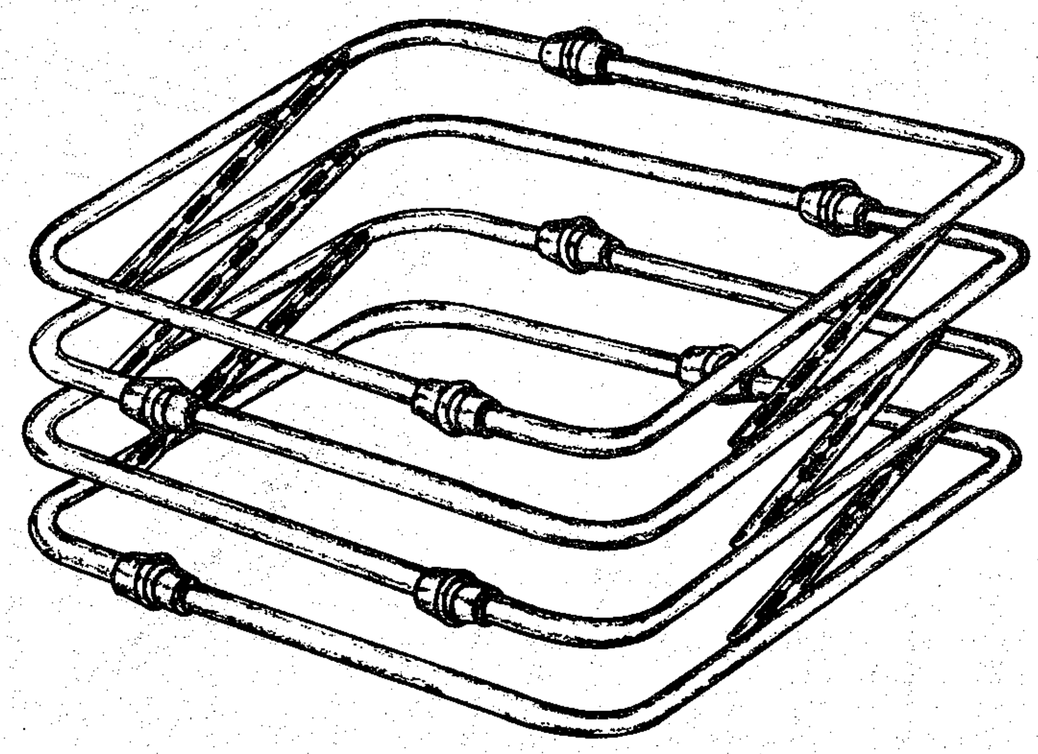


Fig. 3 Connection of Charging Resistors to Grading Rings

charging chain to allow operations to continue without the necessity of capacitor replacement. Ultimately the same fuse might short out the corresponding stage switch to insure continuation of optimum erection performance. One fuse concept utilized in a split-ring Marx is shown in Fig 4. The fuse is a small carbon resistor, under tension, which breaks apart under short circuit charging currents and disconnects the capacitor from the grading ring. To insure that normal erection transients do not open the fuse, the resistor is shunted by a surge arrestor.

A second fuse concept, shown schematically in Fig 5, utilizes a current imbalance detector to disengage the failed capacitor from the charging chain. This concept places several constraints on the Marx design. First, it must be balance charged, i.e., the capacitor terminals are charged plus and minus with respect to ground. Second, the stage capacitors must have a ground or neutral terminal. Third, the neutral terminals must be connected with a resistor chain (called the balance chain) which is similar to the two charging chains.

Neutral terminals on capacitors can be obtained in several ways. For metal cased units with two insulated terminals, the can is usually neutral when the capacitor is balance charged. If metal cased units with a single insulated terminal are used, the cans of two capacitors must be connected, and the two terminals charged plus and minus, the cans then becoming neutral.

For a compact Marx, metal cased capacitors are awkward to use and dielectric-cased units are preferable. If a single dielectric-cased capacitor is used per stage, the manufacturer must provide a neutral terminal. However, a convenient scheme utilizing two capacitors is

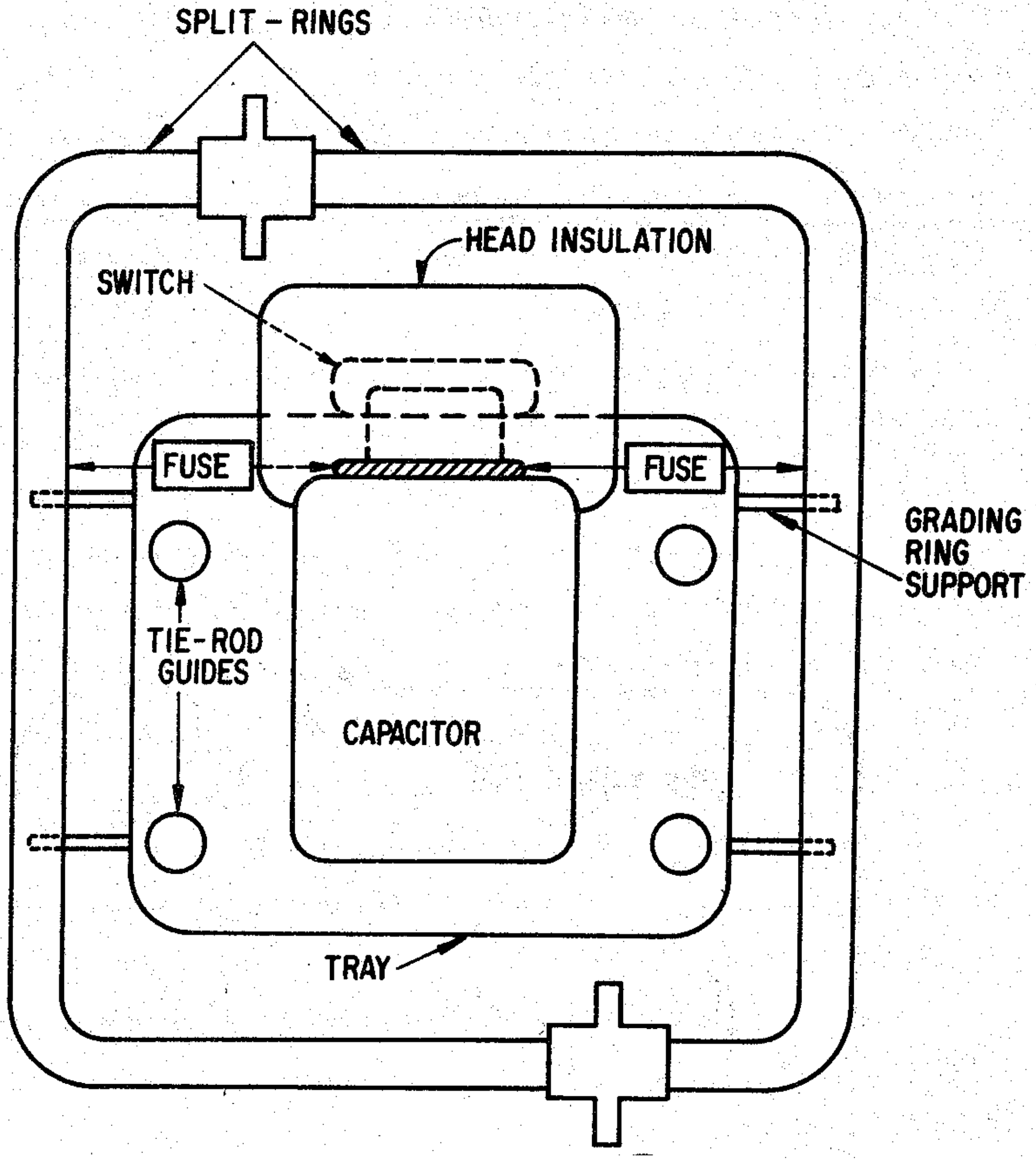


Fig. 4 Carbon Resistor Fuse Connected Between Grading Ring And Capacitor

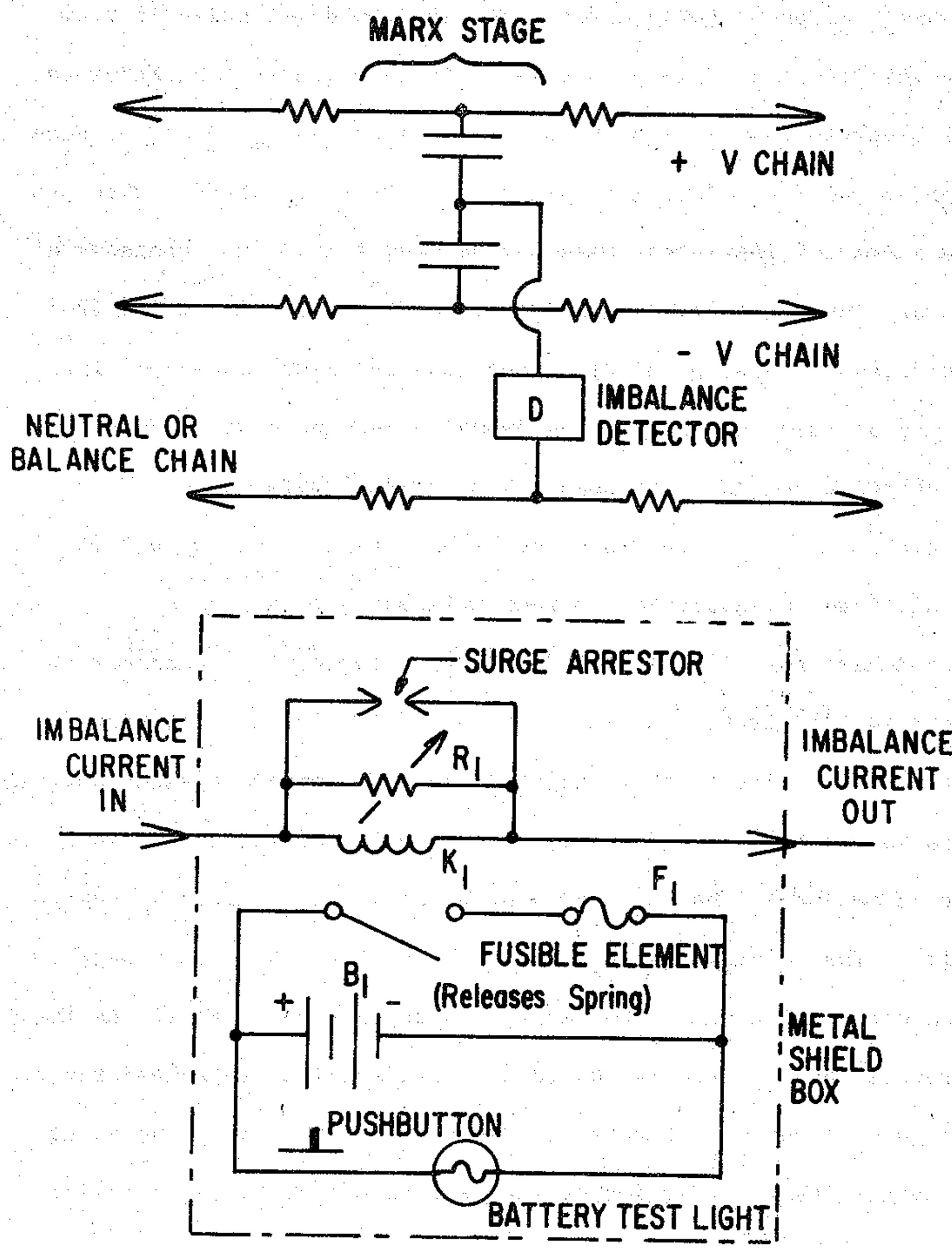


Fig. 5 Schematic of Current Imbalance Detector

shown in Fig 6. Each capacitor is relatively thin compared to its length and width, and has a rail terminal on each end. For convenience it has been called a double-ended flat-pack, to distinguish it from those units with two rails at one end. At least three manufacturers, Maxwell Laboratories, Aerovox Corp, and High Energy, Inc, now produce such units. As shown in Fig 6, two of the units are stacked with one or more sheets of insulating material between them. The terminals at one end are bussed together, connecting the two units in series (for increased capacitance, parallel connections can also be made). The common end becomes neutral and the opposite terminals are connected to the charging chains. The insulating material between the capacitors not only serves to insulate the high-voltage terminals but it can be utilized as insulation between adjacent Marx switches.

One scheme for utilizing an imbalance detector to disconnect a capacitor is illustrated in Figs 7 and 8. Following the detector circuit of Fig 5, the relay is adjusted so that normal balance charging currents do not trip it. However, if a capacitor fails the balance current becomes an "imbalance" current which is high enough to engage the relay. The relay in turn connects the photoflash battery across the fuse wire, which melts and releases a spring-wound spool. As the spool recoils it retracts two dielectric leads which are routed through plastic guide tubes and attached to disconnect fittings at the front of the capacitors. Retraction of the leads disconnects the capacitor from the charging chain.

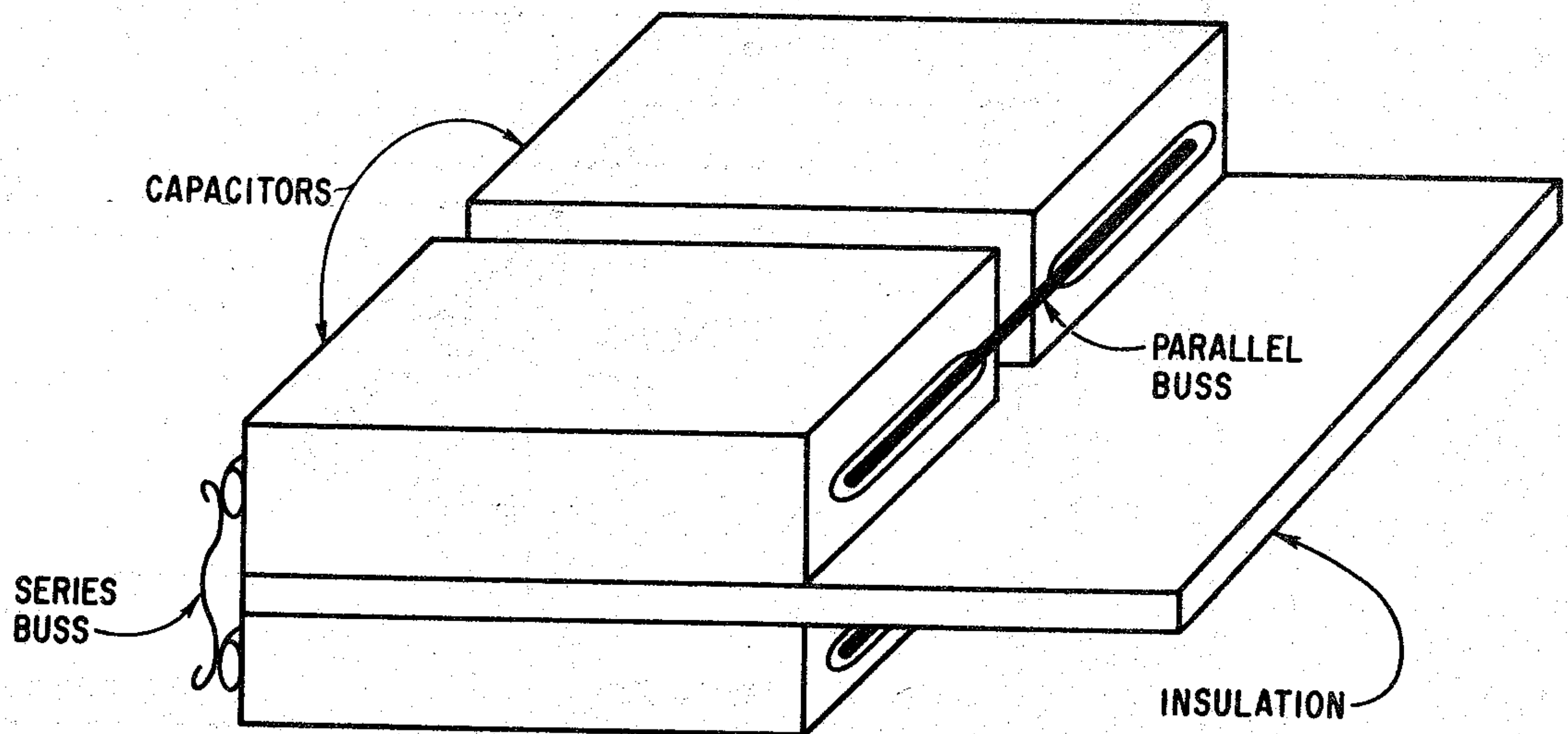


Fig. 6 Connection of Double-Ended Flat-Pack Capacitors

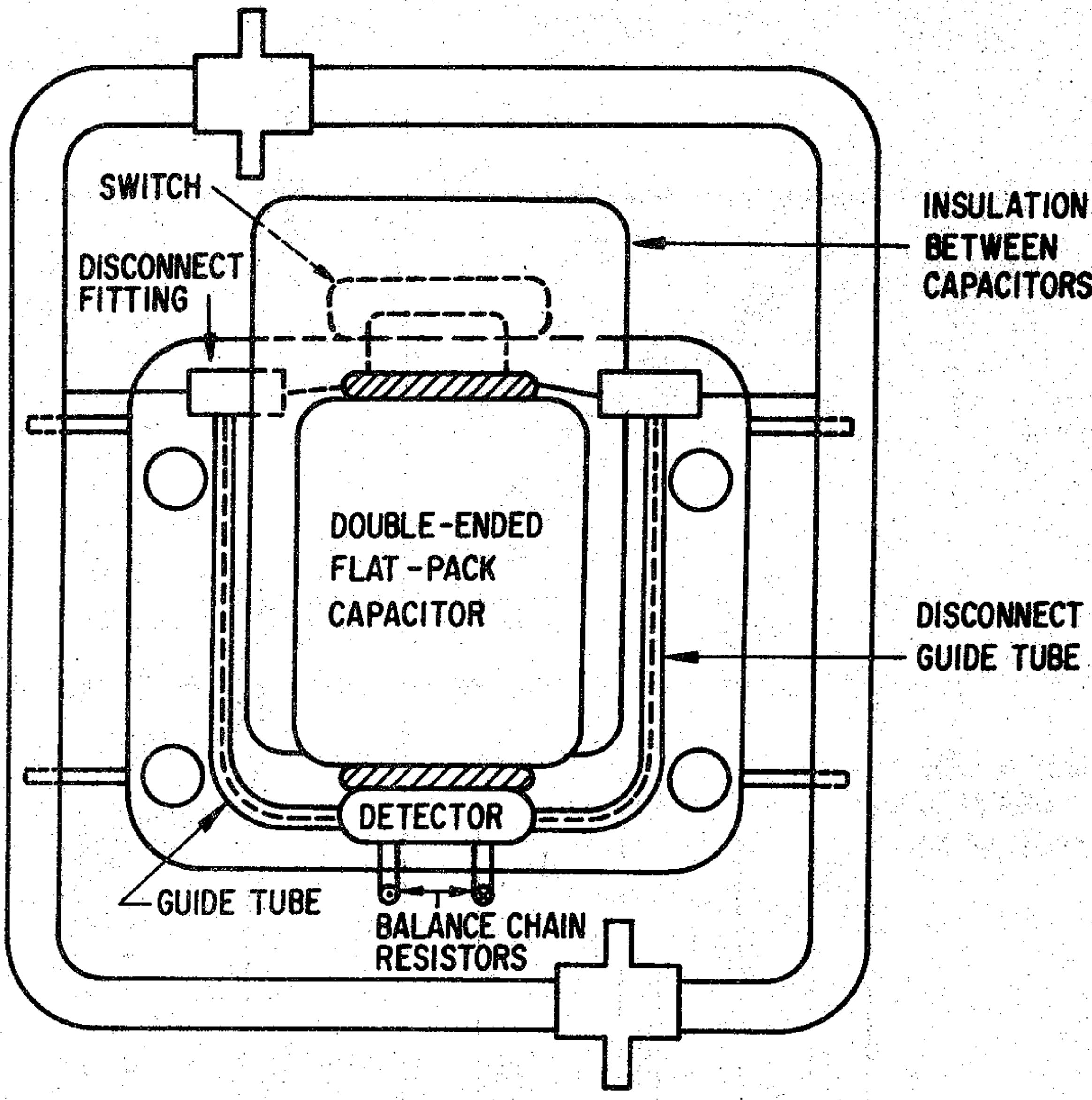


Fig. 7 Imbalance Detector Scheme For Disconnecting Capacitors

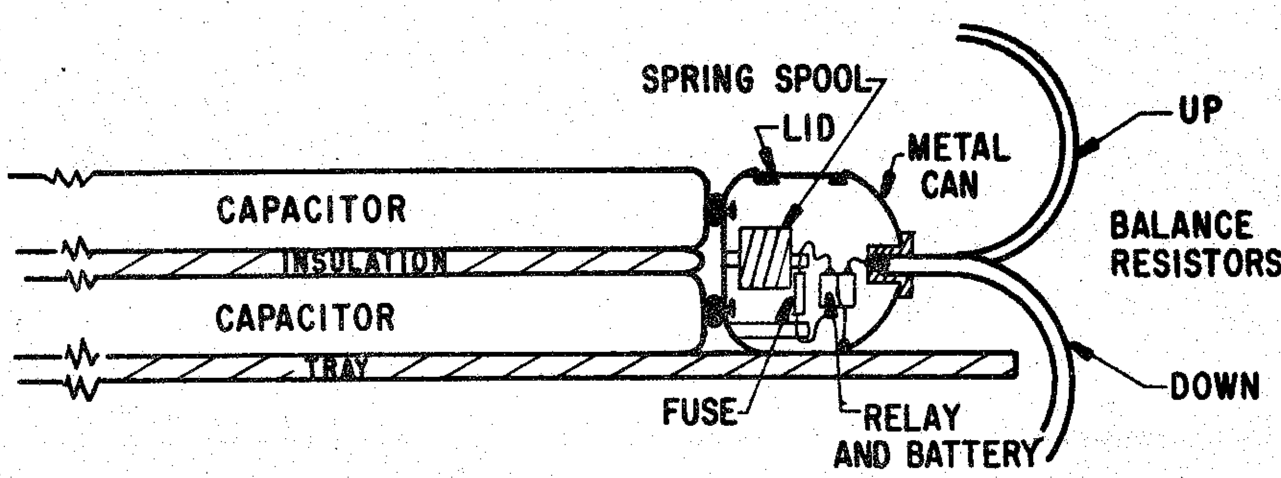


Fig. 8 Detector Detail

Summary

The split-ring grading technique provides a particularly well-defined and convenient interface (electrical and mechanical) between the charging chain and the stage capacitors. All aspects of Marx design, fabrication, and operation can potentially benefit from the technique. The "Molecule" 2 MV Marx generator, which uses split rings, operates at 1 MV/m in atmospheric pressure SF_6 or Freon-12, has a density of nearly 40 joules per pound, and can be assembled by one man in a few hours. In fact, any component can be removed and replaced without disassembling the Marx. Admittedly, all of these features are not unique to the "Molecule", nor do they all accrue from the use of split rings. The combination, however, of compactness, density, and ease of handling is substantially benefitted by the split rings. In addition, the design provides broad flexibility to investigate such technology advancements as fault-correction devices without the necessity of building a special Marx for each device. Almost any device can be added as an afterthought.