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Hofmann

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[54] SWITCH FIELD COILS FOR CROSSED-FIELD INTERRUPTER

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[52] **U.S. Cl.** **313/157,** 313/161, 315/39
[51] **Int. Cl.** **H01j 1/50**
[58] **Field of Search** 313/154, 156, 157, 161, 313/231; 315/39, 39.51

[56] **References Cited**

UNITED STATES PATENTS

3,604,977 9/1971 Hofmann .... 315/39 X

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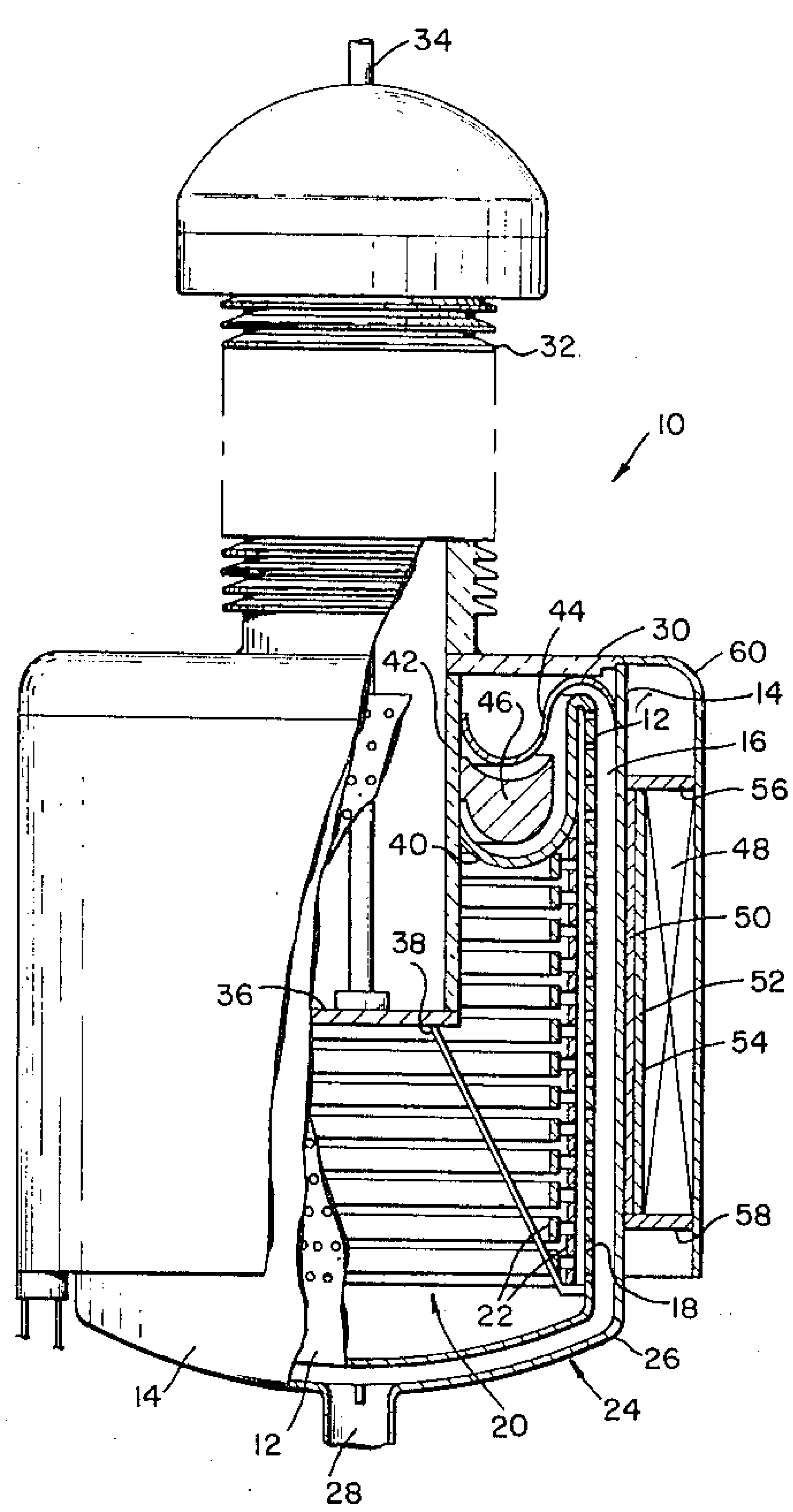
[57] **ABSTRACT**

The arrangement of the main windings and off-switching windings for the magnetic field of a crossed-field switching device permits a large diameter metal cathode inside of the coils.

1 Claim, 1 Drawing Figure



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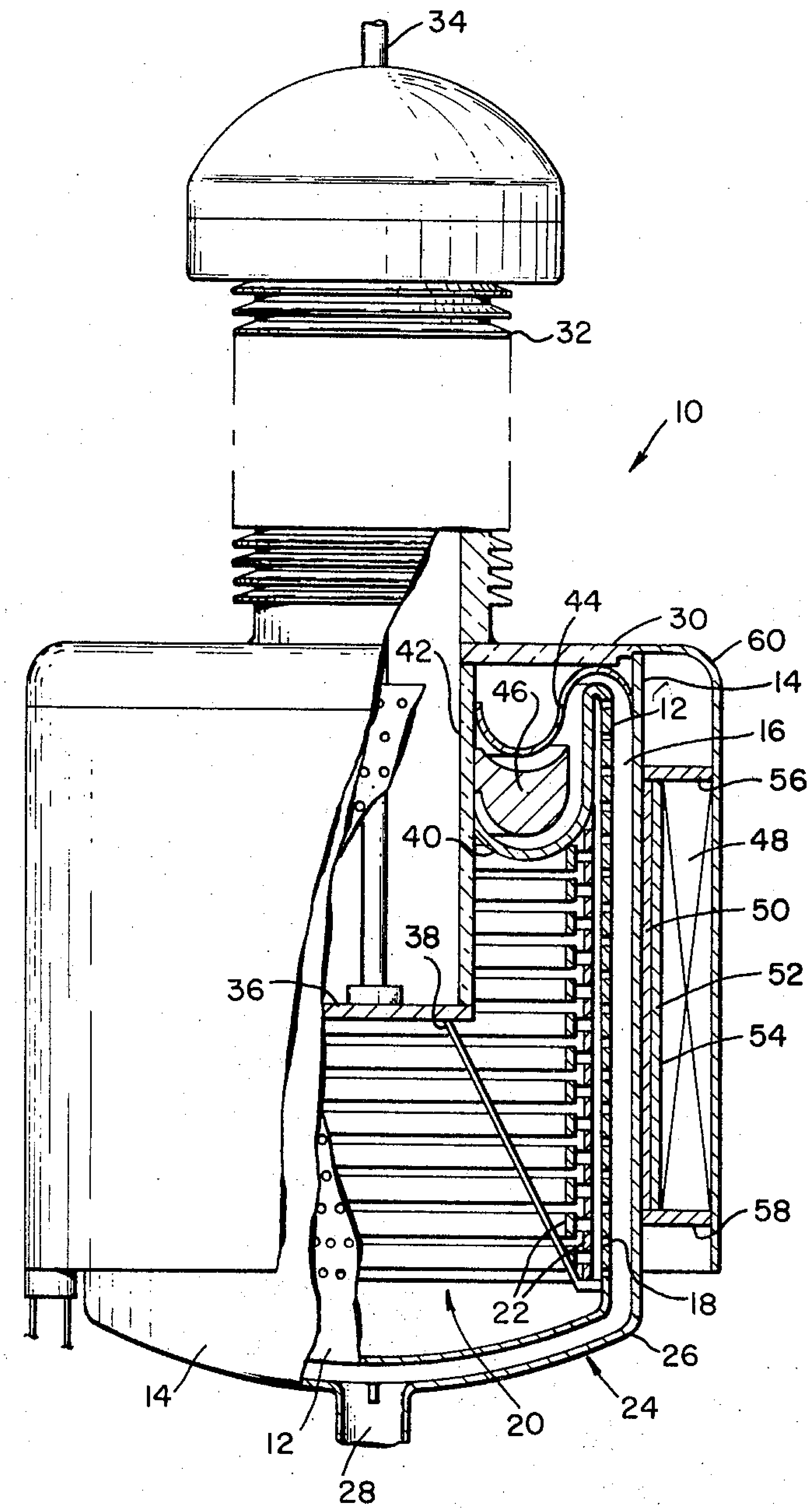

SWITCH FIELD COILS FOR CROSSED-FIELD INTERRUPTER

BACKGROUND

This invention is directed to a crossed-field switching device, and particularly to the structure of the magnetic field coils and their relationship to the electrodes.

Crossed-field electrical discharge devices were primarily laboratory curiosities, until recent developments have shown that they are capable of carrying fairly high direct currents and off-switching against fairly high voltages. This capability has resulted in their design into a number of circuit breakers. In such circuit breakers, the crossed-field devices become crossed-field off-switching devices which perform the function of off-switching direct current to result in increasing circuit breaker impedance. Prior patents which can use suitable crossed-field switch devices as their switching elements in circuit breaker environments include K. T. Lian U.S. Pat. No. RE 27,557; K. T. Lian and W. F. Long U.S. Pat. No. 3,641,358; M. A. Lutz and W. F. Long U.S. Pat. No. 3,660,723. These illustrate the manner in which a crossed-field switch device can be used.

Two patents which illustrate particular structure of a crossed-field switch device are G. A. G. Hofmann and R. C. Knechtli U.S. Pat. No. 3,558,960 and M. A. Lutz and R. C. Knechtli U.S. Pat. No. 3,638,061. These patents discuss the maintenance of pressure in the interelectrode gap and during conduction. Furthermore, G. A. G. Hofmann U.S. Pat. No. 3,604,977 and M. A. Lutz and G. A. G. Hofmann U.S. Pat. No. 3,678,289 discuss the management and control of the off-switching of crossed-field switch devices by control of the magnetic field. Continuing improvements are being made to enhance the voltage and current capabilities, as well as life and reliability of the crossed-field switch devices.

SUMMARY

In order to aid in the understanding of this invention, it can be stated in essentially summary form that it is directed to a crossed-field switch device which has a cylindrical metallic cathode with a magnetic switch coil and a main magnetic field source positioned therearound. The switch coil has only a few turns for maximum rate of generation of an off-switching magnetic pulse. It is surrounded by a short circuit winding. The short circuit winding is in turn surrounded by the main magnetic field coil which normally supplies a field in the interelectrode space above the critical value.

Accordingly, it is an object of this invention to provide particular switch field coils for a crossed-field interrupter. It is another object to provide a structure whereby the capacitive and inductive coupling is minimized between the two magnetic field coils. It is another object to provide a magnetic structure for a crossed-field switch device which achieves the necessary interelectrode field and which can be controlled for off-switching the crossed-field device by reducing the magnetic field in the interelectrode space below the critical value.

Other objects and advantages of this invention will become apparent from a study of the following portion of the specification, the claims, and the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The single FIGURE in the drawings is a side elevation of a crossed-field switch device having switch field coils arranged in accordance with this invention, with parts broken away and parts shown in radial section.

DESCRIPTION

The crossed-field switch **10** constructed in accordance with this invention is shown in the single FIGURE of the drawing. It comprises an outwardly-facing cylindrical anode **12** around which is positioned an inwardly-facing cathode **14** to define an interelectrode space **16** therebetween. The anode **12** is perforated, as by holes **18** so that the interior space **20** within the anode is permitted to supply gas to the interelectrode space **16** to aid in maintaining conduction, as taught by G. A. G. Hofmann and R. C. Knechtli U.S. Pat. No. 3,558,960. In order to prevent a long, straight line path between the interelectrode space **16** and the anode interior space **20,** baffles **22** are provided. These baffles are a first row of axially-spaced cylindrical rings positioned within the interior of the anode and a second set of axially-spaced cylindrical rings spaced interiorly of the first set. These baffle rings are axially offset so that the one set covers the spaces between the rings of the other set. Thus, straight line paths are eliminated. This prevents electrons from directly passing from the interelectrode space **16** into the interior space **20.** This construction is shown in more detail in U.S. Pat. No. 3,769,537 Sept. 14, 1972).

Cathode **14** is part of the pressure vessel **24** which provides a structural strength and vacuum integrity to the crossed-field switch **10** and particularly the interelectrode space. Lower shell **26** closes the lower end of the vacuum space and is attached to the cylindrical wall which forms cathode **14.** Any convenient supporting means, such as leg **28** can be used to support the entire structure.

Metallic plate **30** is in the form of a disc which closes the upper end of the cylinder formed by cathode **14** and seals against it. It is raiseable for disassembly of the device. When raised, the insulators and anode structure come up out of the cathode tank. Stand-off bushing **32** is of insulator material. Anode connection **34** is vacuum-sealed with respect to the bushing and extends out of the end thereof for connection into a circuit. The anode connection **34** is in the form of a rod which extends down the interior of stand-off bushing **32** into the interior of the anode. Anode connection **34** terminates in support plate **36.** A plurality of legs **38** extend from support plate **36** and are attached to anode **12** to support the anode. The anode baffles are supported by rods which are positioned axially between the sets of anode baffles and are secured at their lower ends to legs **38.** The upper end of anode **12** is provided with a re-entrant curved section **40** which engages against the outer surface of insulator tube **42** which descends from plate **30** and which carries support plate **36.** Spacer **44** is at cathode potential and electrically floating electrode **46** fills the gap to prevent Paschen breakdown.

A magnetic field is necessary to interengage with the electrical field in the interelectrode space to provide the crossed-field low pressure plasma discharge in the interelectrode space. The main magnetic field can be provided by a permanent magnet, but the preferred embodiment is provided by field coil **48** which extends circumferentially around the interelectrode space **16.** In the particular example, a 100-turn field coil is provided. By passing ampers through the main field coil **48,** an interelectrode space magnetic field of about **70** Gauss is provided so that conduction conditions exist when the helium gas pressure in the interelectrode space is about 0.05 Torr and an electric potential difference of about 500V is present. In this situation, the magnetic field is said to be above the critical value so that conduction can take place.

In order to quickly turn off the magnetic field to stop conduction of the crossed-field switch, a switch coil is necessary. Switch coil **50** is a one-turn coil. When it is energized to buck the field coil **48,** it drives the net magnetic field below the critical value so that the device becomes nonconducting. Thus, the crossed-field switch device **10** is an off-switch. Problems arise, if the switch tube dimensions are large and the vacuum envelope is a metallic tank, as in the present case. The attenuation of the magnetic field diffusing through the tank wall is considerable and requires a relatively high outside field to achieve the necessary field strength in the interelectrode space.

As is seen in the drawing, the primary or main field coil **48** is separated from off-switching coil **50** to reduce capacitive coupling. Short circuit winding **52** between the coils reduces inductive coupling. As stated, switch coil **50** consists of only one or a few turns. With such few turns, only low driving voltages are necessary with the result that only moderate insulation requirements are present. In the preferred embodiment, the off-switching field coil **50** is a single turn of aluminum with an anodized surface for insulation. A driving voltage of 3,000 volts and a short pulse current of 20,000 amps is sufficient to drive the net magnetic field below the critical value. Furthermore, with a short circuit winding **52,** the injection of transients into the power supply for field coil **48** is reduced. A fast rise time of the switching pulse can be achieved with relatively low driving voltages. Furthermore, no blocking choke is required in the circuit of coil **48,** because of the reduction in transients.

Insulating end rings **56** and **58** support the cylindrical parts of the coil structures. Off-switching coil **50** is supported closely adjacent the outer surface of the cylindrical tank wall which forms cathode **14.** Next, the short circuit winding **52** is positioned around the switch coil **50.** Next, insulating mandrel **54** is positioned around the short circuit winding. Finally, the primary field winding **48** is wound around the mandrel **54.** An electrostatic shield **60** surrounds the field coils to minimize electromagnetic interference from the coils onto the adjacent exterior spaces. Coil **50** is positioned substantially against the outer tank wall, except for insulation and manufacturing fits, and each successive winding similarly lies substantially against the lower one.

Each of the patents and other sources of information referred to above are incorporated herein in their entirety by this reference. This invention having been described in its preferred embodiment, it is clear that it is susceptible to numerous modifications and embodiments within the ability of those skilled in the art and without the exercise of the inventive faculty. Accordingly the scope of this invention is defined by the scope of the following claims.

What is claimed is:

1. A crossed-field switch device comprising:

a cylindrical anode and a cylindrical cathode therearound defining a cylindrical tubular annular interelectrode space therebetween, means for maintaining a sub-atmospheric gas pressure in said interelectrode space, electrical connections to said anode and said cathode for applying an electric field across said interelectrode space and means for applying a magnetic field to said interelectrode space to provide electrical conduction between said anode and said cathode by glow discharge therebetween, said means for applying a magnetic field comprising the improvement:

main magnetic field winding means for providing a magnetic field in the interelectrode space above a critical value, an off-pulse magnetic field winding means for producing a bucking magnetic pulse in the interelectrode space for reducing the net magnetic field below the critical value, and a short circuit winding positioned between said magnetic field winding means, said off-pulse magnetic field winding means being wound around said cathode electrode, said short circuit winding being wound directly thereon and said main field winding being nested thereon, each in substantially radial contact.

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