# INTERRUPTERS

All breakers, electromechanical circuit reclosers, high-current disconnect switches, load break switches, contactors, and low-voltage switches have an interrupter section. Circuit interrupters make and interrupt alternating (ac) or direct (dc) currents ranging from a few amperes to thousands of amperes. All interrupters consists of several components: (1) electrodes (a set of arcing electrodes and a set of main electrodes, or just one set of electrodes), (2) an arcing chamber, (3) a means to activate the electrodes, and (4) a containing vessel. The arcing medium can be air, vacuum, oil, compressed gas such as $SF_6$, or, in rare cases, water.

The process of making and interrupting current is essentially the same for all interrupters used in switches and circuit breakers. Consider a simple interrupter containing one stationary electrode and one movable electrode. A simplified process of initiating current is as follows: (1) Assume the electrodes are initially separated, (2) the movable electrode is activated to move toward the stationary electrode, (3) as the electrodes move closer together, the voltage stress in the gap increases and finally at a small distance before the electrodes touch, the voltage across the gap breaks down and establishes a small diameter arc (known as pre-strike), and (4) the arc burns until the electrodes touch. The process of current interruption is the reverse of the current-making process. The electrodes are initially in the closed position with current flowing through them. The movable electrode is activated to separate from the stationary electrode. As the electrodes separate, the tiny gap cannot withstand the voltage, so that an electric arc is established between the electrodes and the length of the arc increases with the separating electrodes. Usually there are means of controlling the arc position as the electrodes separate to force it into an arc chamber or to rotate it. In this way the arc is cooled by heat convection, conduction, and radiation to the arc chamber walls and/or plates. When the current is alternating, the arc will continue to burn until the current reaches a "natural" current zero, upon which the arc is extinguished and a recovery voltage immediately appears across the electrodes. The recovery voltage is the result of the other circuit elements reacting to the change in current when the arc goes out, and is normally of opposite polarity of the arc voltage. Therefore, during the voltage recovery the new cathode is the arcing anode and the new anode is the arcing cathode. If the arc is sufficiently cooled prior to or during the voltage recovery period, it will not ignite again and the gap between the electrodes will withstand the peak recovery voltage without an electrical breakdown. Therefore, the current interruption is completed.

The medium in which the arc burns identifies the type of interrupter. The standard types are air, oil, compressed gas, and vacuum interrupters. An electric arc conducts current from one electrode to the other. The electric arc is a plasma of hot gases made up of highly ionized decomposed elements of the medium—that is, it contains electrons, ions, and neutral particles. Therefore, the plasma is at a temperature of the order of several thousand degrees kelvin, and electrical conductivity of the arc is a function of the arc temperature. If the arc temperature is high enough, the conductivity can be computed from Saha's equation (1). Each type of interrupter contains the essential components mentioned above. However, the electrodes of each type may differ in electrode shape and material; the length of the electrode stroke may also differ; construction of the arc chambers can differ; and the containment vessel will be made from different materials and have different shapes. Each type of interrupter and the current interruption process will be discussed in detail.

The interrupter must withstand several different types of necessary voltage waveforms that are impressed across the breaker without breaking down. These voltages are ac, dc, and steep front transient voltage (e.g., lightning impulse voltages and switching surges). The breakdown voltage is a function of pressure and media. The voltage breakdown of gases increases with pressure. For example, at 20 psi, the ac 60 Hz voltage dielectric strength of $SF_6$ is approximately six times that of nitrogen and about 1.2 times that of oil for a given electrode configuration and gap. The dielectric voltage breakdown in vacuum is a function of the electrode material, electrode configuration, and distance. For example, structures made from stainless steel that are properly outgassed have extremely high dielectric strengths.

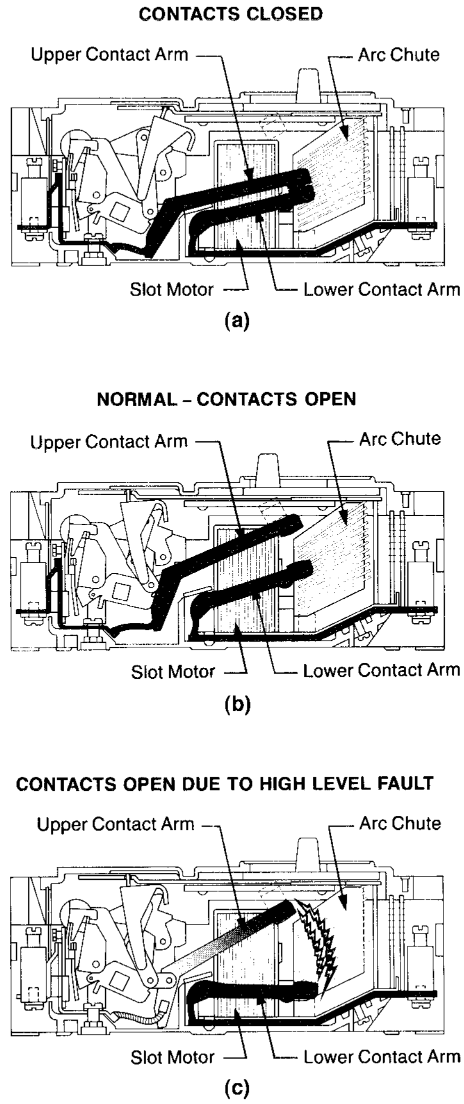


**Figure 1.** A cutaway drawing of a molded-case current-limiting circuit breaker. This figure shows three different positions of the contacts during the opening operation. (a) Contacts are in the closed position. (b) Contacts are in the fully open position. (c) The lower contact is in the fully open position, giving the maximum contact separation.

## AIR INTERRUPTER

### Construction

Low-voltage devices such as molded-case circuit breakers (MCCBs), air contactors, power breakers, and switches have air interrupters. Figure 1 is a cutaway of an MCCB showing the interrupter being integrated into the body of the device and consists of a set of electrodes—one stationary and the other movable. The contact shape is a simple button or butt brazed on a copper conductor. Some of the common contact materials used for these electrodes are (1) Ag with elements of W, Ni, C, or Mo and (2) Ag with WC and metal oxides of Cd and Sn. A silver base material is used because of its high electrical conductivity and low contact resistance.

In interrupters that interrupt very high currents, there may be two sets of contacts in parallel, which are the main contacts and the arcing contacts. Each set of electrodes is made from a different material. The arcing contacts are subjected to high erosion and are made with a low-Ag-content material, while the main contacts are made from materials with high Ag content so that the contacts have both low electrical and thermal resistance and contact resistance. The movable electrode is actuated by a mechanism that may be spring-operated. Surrounding the electrodes is an arc chamber or arc chute made from an electrical insulating material supporting a series of U-shaped metallic plates. Current-limiting molded-case breakers may also have a slot motor that helps increase the opening speed of the movable electrode. The low-voltage power breakers have the same type of interrupter construction as molded-case breakers. Medium voltage magnetic-air type circuit breakers are also similar and may contain a coil that produces a magnetic field to help drive the arc into the arc chamber faster.

### Interruption

Breakers can be single-phase units (e.g., like the breakers in the load center of a home) or have all three phases in one unit. The latter are used in industrial circuits to control transformers, motors, large air conditioners and other larger loads. The cutaway drawing of a molded-case current-limiting breaker shown in Fig. 1 is a three-phase breaker.

Figure 1 shows three different stages of current interruption. The first stage is the electrodes or contacts in the closed position with current flowing through them. The current path is from the terminal to the conductor attached to the lower contact arm, through the slot motor and through the lower contact arm which is stationary. Then the current flows through the contact tips made of a silver alloy material and through the upper contact arm that is the movable electrode. In the second stage the contacts separate, establishing an arc between them. The arc burns at a temperature of approximately 10,000 K to 20,000 K and conducts the current between the electrodes. Current flowing through the contact arms produces a magnetic field that interacts with the arc current. The interaction of the magnetic field, $\boldsymbol{B}$, and the arc current density, $\boldsymbol{J}$, causes an outward force, $\boldsymbol{F} = \boldsymbol{J} \times \boldsymbol{B}$, on the arc to drive it into the arc chamber. As mentioned previously, the chamber contains a series of U-shaped metal plates separated by insulating material. The columnar arc is forced into these plates by this magnetic force; and the main arc is broken into many series arcs that burn between the adjacent plates. Each arc has a burning voltage of approximately 25 V to 30 V. Therefore as the movable electrode continues to separate from the stationary lower contact as shown in the third picture, the arc continues to form more series arcs and the arc voltage increases with electrode separation. Since the voltage required to keep the arc burning is proportional to arc length, as the arc increases in length, the voltage drop from end to end increases. Finally when the voltage drop across the arc equals the system voltage, the arc goes out. The U-shaped plates cool the arc by conduction, convection, and radiation, thereby reducing its temperature and electrical conductivity. In current-limiting breakers, current flowing through the contact interacts with slot motor U-shaped plates, causing an additional opening force on the upper contact arm. This also increases the arc voltage with time.

For low-voltage breakers, the arc voltage is very important to the current interruption process and can be estimated by

$$V_{\mathrm{arc}} = 25(n+1) \tag{1}$$

where $n$ is the number of plates.

Air arcs may have a voltage of ≈300 V to 400 V assuming that the arc chamber contains 11 U-shaped metal plates. For low-voltage breakers (e.g., 250 V, 480 V, or 600 V), the 300 V arc voltage generated is on the order of the source voltage (200 V to 490 V) and limits the potential circuit current. This current is known as "let through" current. When the current reaches a current zero, the arc is deionized by cooling effects of the arc chamber and the current ceases to flow. Additional cooling of the arc is caused by ablation of the side-wall material of the arc chamber. If the arc voltage is significant, the arc appears as a resistive element to the external electrical circuit, causing a damping effect, and the recovery voltage peak is low because the current is almost in phase with the source voltage. Both these effects assist in successful interruption process and prevent the possible reignition of the current.

## GAS BLAST INTERRUPTERS

Figure 2 shows a schematic example of a two-pressure gas blast single-flow interrupter. Compressed gas interrupters, in which the gas pressure is several atmospheres, are used in high-voltage (72 kV and above) circuit breakers because compressed gas such as air or $SF_6$ have both excellent thermal cooling effects on the arc and excellent dielectric withstand properties. The breakdown voltage for a given set of electrodes is a function of pressure, $p$, and gap, $d$, is shown in Fig. 3. Beyond a minimum value of $pd$ and for a given gap, the breakdown voltage increases proportionally with gas pressure; this is known as the Paschen curve.

Construction of a typical gas blast interrupter is shown schematically in Fig. 2. The electrodes are cylinders, one movable and one stationary. When the breaker is closed, cylindrical electrode fits into the movable electrode that has many radial contact fingers known as tulip-shaped contacts. During circuit interruption, the initially closed electrodes start to separate, causing an axial arc to burn between them as shown. A radial flow of gas (either inwards or outwards) cools the axial columnar arc and as the sinusoidal arc current approaches a current zero, the hot arc gases are cooled by convection and the plasma is deionized, and the dielectric strength of the gap is re-established. The nozzle shape and size determine the gas flow and pressure. Immediately following current zero, the recovery voltage appears across the elec-

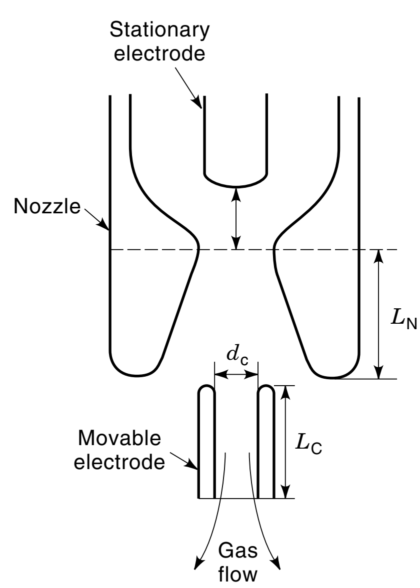


**Figure 2.** Two-pressure single-flow interrupter. Shown are the electrodes separated, and the gas is flowing transverse to the axial arc by the nozzle. The arc burns between the movable and stationary electrodes.

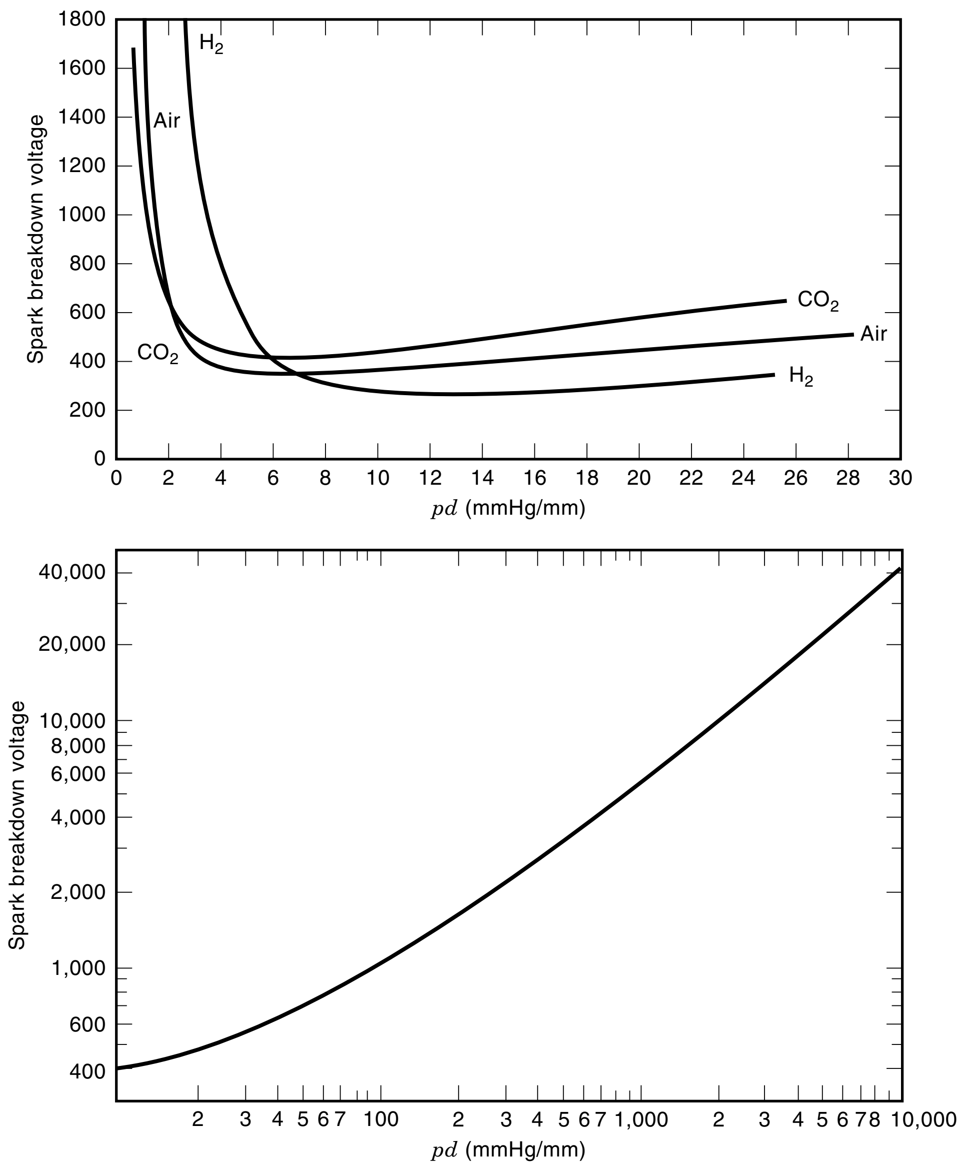


**Figure 3.** Voltage breakdown between electrodes as a function of pressure times gap length for air, $H_2$, and $CO_2$. These data are parallel plates and gases at 20°C. The top graph shows the complete range of the Paschen curves. The bottom graph is voltage breakdown from 10 to 10,000 mmHg/mm for air.

trodes. For these high-voltage breakers, the arc voltage has little influence on the circuit recovery voltage as mentioned above, because the system voltage is much greater than the arc voltage.

Tulip-shaped contacts are chosen for this application to be able to withstand the radial force of the contact fingers, which is a function of current squared through the fingers. The force at the end of the finger is given by

$$F = \mu I^2 L/(45.65\pi N D_I)$$

where $\mu$ is the permeability of the material, $I$ is current, $L$ is the distance the finger overlaps the moving contact, $N$ is the number of fingers, and $D_I$ is the inner diameter of the tulip electrode. Slade (2) shows that the force per finger of a five-finger electrode with 100 kA flowing through it is 5 N.

#### Interruption Phenomena

For current interruption, the electrodes separate axially and an electric arc is established upon contact separation. The arc length increases as the electrodes separate further and the arc voltage across the electrodes increases. The electric arc has three distinct regions: the cathode fall, the positive column, and the anode fall. For high-voltage breakers where the typical electrode separations are on the order of 15 cm (6 in.) or more, the positive column is of most importance. For the air blast breaker, the hot arc not only dissociates the $N_2$ and $O_2$ molecules, but also ionizes the nitrogen and oxygen into various ions and free electrons. At the same time there is ablation of the insulating nozzle into carbon and hydrogen elements that are ionized. For $SF_6$ breakers, the $SF_6$ gas is decomposed first into $S$ and $F$ atoms, and then into electrons and various ions of S and F. The control of the arc and interruption process is achieved by the radial flow of the gas.

These arcs have been modeled analytically by Cassie (3) using conservation of energy equations and assuming that the arc is cooled by convection in steady state. Using Cassie's equation, both the arc temperature and arc diameter were determined. J. J. Lowke (4), for instance, shows the radial temperature distribution of a 2000 A free burning arc in nitrogen. The center temperature of the arc is as high as 16,000

K and the temperature decrease radially. As the arc current approaches a current zero, the energy input to the arc plasma drops, causing rapid deionization, and the rate of dielectric recovery of the interelectrode region rapidly increases. During the recovery period, a Mayr (5) analytical model is used in which the decay in arc temperature is by thermal conduction and by the temperature dependence of electrical conductivity. In this period, recombination of the electrons and positive ions occur and a space charge sheath increases rapidly, causing small post-arc currents to flow. If the energy lost during the recovery period is greater than the energy gain by the post arc current, the breaker will withstand the recovery voltage without a voltage breakdown and the current interruption will be completed.

## OIL INTERRUPTERS

Oil interrupters consist of a set of cylindrical electrodes in which one electrode fits into the other. One electrode is stationary and the other is movable. Surrounding the electrodes are *explosion pots* or *deion grids* that improve arcing and pressure control during arcing. This structure is contained in a steel vessel filled with oil.

Current interruption in oil is similar to that of air and $SF_6$ media. When the electrodes separate, an electric arc is established between the electrodes. The arc decomposes the oil into gaseous elements of carbon, oxygen, and hydrogen and ionizes these elements into electrons and ions. During arcing, the pressure generated within the arc column by decomposing the oil into gas forces the arc into the explosion pot or deion grids, thereby cooling the gases by conduction and convection in a similar fashion as the arc chamber cools the air arcs of low-voltage breakers. Following current extinction, the dielectric recovery of the region between the separated electrodes is enhanced by the hydrogen gas because hydrogen has excellent dielectric withstand and thermal conductivity properties.

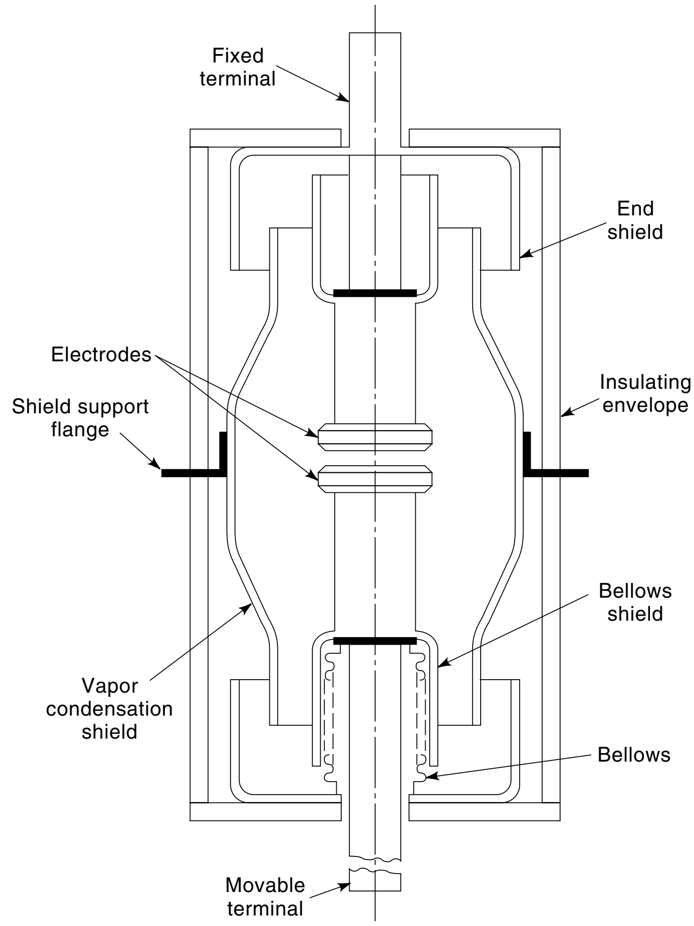


**Figure 4.** Internal parts of a vacuum circuit breaker with the electrodes separated. The electrodes are shown in the open position.

## VACUUM INTERRUPTERS

### Construction

Figure 4 is a cutaway drawing showing the construction of a typical medium-voltage vacuum interrupter. The interrupter contains a set of electrodes—one stationary and the other movable. Each electrode is brazed to an electrode stem or rod. The stationary electrode stem is brazed to a metal end plate made of stainless steel or suitable material. The movable electrode stem is attached to the other end plate via a metal bellows that allows axial movement of the electrode stem so that the electrodes can be separated by a mechanism. The end plates are attached to a cylindrical electrical insulating envelope by glass-to-metal seals. Therefore a vacuum-tight vessel is made from a high-purity glass or ceramic that can contain a vacuum of $10^{-6}$ torr or less for more than 20 years.

Inside the vessel and surrounding the electrodes is a cylindrical metal shield typically made from a pure copper, stainless steel, or other suitable material. This arc shield prevents metal vapor (emitted from the electrodes during arcing) from being deposited on the inside surface of the insulating envelope. This metal shield can be either electrically floating by attaching it to the center of the envelope or nonfloating by attaching the shield to one of the end plates. Usually, additional short cylindrical metal pieces are attached to the end plates, known as end shields. These shields protect the glass, ceramic, or metal seals from arc products and from high-voltage stresses. Since the life of a vacuum interrupter is 20 years, all glass, ceramic, and metal parts must be of very pure material and outgassed in vacuum during the manufacturing process so that they will not emit gases that will deteriorate the vacuum in the vessel over the life of the interrupter.

Vacuum interrupters used for (5 kV to 38 kV) medium-voltage switchgear and (15 kV to 38 kV) outdoor breakers can have an outer diameter ranging from 3 in. to 7 in. and lengths of 4 to 14 in. Westinghouse, GE, and other manufacturers design vacuum interrupter vessels with two ceramic or glass cylinders brazed together by a metal ring that can support the center arc shield. Other manufacturers (e.g., Siemens) construct the envelope by having a metal center cylinder that serves as the arc shield with a short ceramic cylinder brazed to each end.

### Current Interruption Phenomena

Consider the process of a 60 Hz fault current interrupted by a vacuum circuit breaker. The breaker mechanism actuates the vacuum interrupters that actually interrupt the current.

This current interruption process within a vacuum interrupter is discussed below.

Current interruption in vacuum is somewhat similar to that in gas, except that the ionized medium of the arc plasma is metal vapor emanating from the electrodes forming a metal vapor arc. A metal vapor arc is initiated when the electrodes separate, and it burns until the arc current reaches a “natural” current zero. This metal vapor originates from the erosion of the electrode surfaces during the arcing process. Vacuum arcs have three regions: the cathode fall, the positive column, and the anode fall region. Figure 5 shows the three regions of a vacuum arc and the voltage distribution across the various regions. In the cathode region, there are a multiple of highly mobile cathode spots that are emitting plasma into the cathode fall region. Above the cathode region is the positive column which contains electrons, ions, and neutral particles. The region in front of the anode is the anode fall that contains ions from the anode and electrons. The vacuum arc can be either diffuse or constricted. Low-current arcs are naturally diffuse, and high-current arcs can be either constricted or diffuse.

As the current decays to a “natural” current zero, the constricted arc, if it exists, becomes diffuse. Close to current zero, the vacuum arc may become unstable and suddenly extinguishes prior to current zero. This phenomenon is known as current chop, which is a function of the arcing current, electrode material, and circuit parameters. For electrodes made with alloys, containing high vapor pressures such as silver and carbon, the chopping current is less than an ampere. Electrodes made with alloy materials containing materials with lower vapor pressure such as copper or chromium have chopping current on the order of 2 A or 3 A.

At current extinction, the electrons are rapidly lost from the interelectrode region leaving an expanding ion space-charge region at the anode end of the positive column. This space charge supports the transient recovery voltage. If the rate of dielectric recovery of this expanding space charge is greater than that of the rate of rise of the recovery voltage, current interruption is completed, otherwise a voltage breakdown may occur and the arc is re-established causing the device to carry current to the next current zero.

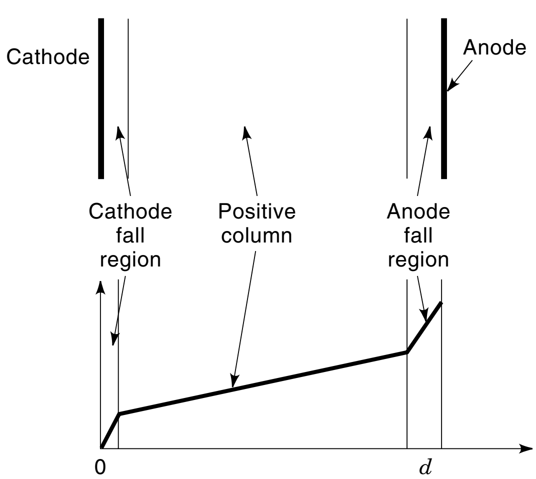


**Figure 5.** Different regions of a vacuum arc burning between two separated electrodes and the voltage distribution. The top figure shows the various arc regions between the cathode and anode electrodes. Assume a cylindrical arc. The lower figure shows the voltage distribution.

**Low-Current Vacuum Arcs.** At low-currents ($<$2000 A), the arc between the separating electrodes is a nonequilibrium thermodynamic metal vapor plasma; that is, the temperature of the electrons is greater than that of the metal ions. As previously mentioned, the cathode electrode has a multitude of highly mobile arc spots moving rapidly over the surface. For copper-based electrodes, each cathode spot supports a typical current of 100 A with a typical current density of $10^8$ A/cm$^2$ (6). For example, a 2000 A arc will produce approximately 20 cathode spots. The voltage drop of the cathode region depends on the electrode material (e.g., 18 V for Cu). The anode surface may have a diffuse current collection without anode spots or may have a constricted anode spot causing gross erosion of the anode surface. A constricted anode spot forms at high currents when the number of positive ions in the arc volume does not balance the number of current-carrying electrons. Subsequently, a space charge is formed, leading to local heating of the anode surface and evaporation of anode material and thereby producing the constricted arc attachment to the anode surface (7). Usually, low-current arcs tend to burn in the diffuse mode.

Low-current vacuum arcs can become unstable as the arc current approaches current zero. This instability can cause high-frequency oscillations in the arc voltage and in turn can cause the current to suddenly drop to zero, known as current chop (discussed above).

**High-Current Vacuum Arcs.** When vacuum interrupters interrupt high currents (e.g., $>$2000 A), the arc column burning between the separating electrodes can be either diffuse or constricted depending on the electrode configuration. Note that the arc is diffuse for currents up to several hundred amperes and that the voltage across it is very low (e.g., 18 V to 20 V). At higher currents, the arc column consists of electrons and ionized metal vapor generated by the material evaporated from both the anode and cathode. The outward radial pressure of the ionized and neutral species balanced by the inward magnetic constriction pressure caused by the current in the arc determines the arc column radius. In this mode, the species in the plasma can be assumed to be in local thermal dynamic equilibrium (LTE) and strongly radiating. The arc appears to be more resistive; that is, the arc voltage increases with current and can reach voltages as high as 200 V. Cooling of the arc column is mainly by radiation to the surrounding surfaces and heat conduction to the electrodes.

As the sinusoidal arcing current approaches a current zero, a constrictive arc will become diffuse and the number of cathode spots will decrease as the instantaneous current decreases. Since the surfaces of the electrodes are hot from the high-current arc, the vacuum arc remains quite stable until current zero. Therefore, a very low probability of a significant current chop occurs and significant overvoltages are unlikely.

Immediately following current zero, the voltage across the electrodes reverse polarity and the electrons in the arc region are quickly accelerated to the new anode, causing an expanding positive space charge region. This space-charge region supports the recovery voltage. Migration of the electrons out of this region results in a post-arc current that may be several amperes (8). If the instantaneous power, which is the

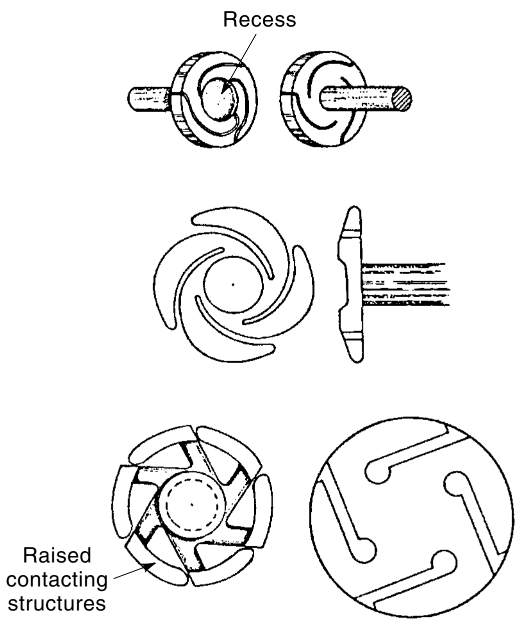


**Figure 6.** Petal electrode configurations. Two different shapes of petal electrodes are shown: one with spiral cuts with recessed center and the other with straight cuts with raised contacting surfaces.

recovery voltage times the post-arc current, is less than the power being dissipated from the prior arc region, a voltage breakdown will be unlikely, and the current interruption process is complete.

## Electrode Designs

Design of electrodes for vacuum interrupters has been explored for many years. There are four common types of electrode configurations: butt electrode, electrodes with spiral cuts, cup-shaped electrodes with diagonal cuts, and butt electrodes with special cuts and coil to produce axial magnetic fields. The shape of the electrodes is designed to control the arc either by self-induced magnetic fields or by externally applied magnetic fields. Butt-shaped electrodes are used for low-current (<1000 A) interruption such as in interrupters for electrical contactors. Both the electrode diameter and the electrode separation are important and influence the current level at which a transition from a diffuse arc to a constricted arc will occur.

Other electrode shapes are used for high-current (e.g., >1000 A) interruption when controlling the arc movement is important for reducing gross erosion of the electrode surfaces. Electrodes with spiral cuts or petals (see Fig. 6) are designed so that the current will flow in the spiral or petal. The spirals or petal of the opposite electrode are arranged so that a radial magnetic field is produced within the interelectrode region (Fig. 7a). The cup electrodes with diagonal cuts also produce a self-induced radial magnetic field (Fig. 7b). In both designs, the interaction of the axial arc current with the radial magnetic field produces a rotation of the arc, so that the arc roots move rapidly over the surface of the electrodes, reducing and minimizing surface erosion and surface temperature of the electrodes. Therefore, current interruption level is increased.

The fourth electrode configuration, known as an axial magnetic field electrode (see Fig. 8), has a series fractional turn coils that are either behind or built into the electrodes. The current flowing in the coil of the electrode pair produces an axial magnetic field in the interelectrode region. When an axial magnetic field is applied to a vacuum arc, the arc remains diffuse at much higher currents (9). The surface of the electrode may be butt-shaped with a raised outer ring, making the surface smoother than spiral electrodes. Therefore, these electrodes have low erosion, longer life, and higher voltage withstand. However, some designs can have higher contact resistance and eddy current losses.

## Voltage Surges and Voltage Escalation

When highly inductive low magnitude currents are interrupted, such as magnetizing currents of transformers less than 100 A, a current chop may occur. During the current chop, the energy stored in the inductance, $L$, of the load must be dissipated to the capacitance, $C$, of the circuit, leading to an overvoltage across the interrupter and across the load. Neglecting the damping effects of the circuit, the overvoltage can be calculated from Eq. (2):

$$V = I_c Z_s \tag{2}$$

where $I_c$ is the current chop value and $Z_s$ is the surge impedance of the load ($Z_s = (L/C)^{0.5}$). For example, if $I_C$ is 3.6 A and the surge impedance of the circuit is 20,000 Ω, the peak recovery voltage to ground of the first phase to clear may reach 72 kV. This is a voltage surge that may appear across the load and the vacuum interrupter. Therefore, vacuum interrupters for vacuum contactors and lower-voltage breakers use inter-

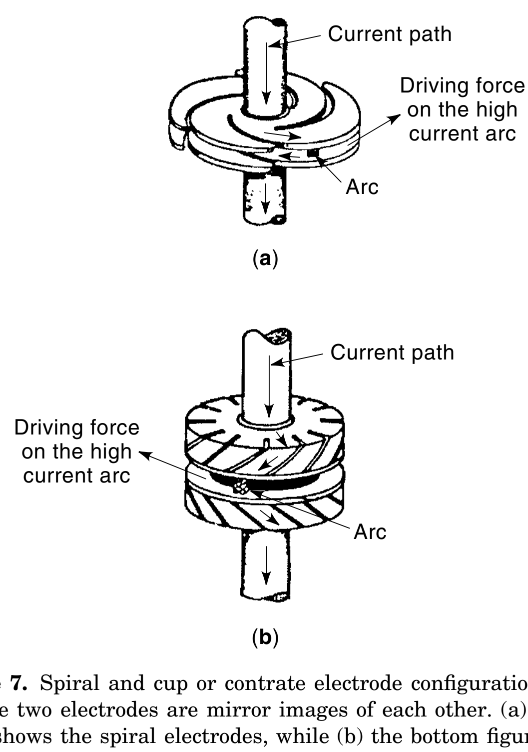


**Figure 7.** Spiral and cup or contrate electrode configurations. Note that the two electrodes are mirror images of each other. (a) The top figure shows the spiral electrodes, while (b) the bottom figure shows the cup electrodes. The current follows the spiral slots in the spiral electrodes or the diagonal slots in the sides of each cup; and these current paths produce a component of radial magnetic field that interacts with the axial arc current giving a rotational force on the arc.

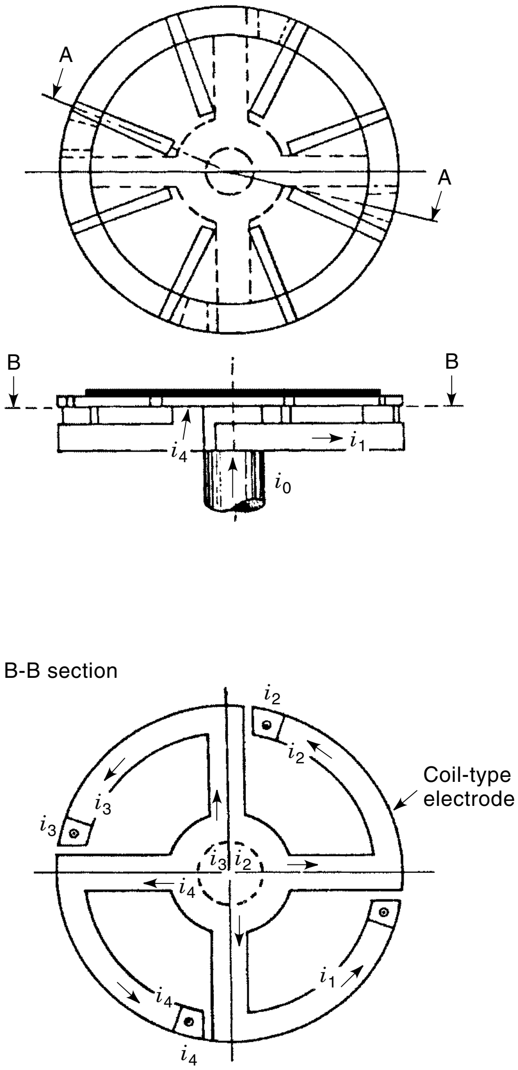


**Figure 8.** Axial magnetic field electrode configuration. This electrode has two parts: the contact surface and four quarter-turn coils behind the contact surface. The contact surface is brazed to the tips of the quarter-turn coils as shown. The opposite electrode is the mirror image so that the current in the coils of both electrodes will produce an axial magnetic field.

rupters with electrodes having very low chop current characteristics. Subsequently, the peak surge voltages are low.

When the vacuum interrupter electrodes separate just before a current zero, the electrode separation is only a fraction of the full stroke and very short arcing times result. Voltage escalation can occur as to be explained. During the recovery period, if the interrupter in this phase reignites, a high-frequency current will flow through it. Sometimes the interrupter clears this high-frequency current, with subsequent recovery voltage having an even higher peak. If the interrupter reignites again, then the process may repeat, thereby causing the recovery voltage to escalate. This is known as voltage escalation, caused by multiple-reignition.

## CONCLUSIONS

The interrupter is the most important component of any electromechanical current switching device. The type of interrupter (including the electrode configuration, arcing chamber, and arcing media) is a function of the current to be interrupted and the recovery voltage that will be impressed across it. Research and development is being continued in this area so that smaller and less expensive devices can be produced.

This article gives only a brief survey of interrupters. The most important interrupters and the basic idea of how they work are presented. For more detailed description of interrupters, refer to the texts listed in the reading list.

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**INTERRUPTERS.** See CONTACTORS.

**INTERRUPTERS FOR SWITCHGEAR.** See SWITCHGEAR PROTECTION.