FUNCTIONS OF CIRCUIT BREAKERS

Circuit breakers are designed to carry out the following functions:

1. They must be capable of closing on and carrying full-load currents at rated power factors continuously.
2. They must be capable of successfully and rapidly interrupting the heavy short-circuit currents at a very low power factor.
3. With their contacts open, the gap must withstand the steady-state power frequency system voltage continuously and transient high-frequency voltage for a short duration of time.
4. They must be capable of carrying out making duty, i.e., closing on to a circuit in which a fault exists and immediately reopening to clear the fault.
5. They must be capable of carrying currents of short-circuit magnitudes until the fault is cleared by another breaker or by a fuse nearest to the point of fault.
6. They must be capable of successfully interrupting quite small currents such as transformer magnetising currents or line and cable charging currents.
7. They must be capable of withstanding the effects of arcing of the contacts and electromagnetic forces produced due to high currents (actually there is an opening tendency of the contacts due to these high currents; the contacts may get deteriorated if this opening tendency is not prevented). Also, they must be capable of withstanding thermal conditions because of passage of current which may be 2 to 10 times the rated current of the breaker.

Air-Break Circuit Breakers

The air-break circuit breakers are available in the range of 415 volts to 11 kV rating, the rated continuous current ranging from 100 to 4000 A and breaking current capacity up to 80000 A. As the name suggests, the insulation between the two contacts is air at normal temperature and pressure. The operating mechanism can be pneumatic, solenoid-operated or spring-operated. *While breaking the fault currents, large electro-dynamic forces are produced. These electro-dynamic forces act on the operating mechanism and because of these forces, there is a tendency for contact opening. This may deteriorate the contact surfaces. Immediately after the fault current is interrupted, large high-frequency voltage transients are produced across the contacts.*

Figure shows the constructional mechanism of one pole of an air-break circuit breaker. The main contacts carry the normal current without giving a high millivolt drop, and the contacts must be made with enough pressure because there could be an opening tendency even when the rated current is carried by the breaker, particularly for breakers with higher current ratings. The main contacts are made of copper cadmium alloys. The arcing contacts are made up of heat-resistant material like copper tungsten, or silver tungsten.

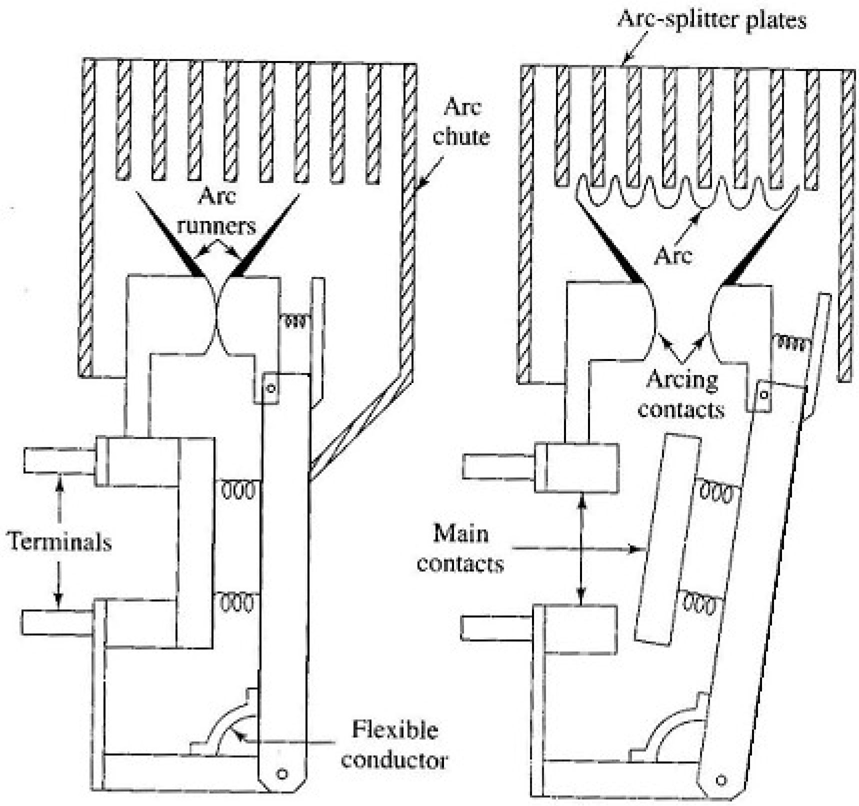
While opening, the main contacts open first and there is negligible arcing at the main contact tips as a parallel path is available through the arcing contacts. This is because of the **compression spring**. While making, the arcing contacts are made first and the main contacts are made following it.

The arc produced while making or breaking the fault current is highly intense. The temperature in the arc varies from 6000°C at the periphery of the arc to as large as 15000°C at the core of the arc. Because of this reason special arcing contacts are used. The main contact material would be otherwise burnt off or the contact welding may result. As shown in Figure, the arc that is struck on the arcing contact tips immediately travels onto the arc runners because of thermal and electromagnetic forces. As the arc runners have a horn-type shape, the arc is lengthened which increases the arc resistance, reduces the intensity of the arc and moves the arc into comparatively a cooler area. This helps in the de-ionising process. When the voltage across the arc is less than that is required to maintain the arc, it may be quenched. Further help in quenching is provided by arc splitters.

There are two alternatives prevalent for arc splitting:

Conducting arc splitters

Insulating arc splitters



Constructional Mechanism of Air-Break C.B

In the case of conducting arc splitters, the conduction of heat of arc onto the surfaces of arc splitter helps in faster heat dissipation. In case of insulating arc splitters, the arc is split into many smaller arcs and lengthened further. This gives rise to faster arc quenching. Thus arc is quenched by **lengthening, splitting and cooling** processes. Also, the inherent resistance of the arc reduces the peak of the re-striking voltage and RRRV (Rate of Rise of Re-striking Voltage), thereby increasing the breaking capacity of the breaker.

Typical reference values of ratings of Air-Break Circuit Breakers are:

460 V, 400-3500 A , 40-75 KA.
3.3 KV, 400-3500 A, 13.1-31.5 KA.
6.6 KV, 400-2400 A, 13.1-20 KA.

Air Blast Circuit Breaker. (ABCB)

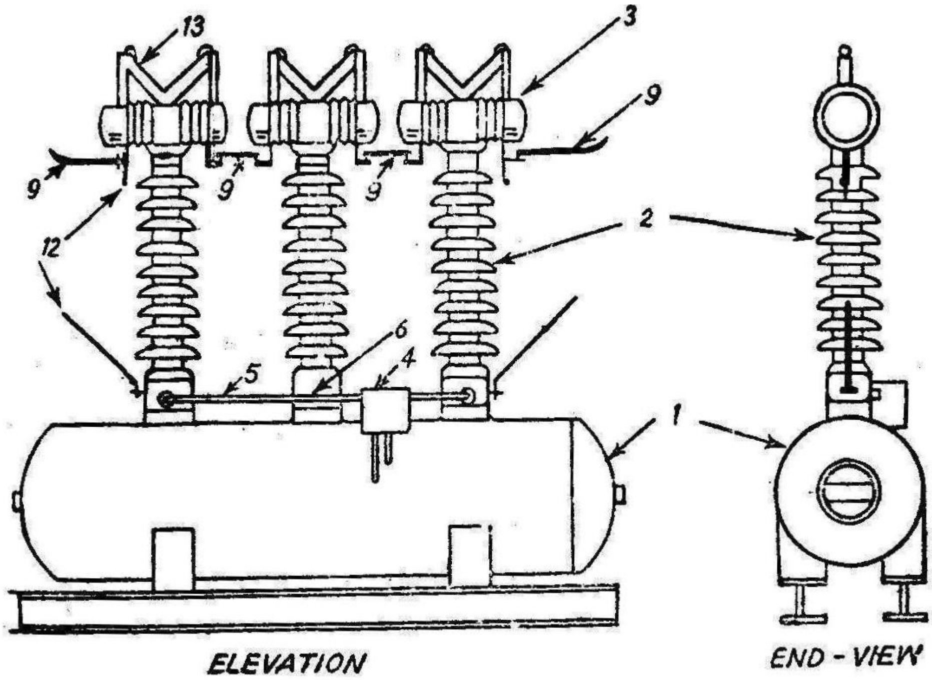
Construction of an Air Blast Circuit-Breaker

In air blast circuit-breaker (also called compressed air circuit-breaker) high pressure air is forced on the arc through a nozzle **at the instant of contact separation**. The ionized medium between the contacts is blown away by the blast of the air. After the arc extinction the chamber is filled with high pressure air, which prevents restrike.

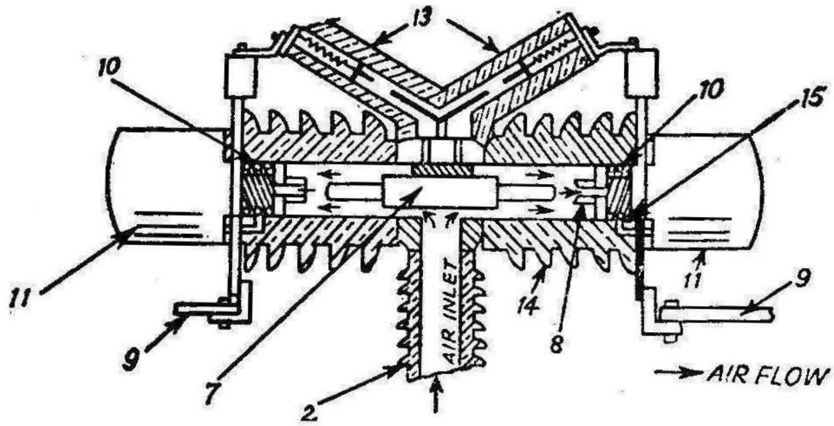
Figure shows one pole of the EHV air blast circuit-breaker. In the complete assembly there are three identical poles.

Description: High pressure air, at a pressure between 20 to 30 kg/cm^2 is stored in the Air reservoir (Item 1 in Figure). Air is taken from compressed air system.

Three hollow insulator columns (Item 2) are mounted on the reservoir. The double arc extinguishing chambers (3) are mounted on the top of the hollow insulator chambers. The current carrying parts (9) connect the three arc extinction chambers to each in series and the pole to the neighbouring equipment.



(a) One pole of an extra-high voltage air blast circuit-breaker.



(b) Details of (3) Double arc extinction chamber.

S. No.	Item	Nos.	Material
15	Port		
14.	Enclosure	6	Porcelain
13.	Resistance switching unit	3	Assembly
12.	Arcing horns Optional	4	Steel
11.	Openings for air outler	6	—
10.	Compression springs	6	Alloy steel
9.	Connection for current	—	Copper or its alloy
8.	Moving contact (in 3)	2	Copper, silver or its alloy
7.	Fixed contact (in 3)	3	Copper, or its alloy
6.	Pneumatic valve		
5.	Operating rod	1	Steel
4.	Pneumatic operating mechanism	1	
3.	Double arc extinctionchamber	3	(Assembly)
2.	Hollow insulator assembly	3	Steatite
1.	Tank air reservior (receiver)	1	Boiler plate steel

The details of the double arc extinction chambers (3) are shown in Figure. Since there are three double arc extinction poles in series, there are six breaks per pole. Each arc extinction chamber [Fig. b] consists of one twin fixed contact (7). There are two moving contacts (8) which are shown in the opening process. The moving contacts can move axially so as to open or close. Its position open or close depends on air pressure and spring (10) pressure.

On receipt of the opening signal the high pressure air is send in the hollow of the insulator. The high pressure air rapidly enters the double arc extinction chamber [Air Inlet in Fig. (b)]. As the air enters into the arc extinction chamber the pressure on the moving contacts (8) becomes more than spring pressure and contacts open.

The contacts travel through a short distance against the spring pressure. At the end of contact travel the port for outgoing air (15) is closed by the moving contact and the entire arc extinction chamber is filled with high pressure air, as the air is not allowed to go out. However, during the arcing period the air goes out through the openings (11) and take away the ionized air of arc.

While closing, the valve lets the air from the hollow insulator to the atmosphere. As a result the pressure of air in the arc extinction chamber (3) is dropped down to the atmospheric pressure and the moving contacts (8) close over the fixed contacts (7) by virtue of the spring pressure.

The opening is fast because the air takes a negligible time to travel from the reservoir to the moving contact. The arc is extinguished **within a cycle**. Therefore, air blast circuit-breaker is very fast in breaking the current.

Closing is also fast because the pressure in the arc extinction chamber drops immediately as the valve (6) operates and the contacts close by virtue of the spring pressure.

Air blast circuit-breaker requires an auxiliary compressed air system.

Air blast circuit-breakers are preferred for Arc Furnace Duty and traction system, because they are suitable for repeated duty. Whereas oil circuit-breakers are not satisfactory for such duties. Typical ratings of Air Blast Circuit-Breakers are:

12 KV, 40 KA.
22 KV, 40 KA.
145 KV, 40 KA, 3 cycle.
245 KV, 40 KA,50 KA, $2^{1}/_{2}$ cycle.
420 KV, 40 KA, 50 KA, 63 KA, 2 cycle

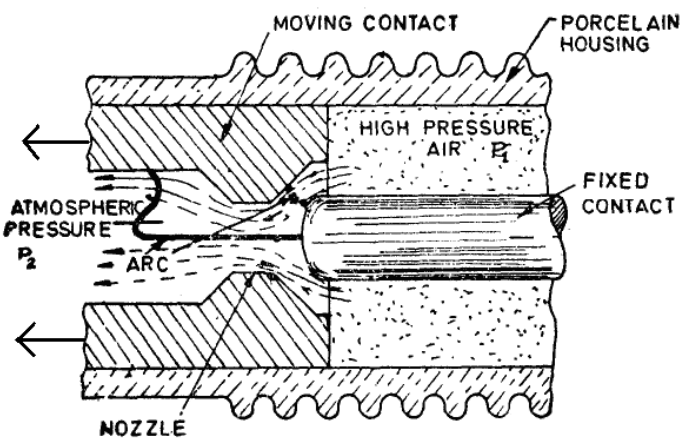
Principle of Arc quenching in ABCB (Air Blast Circuit-Breaker)

The air blast circuit-breaker needs an auxiliary compressed air system which supplies air to the air receiver of the breaker. For opening operation, the air is admitted in the arc extinction chamber. It pushes away the moving contacts. In doing so, the contacts are separated and the air blast takes away the inoized gases along with it and assists are extinction. After a few cycles the arc is extinguished by the air blast and the arc extinction chamber is filled with high pressure air (30 kg/cm^2). The high pressure air has higher dielectric strength than that of atmospheric pressure. Hence a small contact gap of few centimeters is enough.

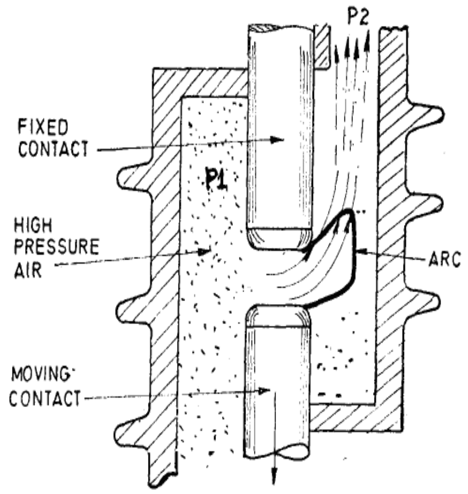
The flow of air around contacts is guided by the **nozzle shaped contacts**. It may be axial, cross or a suitable combination [Figure. (a), (b)]

In the axial blast type air flow Figure (a) the flow air is longitudinal along the arc.

In axial blast type air flow, the air flows from high pressure reservoir **to the atmosphere** through a convergent divergent nozzle. The difference in pressure and the design of nozzle is such that as the air expands into the low-pressure zone, it attains almost supersonic velocity. The mass flow of air through the nozzle is governed by the parameters like pressure ratio, area of throat, nozzle throat diameter and is influenced by the diameter of the arc itself.



(a) Axial flow.



(b) Cross flow in ABCB—(Not used).

The air flowing at a high speed axially along the arc causes removal of heat from the periphery of the arc and **the diameter of the arc reduces** to a low value at current zero. At this instant the arc is interrupted and the contact-space is flushed with fresh air flowing through the nozzle.

The flow of fresh air through the contact space **ensures removal of hot gases and rapid building up of the dielectric strength.**

The principle of cross-blast illustrated in Figure (b) is used only in circuit-breakers of relatively low rating such as 12 kV, 500 MVA.

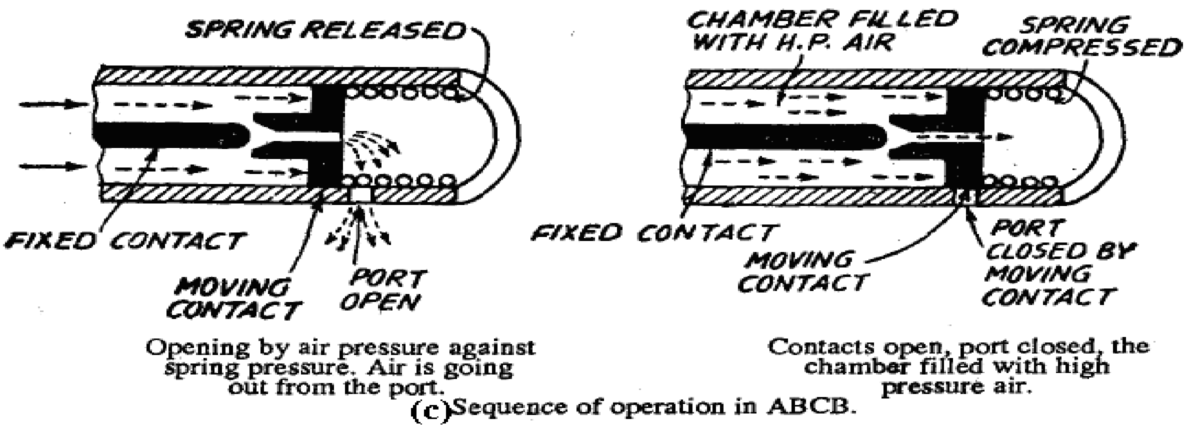
The experience has shown that in the cross-blast flow, the air flows around the arc and the diameter of arc is likely to remain stable for higher values of current.

During the period of arc extinction, the air continues to flow through the nozzle. The mass flow rate can be increased by increasing the pressure of the high pressure system. The increase in the mass flow results in increased breaking capacity.

After the brief duration of air flow, the interrupter is filled with high pressure air. The dielectric strength of air increases with pressure. Hence the fresh high pressure air in the contact space is capable of withstanding the transient recovery voltage.

After the arc extinction the interrupter chamber is filled with high pressure air. For closing operation, the air from this chamber is let out to the atmosphere. Thereby the pressure on the moving contacts from one side is reduced and the moving contacts close rapidly by the spring pressure (Fig. d.)

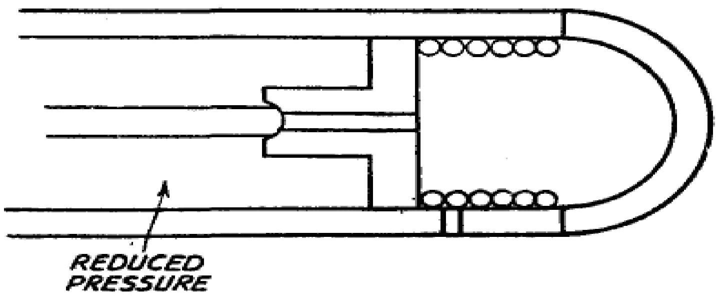
The air blast circuit-breakers come under the class external extinguishing energy type. The energy supplied for arc extinction is obtained from high pressure air and is independent of current to be interrupted.



Opening by air pressure against spring pressure. Air is going out from the port.

Contacts open, port closed, the chamber filled with high pressure air.

(c) Sequence of operation in ABCB.



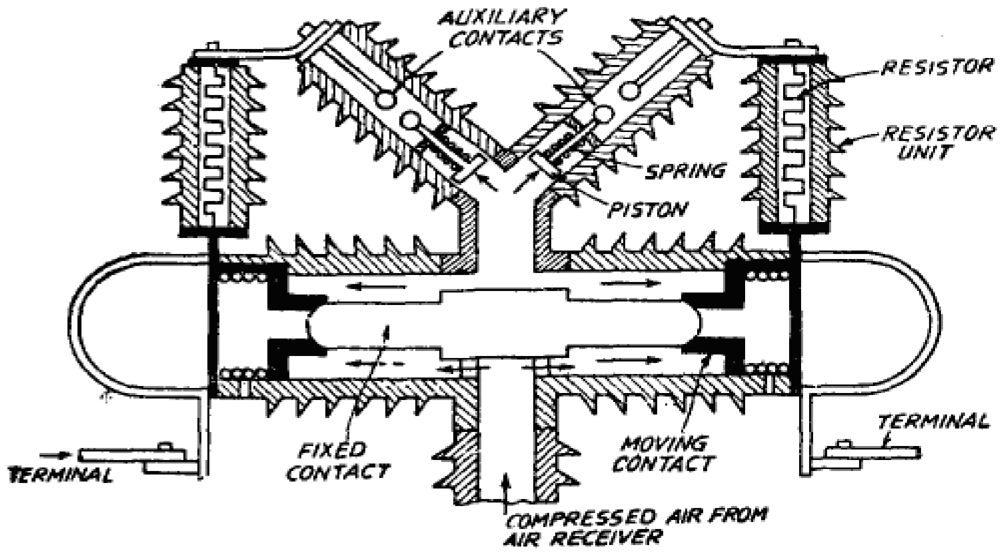
(d) Contact close by spring pressure against reduced air pressure.

Resistance Switching in ABCB

We have noted earlier that the post zero resistance of contact space is high in air blast circuit-breakers. This is because the contact clearance space is filled with high pressure air after final current zero and high pressure air has high dielectric strength. The high restriking voltage appearing across the contacts does not damp out through the contact gap because of the high post zero resistance.

Further, voltages of the order of several times the normal voltage appear across the contacts because of current chopping. If these voltages are not allowed to discharge, they may cause break down of insulation of the circuit-breaker or the neighbouring equipment. To overcome this difficulty. 'Resistance Switching' is adopted. The usual procedure is to connect a resistance is shunt with the arc.

Figure shows another popular arrangement used for a double arc extinguishing chamber. During the opening operation, air is admitted in the arc extinguishing chamber. It separates main contacts and pushes the auxiliary contacts. The auxiliary contacts close, thereby the resistors are connected across the arc for a short time of arcing. The auxiliary contacts are located in the inclined V-shaped insulators while the resistors are located in the vertical insulators. Immediately after arc extinction, the pressure on either side of the piston of auxiliary contacts gets so adjusted that the auxiliary contacts open and resistor circuit is interrupted. Ceramic resistances of nonlinear characteristics, similar to those used in the lightning arresters were used for resistance switching.



Configuration of switching resistors.

During high current, non-linear resistor offers low resistance. Thus the main arc current is partly diverted through resistor unit. As current reduces, the resistance offered by non-linear resistors increases, causing a greater drop across the resistor units. Thereby the voltage available for arc between auxiliary contacts is no more sufficient and arc between auxiliary contacts is automatically extinguished.