ARC phenomenon

- When short circuit occurs, heavy current flows through the CB contacts
- When the contacts begin to separate the large fault current increases the current density and temperature rises
- This heat ionize the medium between the contact (oil or air)
- The ionized air or vapour act as a conductor and an **Arc** is struck between the contacts
- Arc resistance depends upon
    - degree of ionization
    - length of the arc
    - cross section of Arc

Methods of Arc extinction

1. **High resistance method** - resistance of the arc is increased so that current is reduced to a value insufficient to maintain the arc. Any of the following methods can be used to increase the arc resistance
    a. Lengthening arc - length of the arc can be increased by increasing gap between contacts
    b. Reducing cross section of the arc - cross section of the arc can be reduced by passing the arc through a narrow opening or by having smaller area of contact
    c. Cooling the arc - cooling helps in the deionization of the medium between the contacts and increases the arc resistance. Gas blast directed along the arc cools it
    d. Splitting the arc - Arc is splitted into a number of smaller arcs in series by using a conducting plates between the contacts. Each smaller arc experiences the effect of lengthening and cooling

2. **Low resistance (current zero method)** - In AC system current drops to zero after every half cycle. At every current zero the arc extinguishes for a brief moment. As soon as the current becomes zero the medium between the contacts should be deionized so that the rising contact voltage (restriking voltage) cannot break down the medium between contacts again. Any of the following methods can be used

    a. Lengthening of the gap
    b. High pressure
    c. Cooling
    d. Blast effect - ionised particles are swept away by directing a gas blast or forcing oil into the contact space

Important terms related to ARC

Arc voltage - voltage that appear across the contacts of the circuit breaker during the arcing period

Restriking voltage - transient voltage that appears across the contacts of the circuit breaker at or near current zero during arcing period

- if the restriking voltage rises more rapidly than the dielectric strength of the medium the arc will persist for another half cycle
- If the dielectric strength of the medium build up more rapidly than restriking voltage, arc fails to restrike and the current will be interrupted

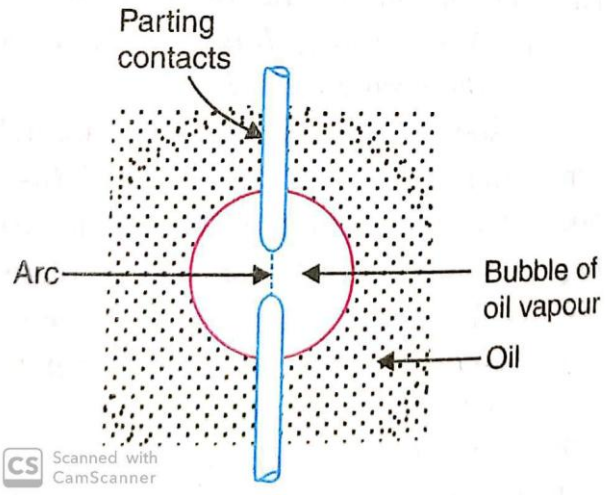
Recovery voltage - normal frequency RMS voltage that appears across the contacts of the circuit breaker after final Arc extinction. It is approximately equal to the system voltage

Classification of circuit breaker

(based on medium used for arc extinction)

1. **Oil circuit breakers** - uses some insulating oil (transformer oil) for Arc extinction
    i. Bulk oil CB
    ii. Low oil CB
2. **Air blast circuit breaker** - high pressure air blast is used for Arc extinction
    i. Axial blast type
    ii. Cross blast type
3. **SF6 (sulphur hexafluoride) circuit breaker –** uses SF6 gas
4. **Vacuum circuit breaker** - uses vacuum

OIL CIRCUIT BREAKER

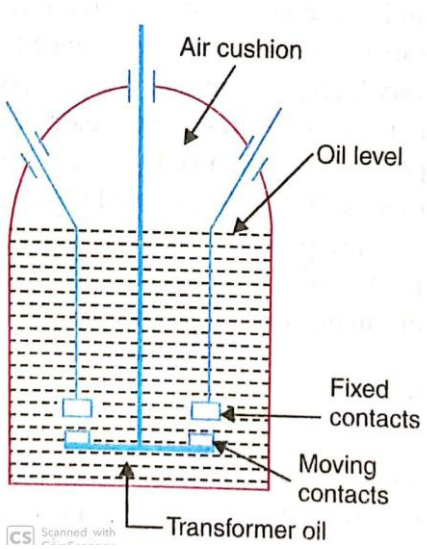


- Some insulating oil (eg: transformer oil)is used as Arc quenching medium
- When the contacts are opened an arc is struck between them
- Heat of the arc evaporates oil and produces hydrogen gas at high pressure
- Hydrogen gas bubble surrounds the arc region
    - ✓ It cools the arc, deionise the medium between the contacts
    - ✓ Gas creates turbulence in the oil and forces it into the space between the contacts remove the arcing products from the arc path

Bulk oil circuit breaker

- Uses large quantity of oil
- 10 % of the oil is used for Arc extinction and remaining for insulation
- Quantity of oil increases with the increase in system voltage which in turn increases the cost, tank size, weight of the breaker

Plain break oil circuit breaker (double break bulk oil CB)



- It consists of fixed and moving contact enclosed in a strong weather tight earthed tank containing oil up to a certain level
- when fault occurs moving contacts are pulled down by the protective system and an Arc is struck which vaporises oil into hydrogen gas
    - ✓ Hydrogen gas bubble generated around the arc cools the arc and deionise the medium between the contacts
    - ✓ Gas creates turbulence in the oil that helps in eliminating the arcing products from the arc path
    - ✓ As the contacts separate, length of the arc increases, increasing arc resistance and finally arc extinguishes
- These breakers are used only for low-voltage application (less than 11kV)

Advantages

- Oil acts as an insulator and permits smaller clearance between live conductors and earthed components.
- The hydrogen gas bubble cools the arc and helps in de-ionisation of the medium between the contacts.

Disadvantages.

- It is inflammable and there is a risk of a fire.
- It may form an explosive mixture with air
- The arcing products (e.g., carbon) remain in the oil and its quality deteriorates with successive operations. Periodic checking and replacement of oil is necessary
- There is no special control over the arc other than the increase in length by separating the moving contacts. For successful arc interruption, long arc length is necessary
- Oil breakers do not permit high speed interruption.

AIR BLAST CIRCUIT BREAKER (ABCB)

- Uses high pressure air blast as an Arc quenching medium
- Compressed air is stored in a tank.
- When a fault occurs, tripping impulse is produced which causes opening of the air valve that is connected between **compressed air tank** and **arcing chamber** (where arc is produced), and a high pressure air blast is directed into the arcing chamber
- Air blast cools the arc and removes the arcing products to the atmosphere
- This increases dielectric strength of the medium between the contacts and extinguishes the arc

Advantages.

An air-blast circuit breakers has the following advantages over an oil circuit breaker

- No risk of fire
- The arcing products are completely removed by the blast whereas the oil deteriorates with successive operations; the expense of regular oil replacement is avoided.
- The growth of dielectric strength of air is so rapid that final contact gap needed for arc extinction is very small. This reduces the size of the device.
- The arcing time is very small in Air blast CB due to the rapid build up of dielectric strength between contacts. Therefore, the arc energy is only a fraction of that in oil circuit breakers, thus resulting in less burning of contacts.
- Due to lesser arc energy, air-blast circuit breakers are very suitable for conditions where frequent operation is required

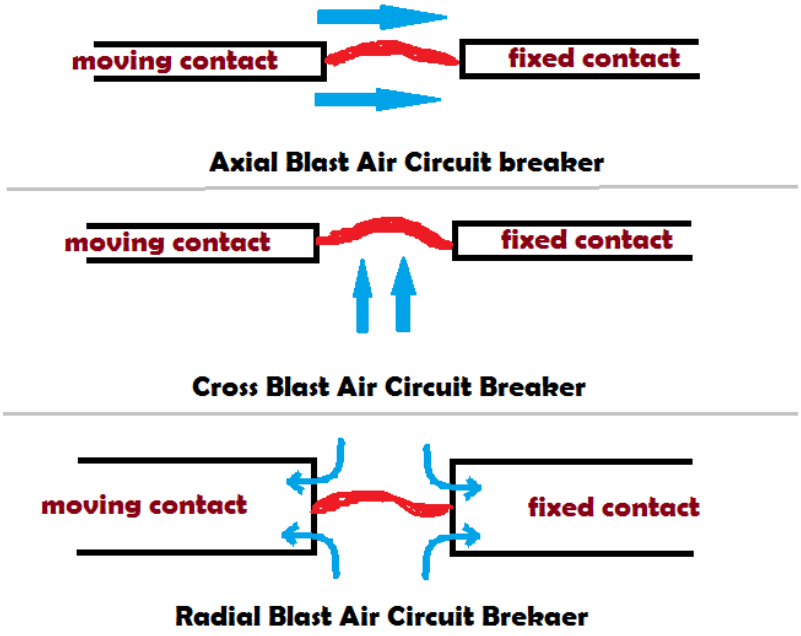
Disadvantages.

- The air has relatively inferior arc extinguishing properties.
- Considerable maintenance is required for the compressor plant which supplies the air-blast

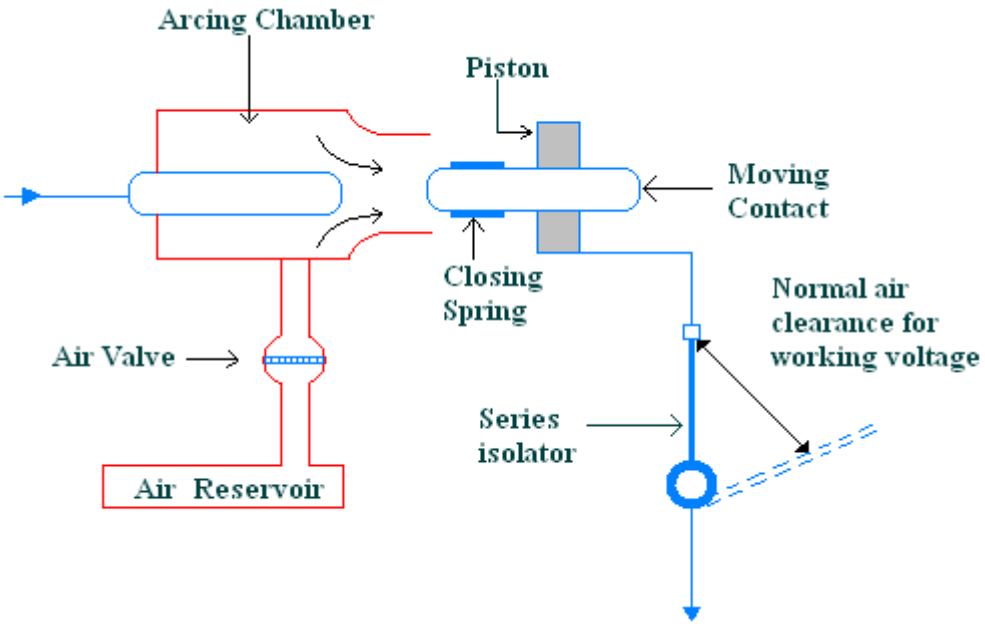
Types of air blast circuit breaker

Based on the direction of flow of air blast with respect to arc they are classified into

1. **Axial blast type**: air blast is directed along the arc path.
2. **Cross blast type:** air blast is perpendicular with respect to arc.
3. **Radial blast type:** air blast is directed radially**.**



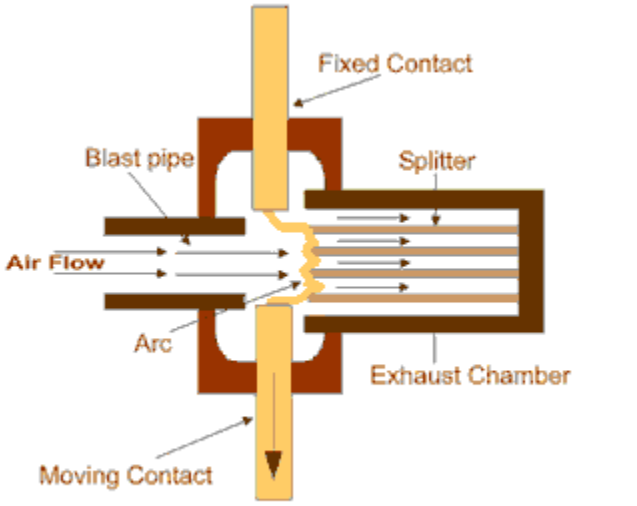
Axial blast air circuit breaker



- Fixed and moving contacts are held in position by spring pressure under normal conditions
- The **air reservoir** is connected to the **arcing chamber** through an **air valve**.
- When a fault occur, tripping impulse causes opening of air valve and high pressure air enters to the arcing chamber.
- This air pushes away the moving contacts against spring pressure.
- As the moving contacts separates, an arc is struck between them. At the same time high pressure air blast flow along the arc and sweep away the ionised particles.
- This increases the dielectric strength of medium, as a result of it the arc fails to re-strike and flow of current is interrupted.
- The final gap between contacts for arc interruption is very small. So an isolating switch is included as a part of this circuit breaker.
- This switch opens immediately after the fault interruption, to provide necessary clearance for insulation. The isolating switch is not needed for low voltage.

Cross blast air circuit breaker

- Blast pipe is fixed in perpendicular to the movement of moving contact
- Exhaust chamber is fitted on the opposite side of the arcing chamber
- The exhaust chamber consist of arc splitters
- When moving contact and fixed contact are separated, an arc is established in between the contact, and at the same time high pressure air coming from blast pipe will pass through the contact gap and will forcefully take the arc into exhaust chamber where the arc is split with the help of arc splitters and finally arc is extinguished and current is interrupted



Principle of Cross Blast Air Circuit Breaker

SF6 CIRCUIT BREAKER

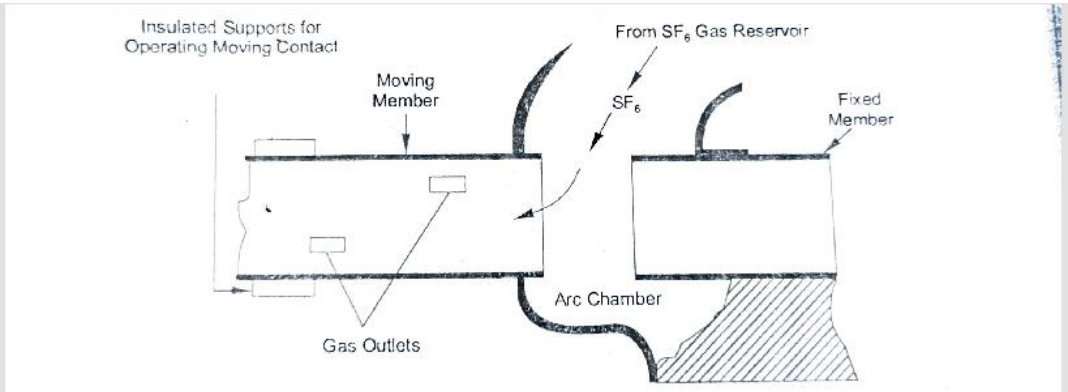


Fig. 1.14 SF_6 Gas Circuit Breaker

Construction

- Fixed and moving contacts are enclosed in an arc chamber containing SF_6 gas
- Arc chamber is connected to SF_6 gas reservoir
- **SF_6 is a highly electronegative gas that has a strong tendency to absorb free electrons**
- Fixed contact is a hollow cylinder fitted with an Arc horn
- Moving contact is also a hollow cylinder with rectangular holes in the sides to permit the SF_6 gas out after flowing through the arc
- Tips of the contacts and arcing horn are coated with copper tungsten (Arc resistant material)
- Since SF6 is costly, it is reconditioned by suitable auxiliary system after each operation of the breaker

Working

- at normal closed position of the breaker, contacts are surrounded by SF_6 gas at a pressure of 2.8kg/cm²
- When the contacts are separated an Arc is struck, at the same time a valve of SF_6 gas reservoir opens and SF_6 gas at high pressure of 14 kg/cm² is permitted to the arc chamber
- The high pressure flow of SF_6 rapidly absorbs the free electrons in the arc
- Removal of charge carriers from the arc helps in build up the dielectric strength of the medium between the contacts and causes the extinction of Arc

Advantages

- Very short arcing time due to the superior Arc quenching property of SF_6
- Dielectric strength of SF_6 is 2 to 3 times that of air
- No risk of fire as SF_6 gas is non inflammable
- Noiseless operation
- No exhaust to atmosphere
- Low maintenance cost

Disadvantage

- Costly due to high cost of SF6
- SF6 gas has to be reconditioned after every operation of the breaker with the help of an additional equipment

VACUUM CIRCUIT BREAKER (VCB)

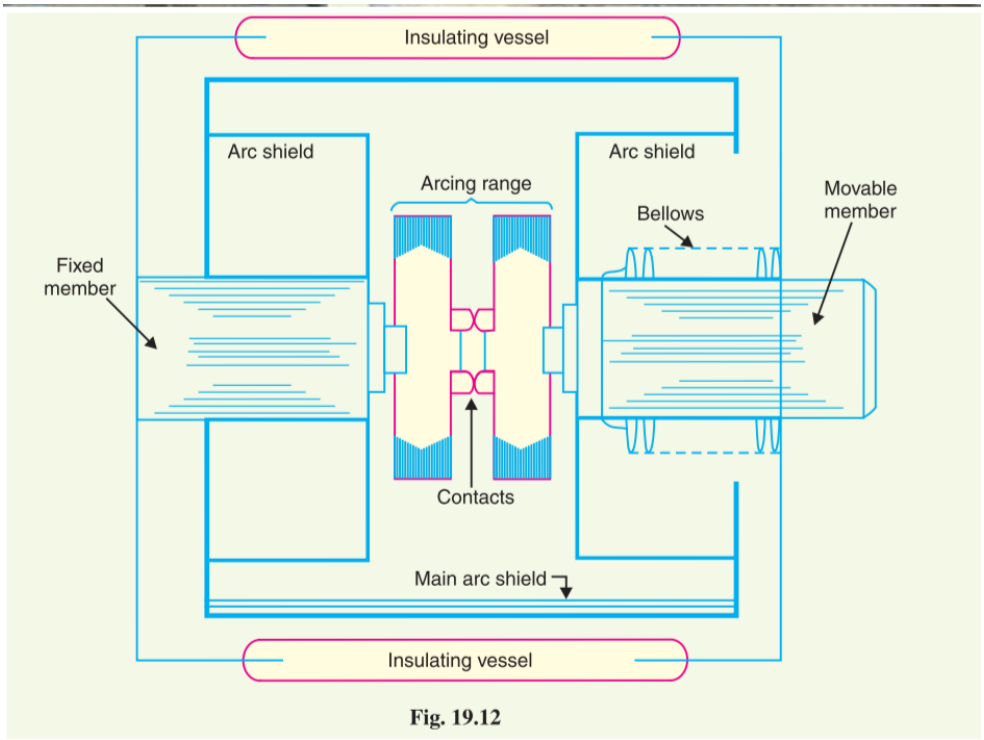


Fig. 19.12

Construction

- Vacuum is used as Arc quenching medium
- Degree of vacuum is in the range of 10^{-7} to 10^{-5} torr
- It consists of a fixed contact moving contact and arc shield mounted inside a vacuum chamber
- Moving contact is connected to the operating mechanism by stainless steel bellows
- Steel bellows permanently seal the vacuum chamber and prevent leak
- Glass vessel or ceramic vessel is used as the outer insulating body
- Arc shield prevents the metallic vapours falling on the surface of outer insulating cover

Working

- When the contacts separate an Arc is struck between them
- Arc is produced due to the ionization of metal vapours of contacts
- This arc is quickly extinguished as the metallic vapours, electrons and ions in the arc are condensed by the surface of moving contacts, fixed contacts and arc shields
- Arc extinction in VCB occurs with short contact separation 0. 625cm

Application

- Most reliable current interruption technology for medium voltage switchgear.
- For higher voltage vacuum technology is not commercially feasible.
- Vacuum circuit breakers are used in metal-clad Switchgear and also in porcelain housed circuit breakers.

Advantages

- VCB has long life.
- Unlike Oil Circuit Breaker (OCB) or air blast Circuit Breaker (ABCB), the explosion of VCB is avoided. This enhances the safety of the operating personnel.
- No fire hazard
- VCB is fast in operation and suitable for repeated operation.
- almost maintenance free.
- No exhaust of gas to the atmosphere and Noiseless operation.

Disadvantages

- VCB is uneconomical at voltages exceeding 38 kVolts.
- The cost of the breaker becomes excessive at higher voltages ie, at high voltages (above 38 kV) more than two numbers of the circuit breaker are required to be connected in series.

Circuit breaker ratings

a circuit breaker is required to perform the following three duties

1. It must be capable of opening the faulty circuit and breaking the fault current.
2. It must be capable of being closed on to a fault.
3. It must be capable of carrying fault current for a short time

Corresponding to the above mentioned duties, the circuit breakers have three ratings

- breaking capacity
- making capacity
- Short time capacity

- **Breaking capacity :** it is The RMS current that the circuit breaker is capable of breaking at given recovery voltage and under specified conditions (Power factor, rate of rise of restriking voltage)

  Breaking capacity = $\sqrt{3}VI \times 10^{-6}$ MVA

- **Making capacity :** peak value of current during the first cycle of current wave after the closure of circuit breaker

  Making capacity: 2.55× symmetry breaking capacity
- **Short time rating:** It is the time period for which a circuit breaker is able to carry fault current while remaining closed.
- **Normal current rating :** RMS value of current which circuit breaker is capable of carrying continuously at its rated frequency and other specified condition

1.20 DIFFERENCE BETWEEN FUSE AND CIRCUIT BREAKER :

The difference between Fuse and Circuit Breaker is given below in the tabulated form :

	Basis	Fuse	Circuit Breaker
1.	Working Principle	Fuse works on the electrical and thermal properties of the conducting materials.	Circuit breaker works on the electro-magnetism and switching principle.
2.	Reusability	Fuses (HRC) can be used only once.	Circuit breakers can be used a number of times.
3.	Status indication	It does not give any indication.	It gives an indication of the status.
4.	Switching action	Fuse cannot be used as an ON/OFF switch.	The circuit breaker is used as an ON/OFF switches.
5.	Temperature	They are independent of ambient temperature.	Circuit breaker depends on ambient temperature.
6.	Characteristic curve	The characteristic curve shifts because of the ageing effect.	The characteristic curve does not shift.
7.	Protection	The fuse provides protection against only power overloads.	Circuit breakter provides protection against power overloads and short circuits.
8.	Function	It provides both detection and interruption process.	Circuit breaker performs only interruption. Faults are detected by relay system.
9.	Breaking capacity	Breaking capacity of the fuse is low as compared to the circuit breaker.	Breaking capacity is high.
10.	Operating time	Operating time of fuse is very less (0.002 seconds)	Operating time is comparatively more than that of the fuse. (0.02 - 0.05 seconds)
11.	Version	Only single pole version is available.	Single and multiple version are available.
12.	Mode of operation	Completely automatically.	Manually as well as automatically operated.
13.	Cost	Cost of fuse is low.	Cost of circuit breaker is high.

S. No.	Particular	Fuse	Circuit breaker
1.	*Function*	It performs both detection and interruption functions.	It performs interruption function only. The detection of fault is made by relay system.
2.	*Operation*	Inherently completely automatic.	Requires elaborate equipment (*i.e.* relays) for automatic action.
3.	*Breaking capacity*	Small	Very large
4.	*Operating time*	Very small (0·002 sec or so)	Comparatively large (0·1 to 0·2 sec)
5.	*Replacement*	Requires replacement after every operation.	No replacement after operation.