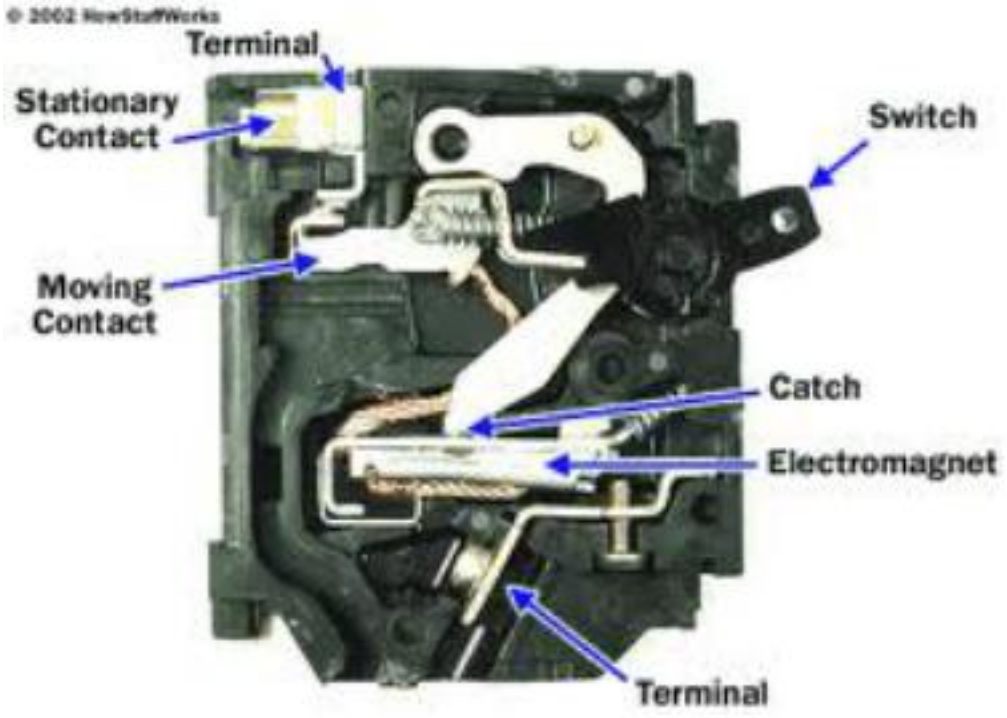
Circuit Breaker

CIRCUIT BREAKERS



What is a circuit breaker?

- A circuit breaker can make or break a circuit either manually or automatically under all conditions viz. no-load, full load and short circuit

A circuit breaker is an equipment which is designed to protect an electric circuits from damage caused by short circuit or overload.

The basic **circuit breaker working** principle is that it is an automatically operated electric switch.

It detects the fault condition and interrupt the continuity to stop the flow of electricity immediately.

It is not like a fuse which operates once and need to be replaced, a circuit breaker can be reset (either manually or automatically) to resume it's normal operation.

There are variable sizes and varieties of circuit breakers are available according to the use.

It is used for the protection of small household appliances up to the large distribution systems(Power Stations).

Requirements of Circuit Breaker :

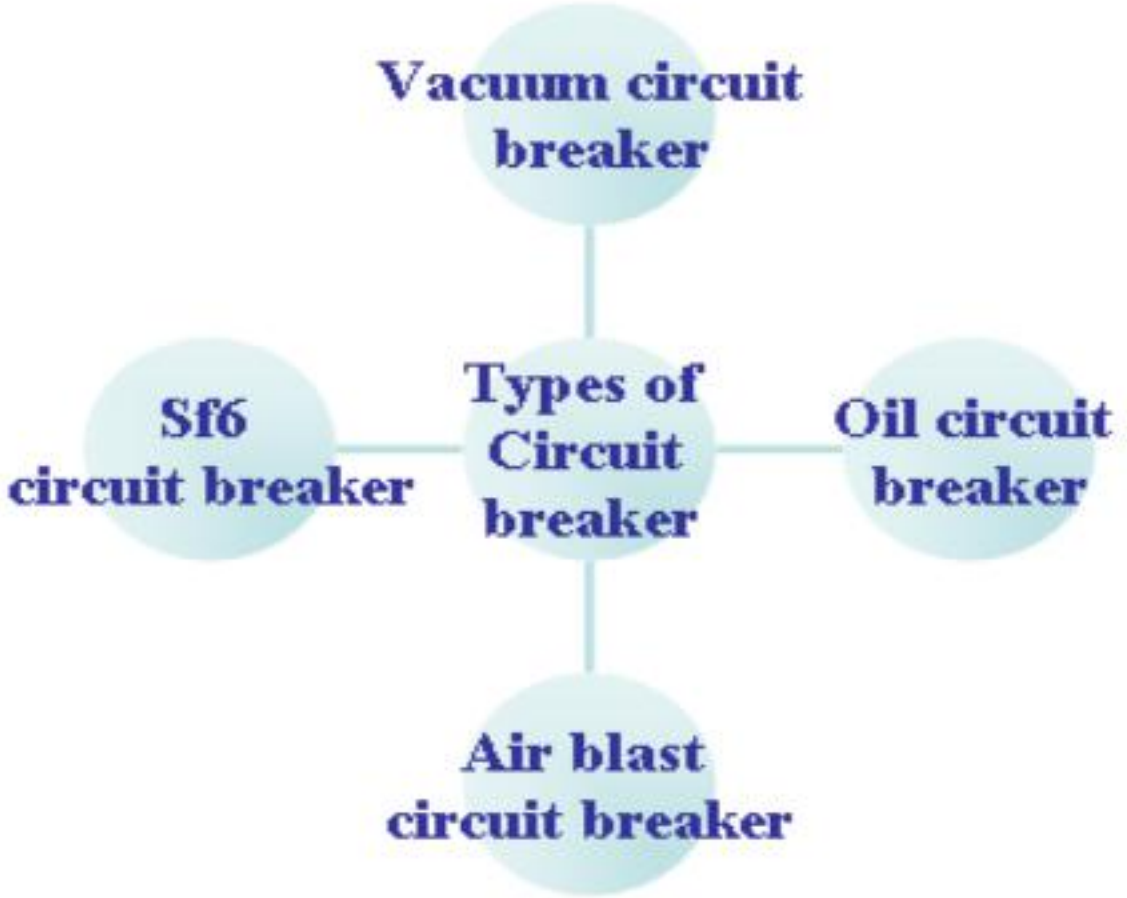
1. The normal working current & the short circuit current must be safely interrupted by the circuit breaker .

2. The faulty section of the system must be isolated by circuit breaker as quickly as possible keeping minimum delay.

3.It should not operate with flow of over current during healthy conditions.

4. The faulty circuit only must be isolated without affecting the healthy one.

TYPES OF CIRCUIT BREAKERS:–



TYPES OF CIRCUIT BREAKERS:–

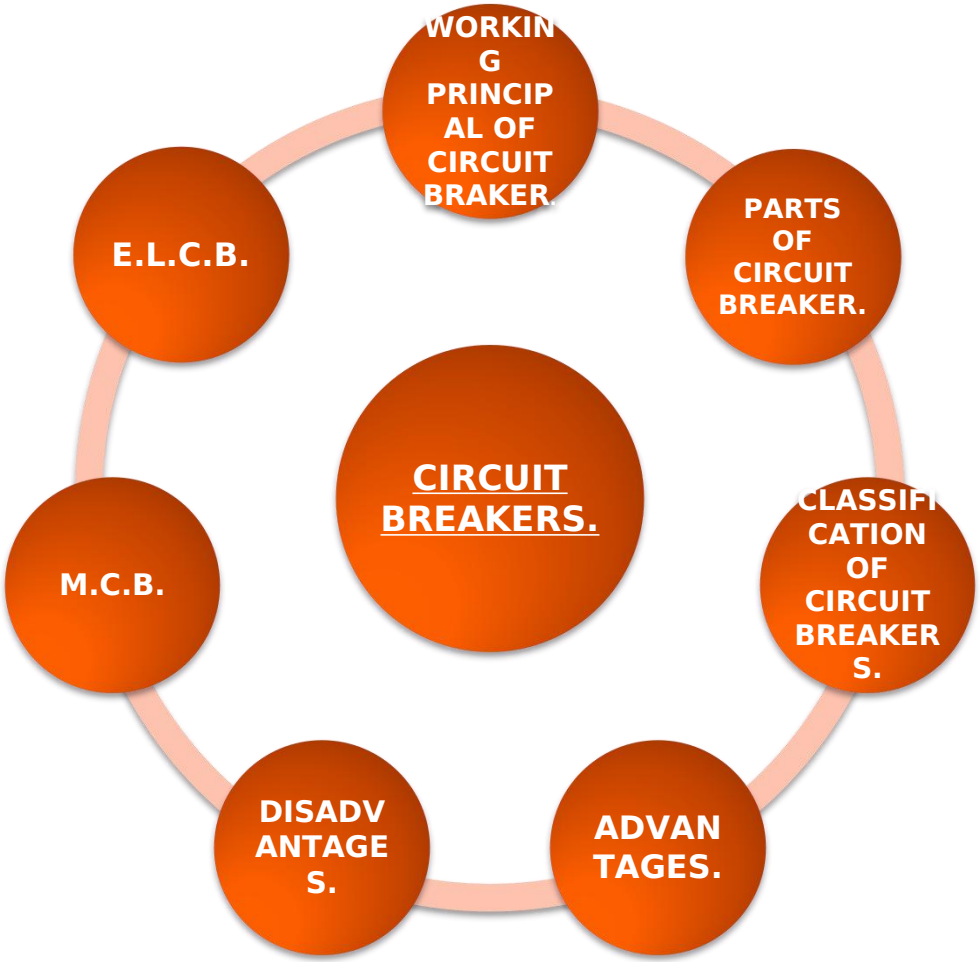
MV

1.Air Circuit Breaker (ACB)
2.Vaccum Circuit Breaker (VCB)
3.Oil Circuit Breaker
4.SF6 Circuit Breaker

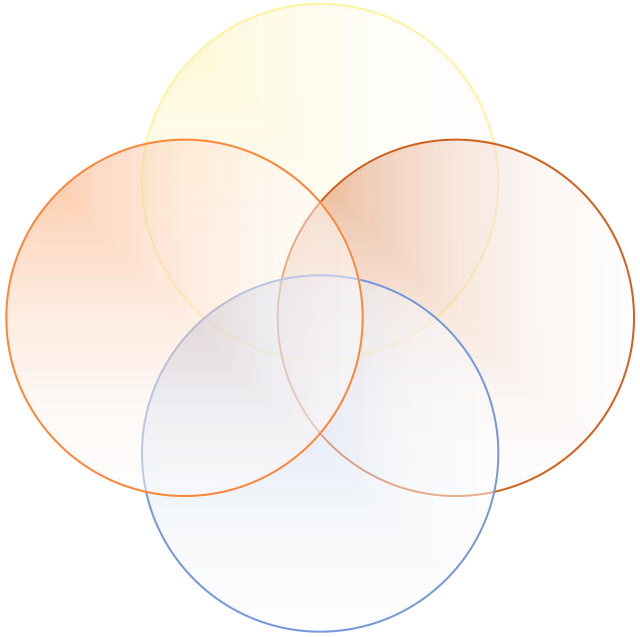
LV

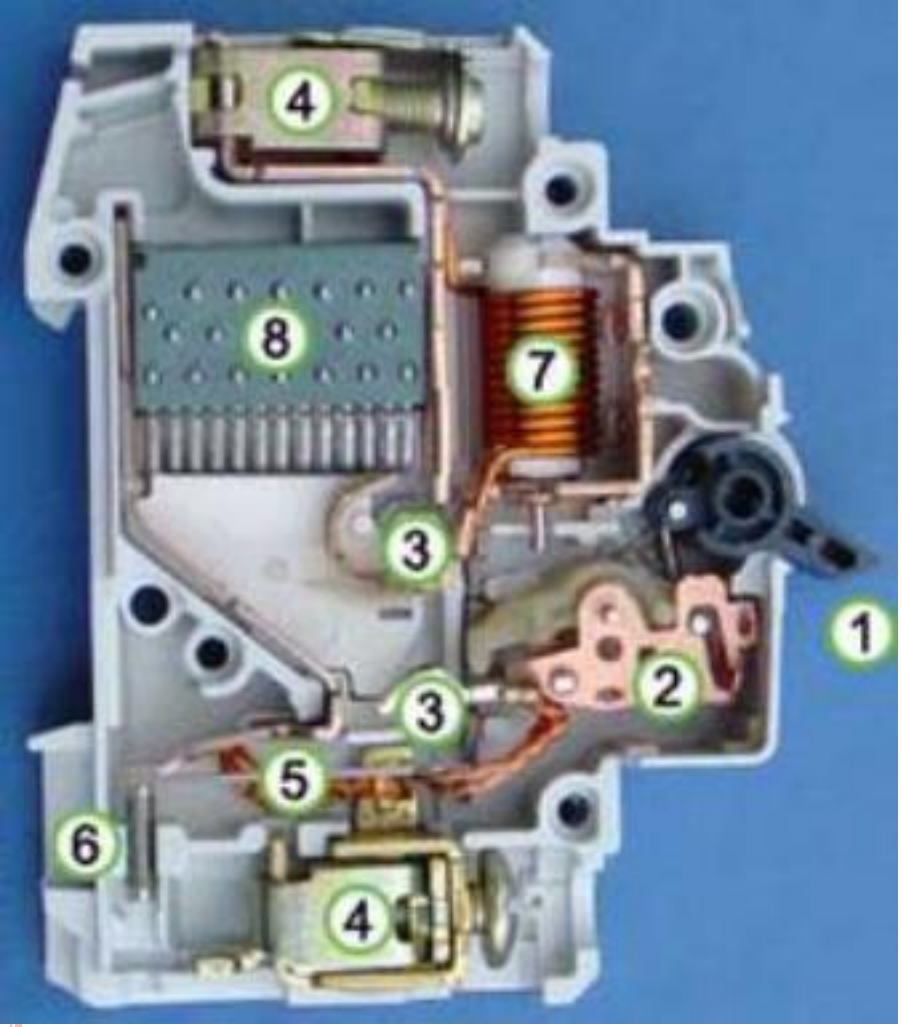
1.Air Circuit Breaker (ACB)
2.Moulded Case Circuit Breaker (MCCB)
3.Earth Leakage Circuit Breaker (ELCB)
4.Miniature Circuit Breaker (MCB)
5.Motor Protection Circuit Breaker (MPCB)

CIRCUIT BREAKERS



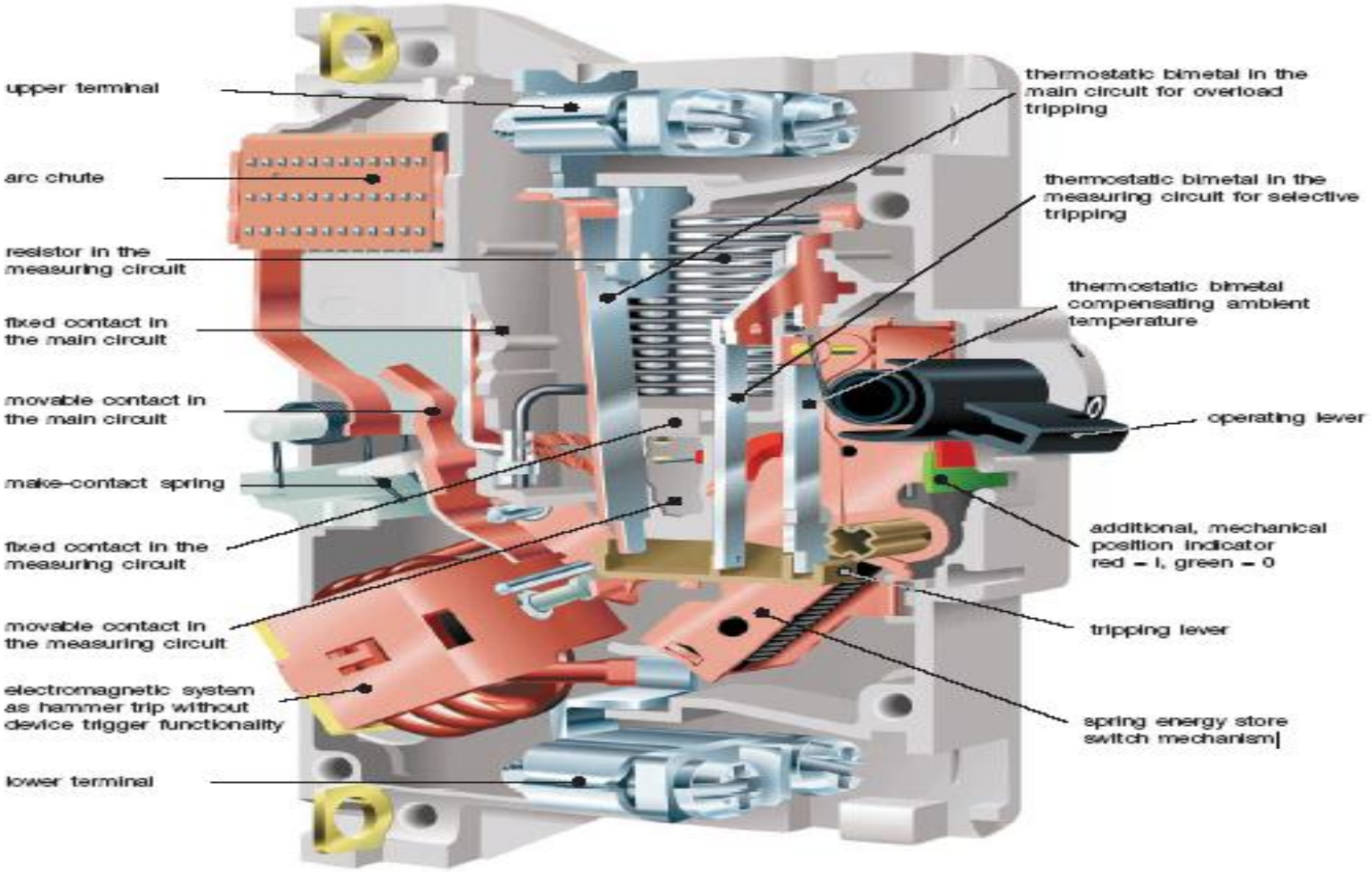
BASIC ELEMENTS OF CIRCUIT BREAKER:–





The design includes the following components:

1. **Actuator lever** - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the "on" position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. **Actuator mechanism** - forces the contacts together or apart.
3. **Contacts** - Allow current when touching and break the current when moved apart.
4. **Terminals**
5. **Bimetallic strip**.
6. **Calibration screw** - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. **Solenoid**
8. **Arc divider/extinguisher**


upper terminal
arc chute
resistor in the measuring circuit
fixed contact in the main circuit
movable contact in the main circuit
make-contact spring
fixed contact in the measuring circuit
movable contact in the measuring circuit
electromagnetic system as hammer trip without device trigger functionality
lower terminal
thermostatic bimetal in the main circuit for overload tripping
thermostatic bimetal in the measuring circuit for selective tripping
thermostatic bimetal compensating ambient temperature
operating lever
additional, mechanical position indicator red – I, green – 0
tripping lever
spring energy store switch mechanism

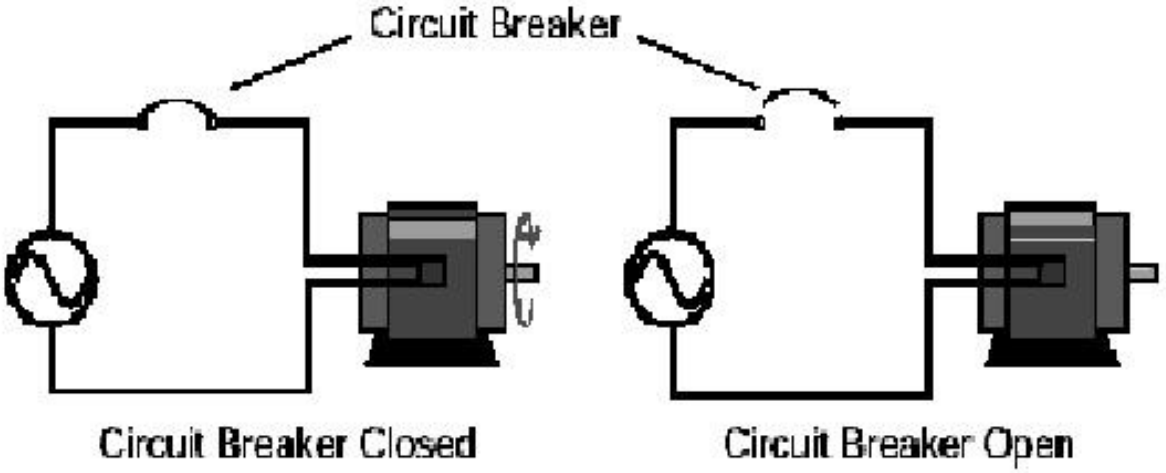
Now for understanding the circuit breaker working let us take an example of AC motor(See the diagram below).

In the following explanation, an AC motor is connected through a circuit breaker to a voltage source.

When the circuit breaker is closed, a complete path for current exists between the voltage source and the motor allowing the motor to run.

Opening the circuit breaker breaks the path of current flow and the motor stops. The circuit breaker automatically opens when it senses a fault.

After the fault has been cleared, the breaker can be closed, allowing the motor to operate.



Operating Mechanism

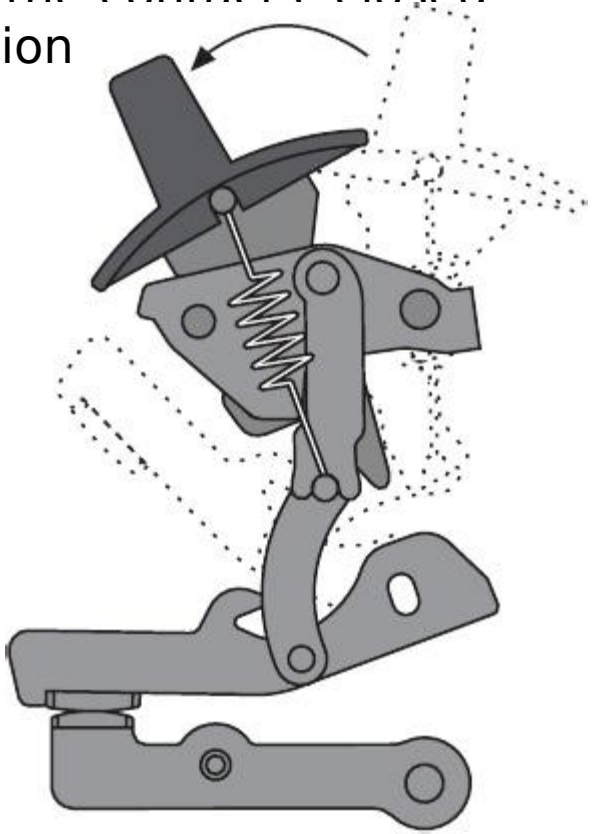
- The operating handle is connected to the moveable contact arm through an **operating mechanism**
- In the following illustration,

The operating handle is moved from the “OFF” to the ON” position

In this process a spring begins to apply tension to the mechanism.

When the handle is directly over the center, the tension in the spring is strong enough to snap the contacts closed

Handle in On Position
Contacts Closed



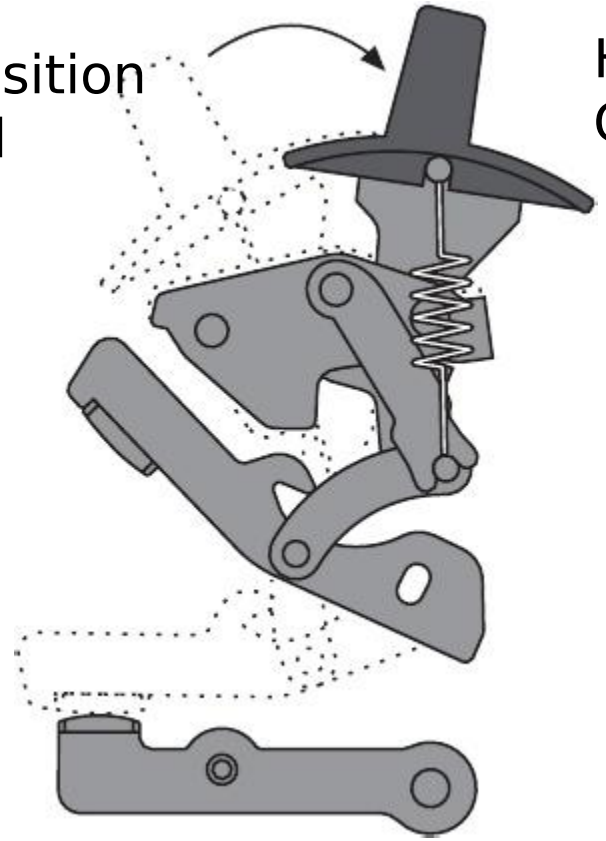
Handle in Off Position
Contacts Open

The contacts are opened by moving the operating handle from the “ON” to the “OFF” position.

In this process a spring begins to apply tension to the mechanism.

When the handle is directly over the center, the tension in the spring is strong enough to snap the contacts open.

Handle in On Position
Contacts Closed



Handle in Off Position
Contacts Open

CLASSIFICATION OF CIRCUIT BREAKER

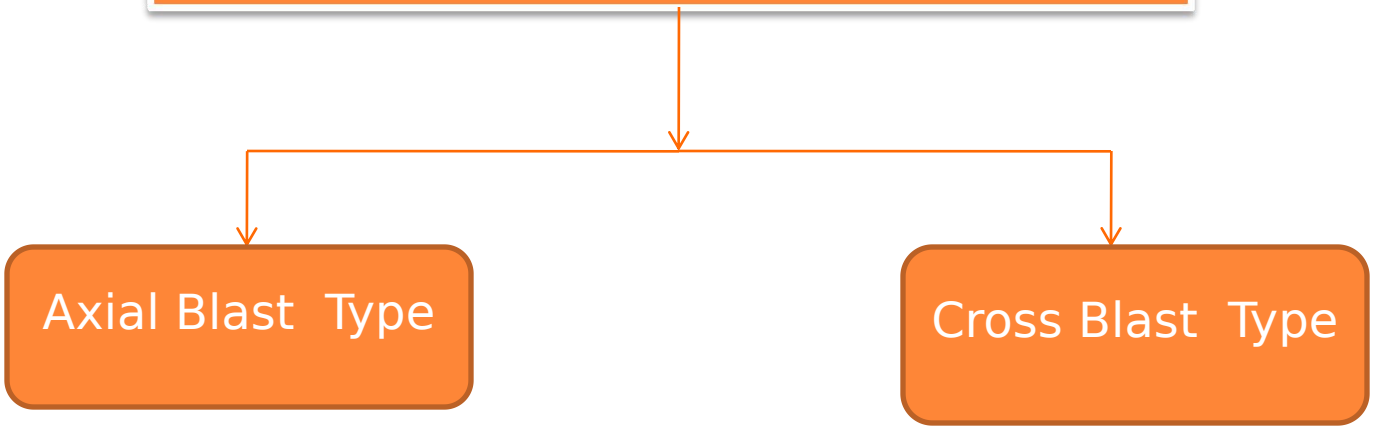
The circuit breaker are classified by various ways.

The different criteria for classification of circuit breaker are as follows,

1. Interrupting medium,
2. According to service,
3. Way of operation,
4. Action,
5. Method of control,
6. Way of Mounting,
7. Tank construction,
8. Contacts

- According to the Interrupting medium the circuit breakers are classified as air circuit breaker, air blast circuit breaker, oil circuit breaker & magnetic circuit breaker.
- According to service there are two types of circuit breakers viz indoor circuit breaker & outdoor circuit breaker.
- Depending on the operation, the types of circuit breakers are gravity opened, gravity closed & horizontal break circuit breaker.
- On the basis of action, the circuit breaker are classified as automatic & non-automatic circuit breaker
- According to method of control, the circuit breaker may be controlled directly or it may be operated remotely.
- The Way of Mounting, classifies the circuit breakers into panel mounted, near of panel or remote from panel
- Depending on the tank construction, the circuit breakers are classified as separate tank for each pole or one tank for all poles type.
- On the basis of contacts, the different types of circuit breaker are Butt,
Wedge, Laminated flat contacts.

Types of Air–Blast Circuit Breakers:

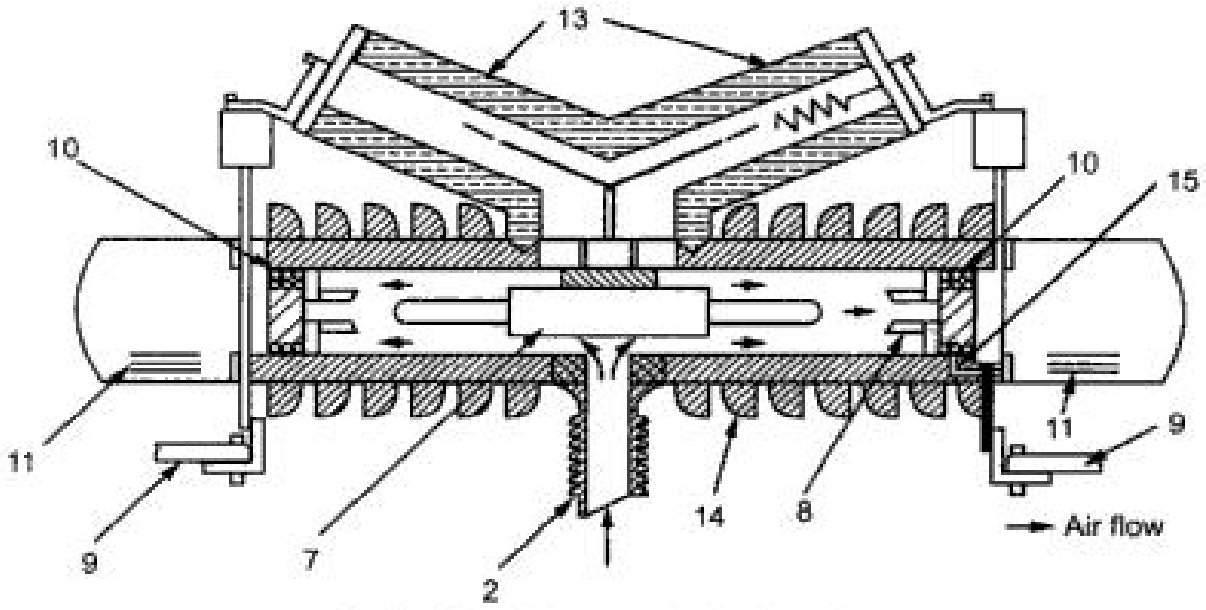


Air Blast Circuit Breaker

These type of circuit breaker were employed in earlier days for voltage ranging from 11 to 11000 KV.

At high voltage this type of circuit breaker are most suitable.

In this type of circuit breaker the compressed air is used for the arc extinction. Hence it is called compressed air circuit beaker.

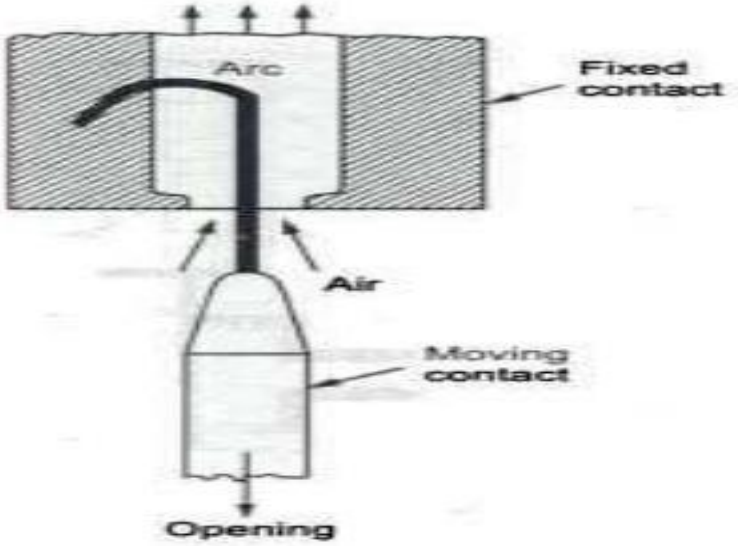


Details of double arc extinction chamber

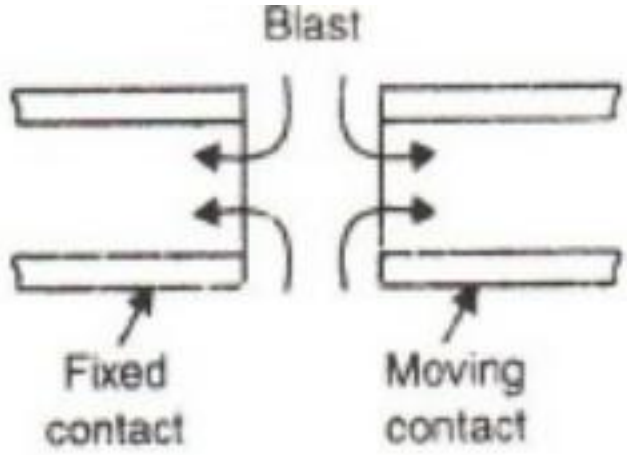
1. Tank air reservior (receiver)
2. Hollow insulator assembly
3. Double arc extinction chamber
4. Pneumatic operating mechanism
5. Operating rod
6. Pneumatic value
7. Fixed contact (in 3)
8. Moving contact (in 3)
9. Connection for current
10. Compression springs
11. Openings for air outler
12. Arcing horns Optional
13. Resistance switching unit
14. Enclosure
15. Port

Axial-Blast type

In which the air-blast is directed along the arc path .



Single Blast Type



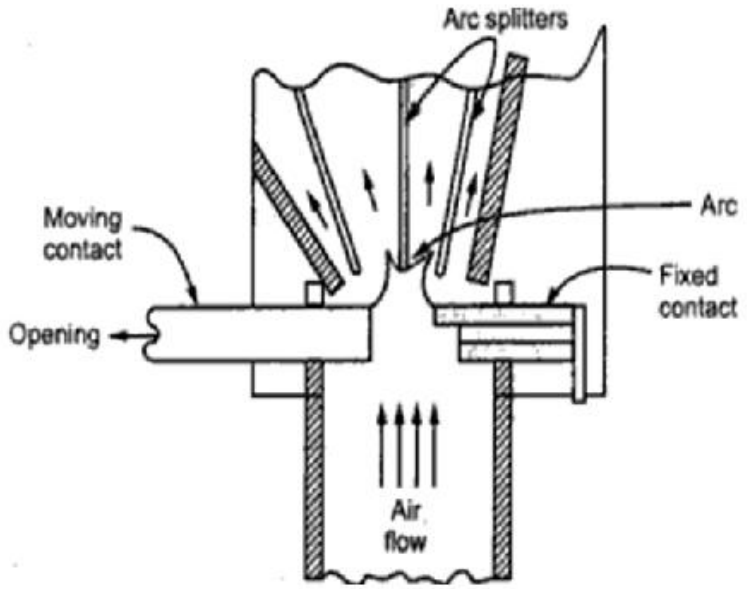
Double Blast Type

OR

Radial Blast Type

Cross-Blast type

In which the air-blast is directed at right angles to the arc path.



The cross blast breakers are commonly used in indoor circuit breaker of medium high voltage class.

Advantages:

- No fire hazard.
- High speed of operation.
- In every operation fresh air intake.
- Arcing time is less so burning of contact is less.

Disadvantages:

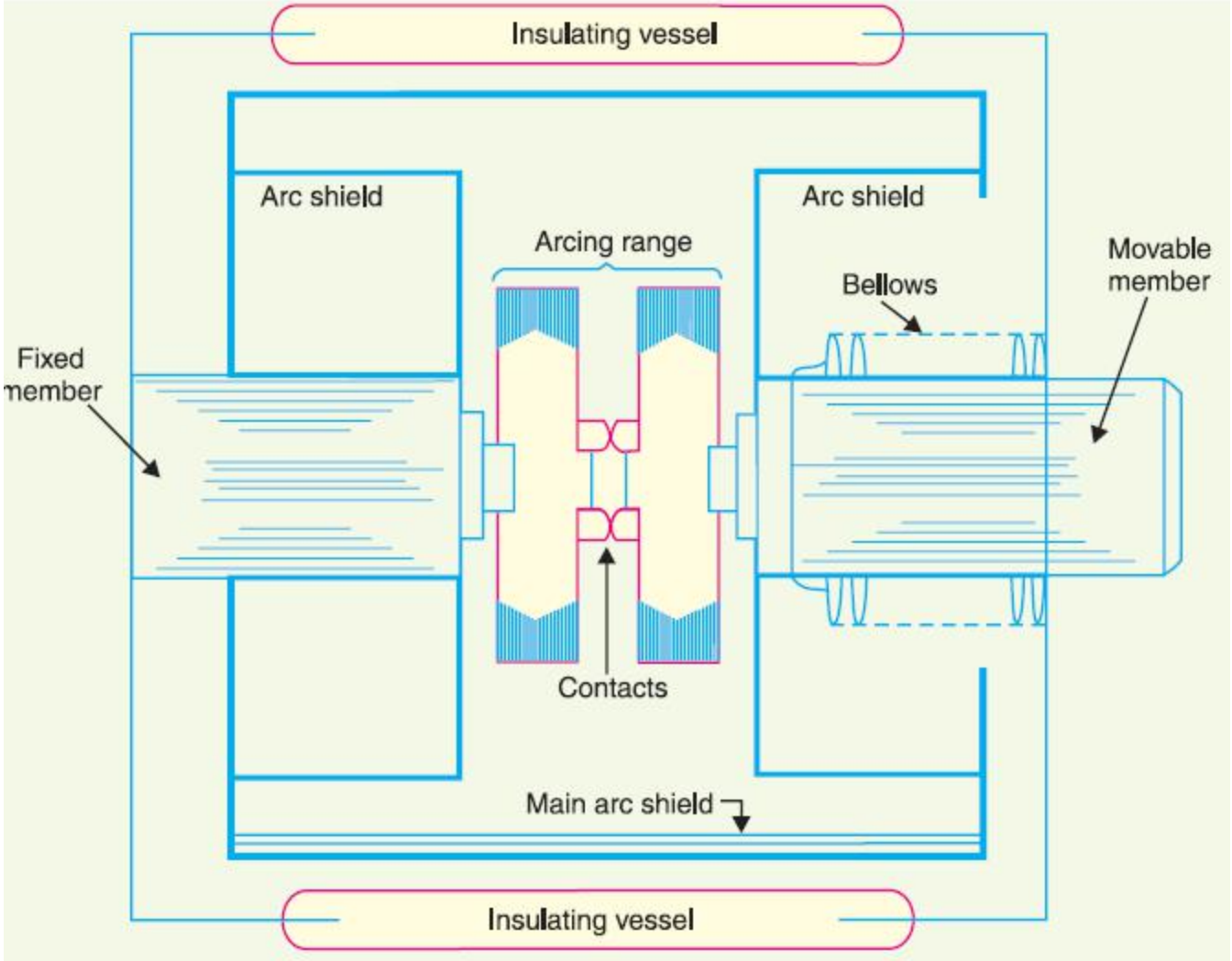
- Air compressor maintenance is high,
- Air compressor is noise making device,
- Air leakage problems are present,
- Contacts get damaged frequently,

Application:

The ABCB, their best application in system operating range of 132 KV to 400 KV with breaking capacities upto 700 MVA.

Vacuum Circuit Breakers (VCB):

In such breakers, vacuum (degree of vacuum being in the range from 10 -7 to 10-5 torr) is used as the arc quenching medium. Since vacuum offers the highest insulating strength, it has far superior arc quenching properties than any other medium.



Vacuum Circuit Breaker

Advantages.

(i) They are compact, reliable and have longer life.

(ii) There are no fire hazards.

(iii) There is no generation of gas during and after operation.

(iv) They can interrupt any fault current. The outstanding feature of a VCB is that it can break any heavy fault current perfectly just before the contacts reach the definite open position.

(v) They require little maintenance and are quiet in operation.

(vi) They can successfully withstand lightning surges.

(vii) They have low arc energy.

(viii) They have low inertia and hence require smaller power

Applications:

For a country like India, where distances are quite large and accessibility to remote areas difficult, the installation of such outdoor, maintenance free circuit breakers should prove a definite advantage. Vacuum circuit breakers are being employed for outdoor applications ranging of applications in rural areas.

Air Break Circuit Breaker

In the Air Break Circuit Breaker the atmospheric air is used as an arc extinguishing medium.

These circuit breakers employ high resistance interruption principle.

These type of circuit breaker is employed in both a.c & d.c type of circuits upto 12 KV.

These are generally indoor type & installed on vertical panels.

These type of circuit breaker are 460 V – 3.3 KV with current range 400-3500A

OR

6.6 KV with current range 400-2400 A.

There are two set of contacts:

(1) Main contacts

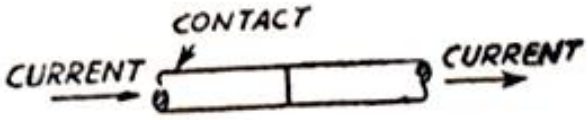
(2) Arching contacts

Under the normal operation the Main contacts are closed. They have low contact resistance and are silver plated.

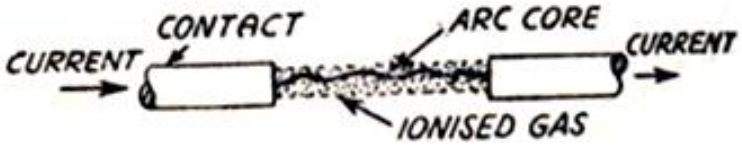
The arching contacts are hard, heat resistance and usually made of copper alloy

In below fig, the contact remain in closed position during normal condition. Whenever fault occurs ,the tripping signal makes the circuit breaker contacts to open.

While opening the contact, the main contacts separated first. The current is shifted to the arcing contacts.



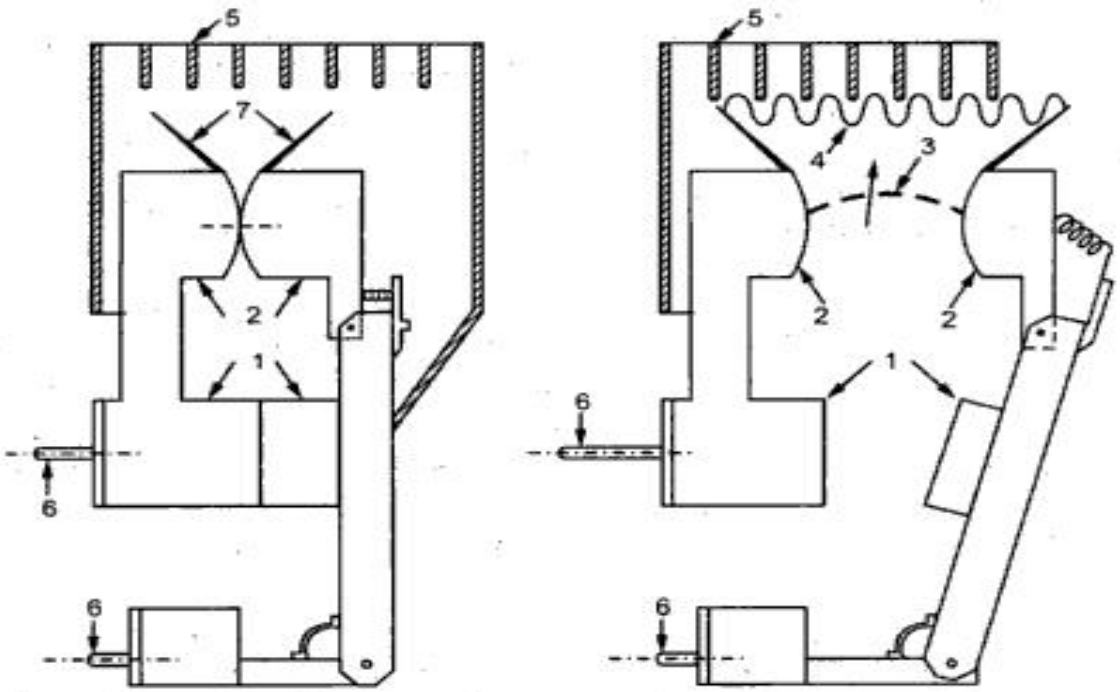
Contects in closed



The arching contacts separating and arc is drawn between them (3). This arc is forced upwards by the electromagnetic force and thermal action.

The arc ends travel along the Arc Runner (Arcing horns). The arc moves upwards and is split by arc splitter plates (5). The arc is extinguished by lengthening, cooling, splitting etc.

In some breakers the arc is drawn in the direction of the splitter by magnetic field.



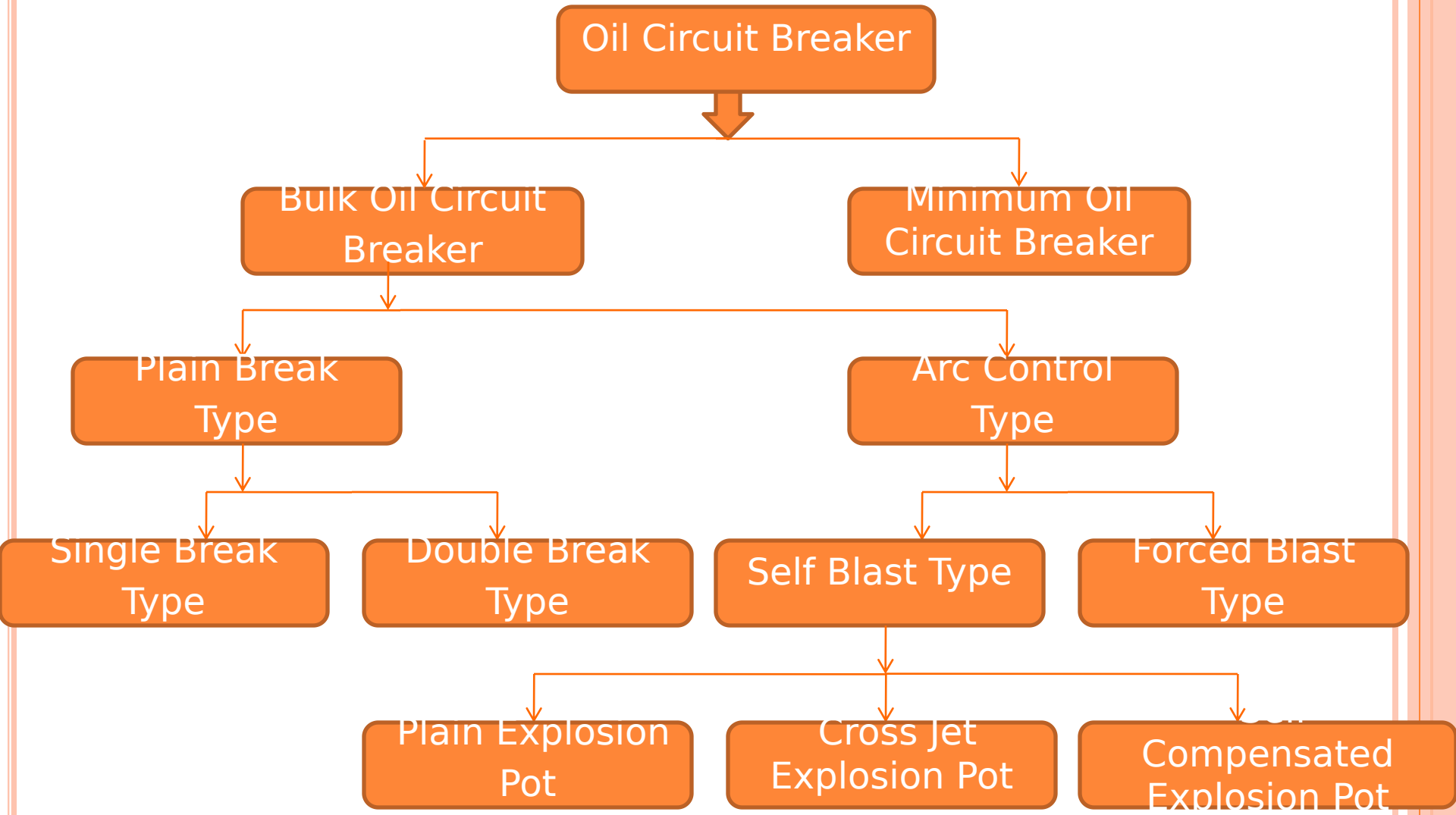
(I) Contact closed (II) Contacts open

Principle of air-break circuit-breaker

1. Main contacts
2. Arcing contacts
3. Arc rising in the direction of the arrow
4. Arc getting split
5. Arc splitter plates
6. Current carrying terminals
7. Arc runners

Applications:

This type of circuit breaker are commonly employed for industrial switchgear, auxiliary switchgear in generating station.


Oil Circuit Breaker
Bulk Oil Circuit Breaker
Minimum Oil Circuit Breaker
Plain Break Type
Arc Control Type
Single Break Type
Double Break Type
Self Blast Type
Forced Blast Type
Plain Explosion Pot
Cross Jet Explosion Pot
Compensated Explosion Pot

OIL CIRCUIT BREAKER

These are one of the oldest type of circuit breakers which employs oil as arc quenching medium.

The contacts of the circuit breakers are separated in the oil.

There are two types of circuit breaker:

(i) The Bulk Oil Circuit Breaker,

(ii) Minimum Oil Circuit Breaker.

Plain Break Oil Circuit Breaker

Bulk oil circuit breakers are enclosed in metal–grounded weatherproof tanks that are referred to as dead tanks.

There are two types of plain–break circuit breaker,

(i) Single break oil circuit breaker

(ii) Double break oil circuit breaker

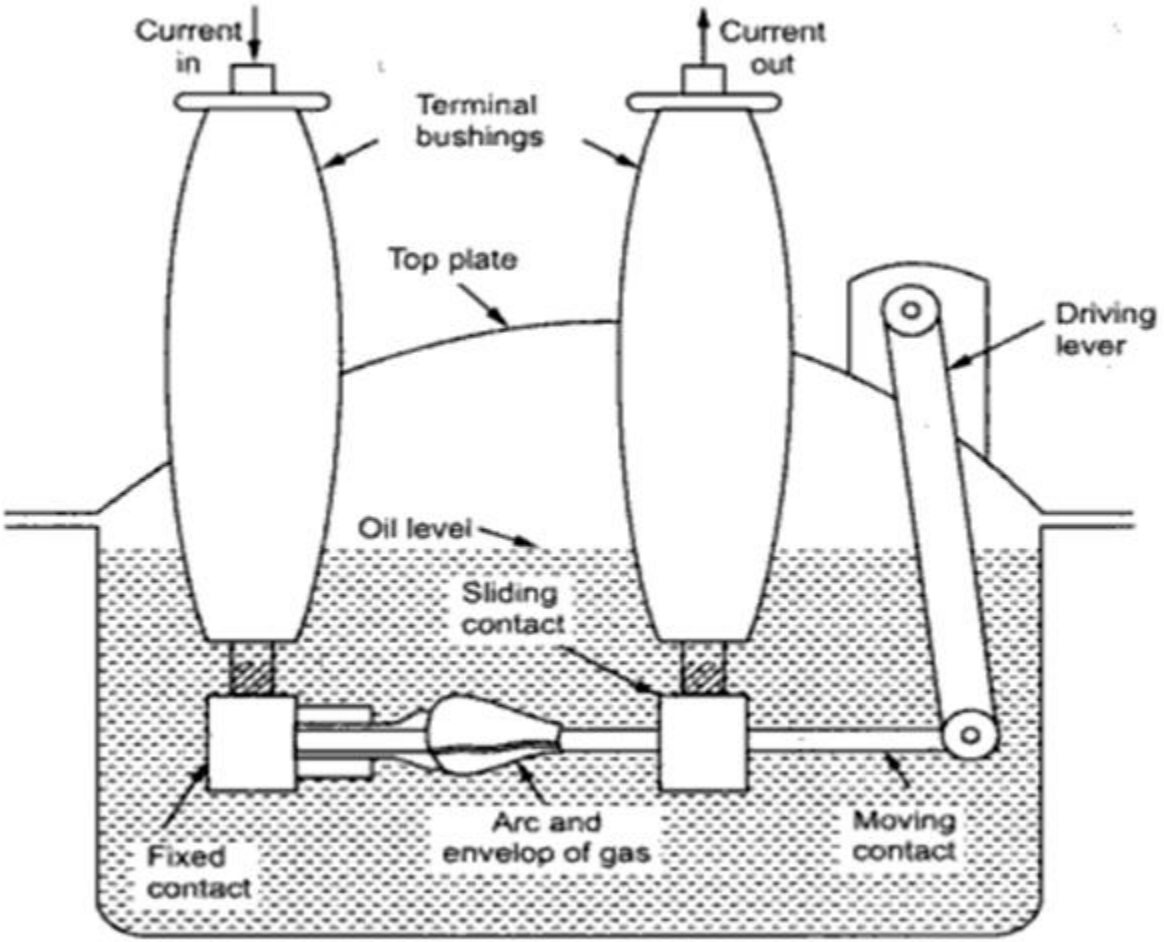
There are two types of contact in single break OCB.

(i)Fixed Contact

(i i)Moving Contact.

The IN and OUT of current is through the terminal bushings.

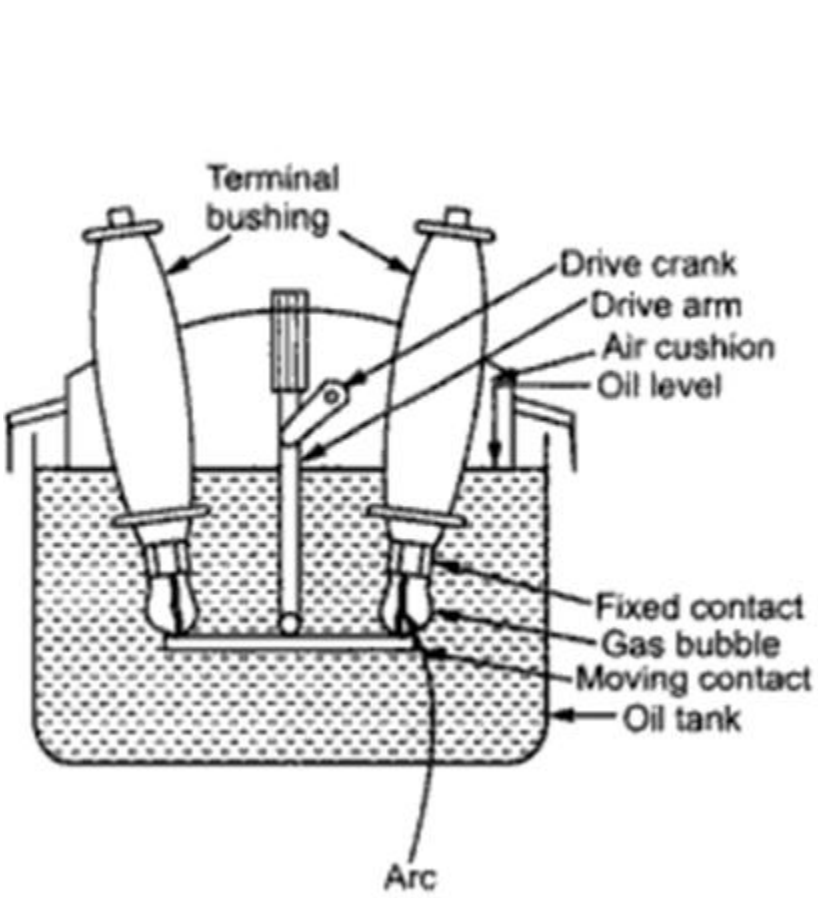
When separation of contact, there is only one arc, because of one contact pair.

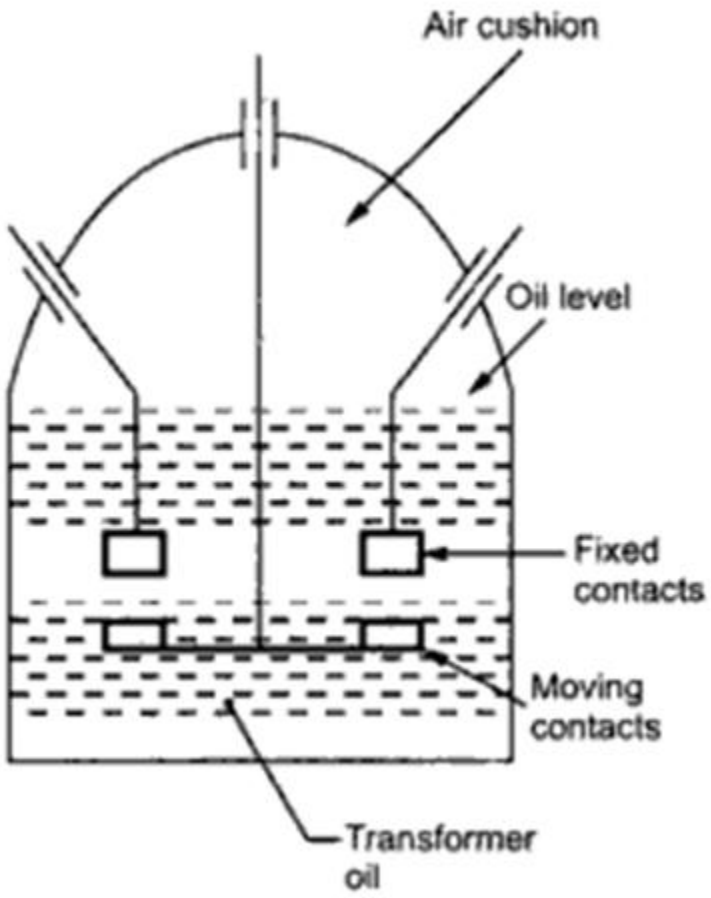


Single break OCB

This type of CB there are two bushings, IN and OUT of current is through the terminal bushings.

In this, there are two pairs of contact, when contacts are separated, two arcs are drawn.





Double Break Type Circuit Breaker

ARC CONTROLLED TYPE OIL CIRCUIT BREAKER

In case of a plain break oil circuit breaker, there is no control over the arc other than increase in length caused by the moving contact.

However, it is necessary and desirable that final arc extinction should occur while the contact gap is still short.so for this purpose,some arc control is to be provided and the breaker provided with such control are called arc control circuit breaker.

This breaker is of two types

(a) Self blast or Self Generated Pressure oil circuit breaker

(b) Forced Blast or Externally Generated Pressure Impulse oil circuit breaker

(a) Self Blast or Self Generated Pressure Oil Circuit Breaker:

This type of circuit breaker are also called Self blast oil circuit breaker, where arc is control by internal means.

The pressure developed by the arc is used in speeding up the movement of oil in the contact by pressure chamber.

The size of the pressure chamber is small.

Due to the small pressure chamber ,pressure of gas developed between the contact is very high.

Advantages:

(i)Breaking Capacity is high,
(i i)Arcing time is less,
(i i i) The pressure chamber is relatively cheap to make.

Disadvantages:

The design of the chamber or pot should be such that the pressure developed is sufficient to quench the arc even at low values of current but not so much as to break the chamber or pot on heavy current.

Due to this reason different types of circuit breakers are developed,
(i)Plain Explosion Pot
(i i)Cross Jet Explosion Pot
(i i i) Self Compensated Explosion Pot

(i) Plain Explosion Pot:

It is a rigid cylinder of insulating material enclosing the fixed & Moving contacts, closed at the top but with a restricted opening called throat at the bottom.

The moving contact is a cylindrical rod which can pass through a small opening called throat. The motion of moving contact is vertical.

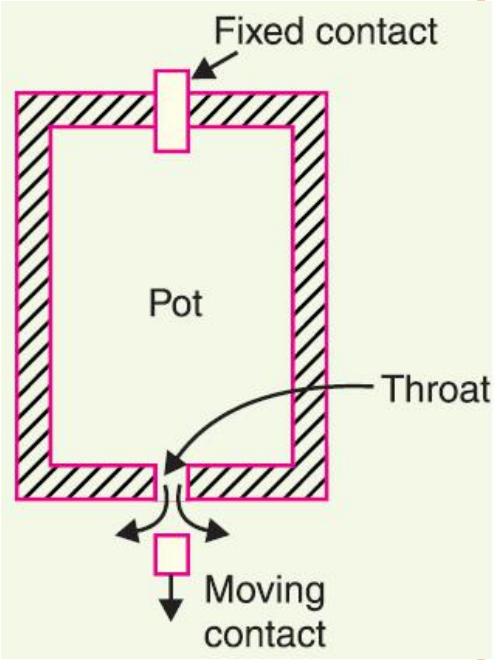
When fault occurs in the system the contacts will start separating with the formation of arc between them.

The heat contained in the arc causes the decomposition of the oil into gas at very high pressure in the pot.

This high pressure forces the oil and gas around the arc to extinguish it.

If the arc is not extinguished while the moving contact is still within the pot, it happens just after the moving contact leaves the pot due to axial high velocity blast,released through the slot.

Since the plian explosion pot performs axial extinction of the arc, it is sometimes **called the axial extinction pot.**



Plain Explosion Pot

Disadvantages:

(i) It cannot be used for very high or very low fault current.

(ii) Cross Jet Explosion Pot:

This type of pot is just a modification of plain explosion pot.

It is made up of insulating material & has channel on one side which act as a arc splitters.

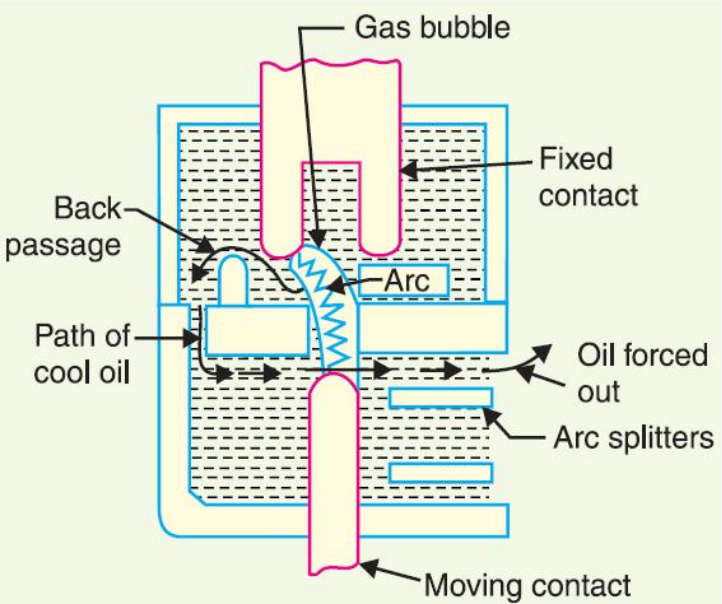
The arc splitter help in increased the arc length.thus faciliating arc extinction.

When a fault occurs, the moving contact of the circuit breaker begings to separate.

When the moving contact uncovers the arc splitter ducts, fresh oil is foced across the arc path.

The arc is therefore, driven sideway into the “arc splitter ” which increased the arc length, causing arc extinction.

Since jet of oil of is forced at right angles to the arc path, this type of pot is referred to the **“Cross Jet Explosion Pot”.**



f Compensated Explosion Pot:

This type of pot is essentially a combination of plain explosion pot and cross jet explosion pot. Therefore , it can interrupt low as well as heavy short circuit currents with reasonable accuracy.

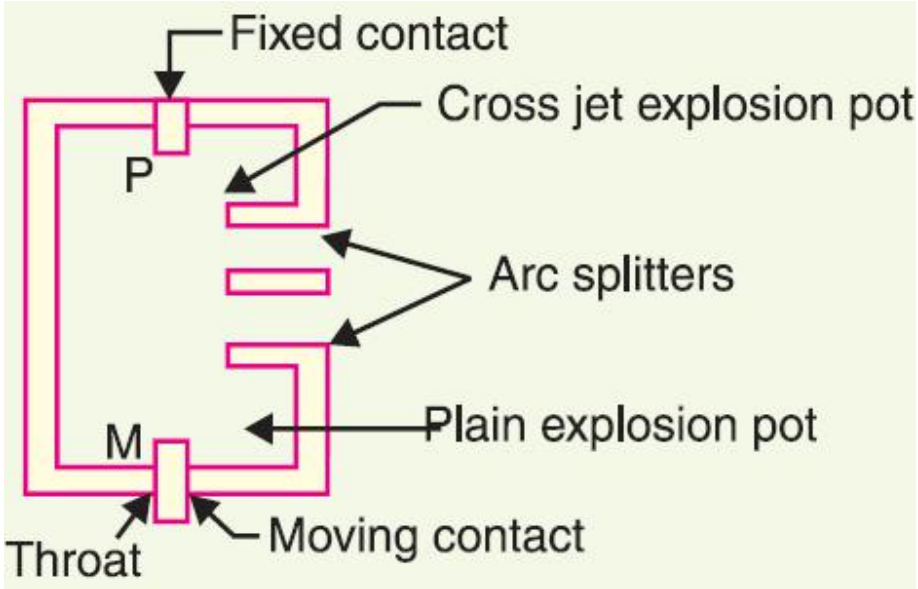
From the fig. it consists of two chambers, the upper chamber is the cross jet explosion pot with two arc splitter ducts while the lower one is the plain explosion pot.

When the short circuit current is heavy, the rate of generation of gas is very high and device behaves a cross jet explosion pot.

When the low short circuit current ,the rate of generation of gas is low & the tip of the moving contact has the time to reach the lower chamber.

During this time , the gas builds up sufficient pressure as there is very little leakage through arc splitter ducts due to the obstruction offered by the arc path & right angle bends.

When the moving contacts comes out of the throat, the arc is extinguished by plain pot action.



Advantages:

How air blast circuit breaker is better than oil circuit breaker:

1. The growth of dielectric strength is so rapid that final contact gap needed for arc extinction is very small. this reduces the size of device.
2. The risk of fire is eliminated.
3. Due to lesser arc energy, air blast circuit breakers are very suitable for conditions where frequent operation is required.
4. The arcing products are completely removed by the blast whereas the oil deteriorates with successive operations; the expense of regular oil is replacement is avoided.
5. The energy supplied for arc extinction is obtained from high pressure air and is independent of the current to be interrupted.
6. The arcing time is very small due to the rapid build up of dielectric strength between contacts. Therefore, the arc energy is only a fraction that in oil circuit breakers, thus resulting in less burning of contacts.

Disadvantages:

1. Considerable maintenance is required for the compressor plant which supplies the air blast.
2. Air blast circuit breakers are very sensitive to the variations in the rate of restriking voltage.
3. Air blast circuit breakers are finding wide applications in high voltage installations. Majority of circuit breakers for voltages beyond 110 kV are of this type

Forced blast oil circuit breaker OR Externally generated pressure type oil circuit breaker

In self blast circuit breaker discussed, the arc itself generates the necessary pressure to force the oil across the arc path.

The major limitation of such breaker is that arcing times tend to be long,it is because the gas generated is much reduced at low values of fault current.

This difficulty is overcome in forced blast oil circuit breakers in which the necessary pressure is generated by external mechanical means independent of the fault currents to be broken.

In a forced blast circuit breaker ,oil pressure is created by the piston-cylinder arrangement.

When fault occurs , the contacts get separated by the protective system & arc is struck between the contacts.

The piston forces a jet of oil towards the contact gap to extinguish the arc.

Advantages:

The performance at low current is more consistent than with self blast oil circuit breaker.

The quantity of oil required is reduced considerably.

LOW OIL CIRCUIT BREAKER

The oil has to perform two functions.

(i) It acts as an arc quenching medium,

(ii) It insulates the live parts from the earth.

It has been found that only a small percentage of oil is actually used for arc extinction while the major part is utilized for insulating purpose.

For this reason, the quantity of oil in bulk oil circuit breakers reaches very high values as the system voltage increased.

This circuit breaker is divided in three parts:

(a) Supporting Chamber

(b) Circuit Breaking Chamber

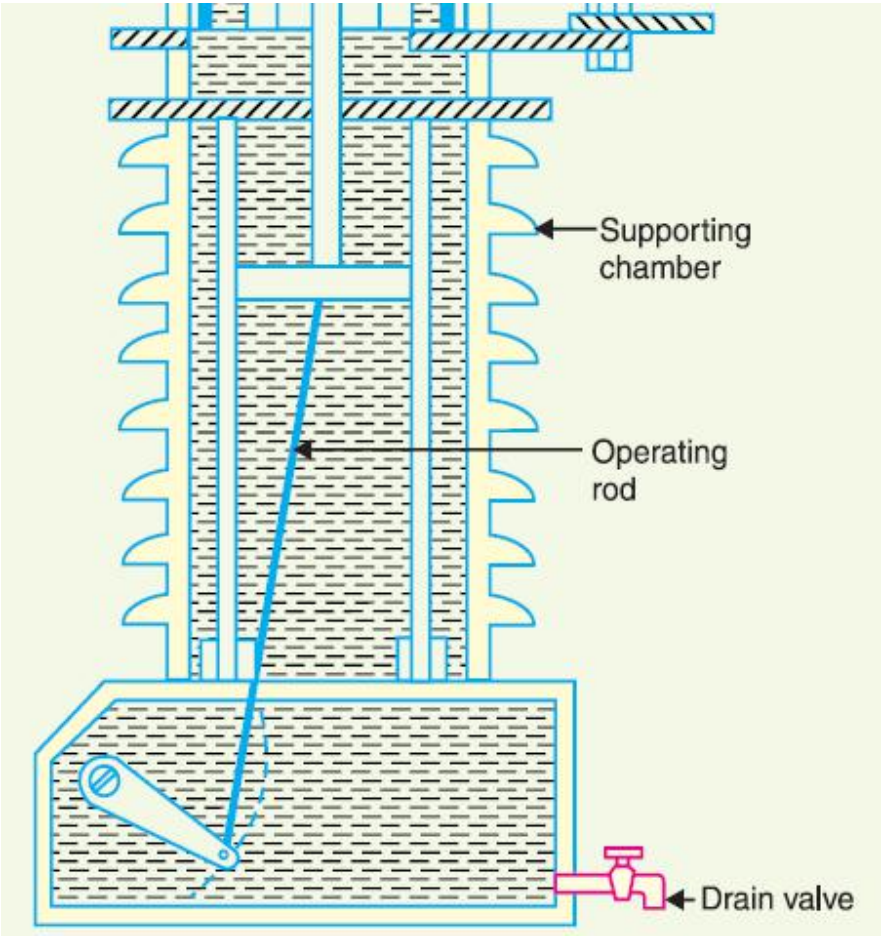
(c) Top Chamber

Supporting Chamber:

It is a porcelain chamber mounted on a metal chamber.

It is filled with oil in which is physically separated from the oil in the circuit breaker compartment.

This oil is used for insulation purpose.



Circuit Breaking Chamber:

It is made up of a porcelain chamber .

It is mounted on the top of the supporting compartment.

It is filled with oil.

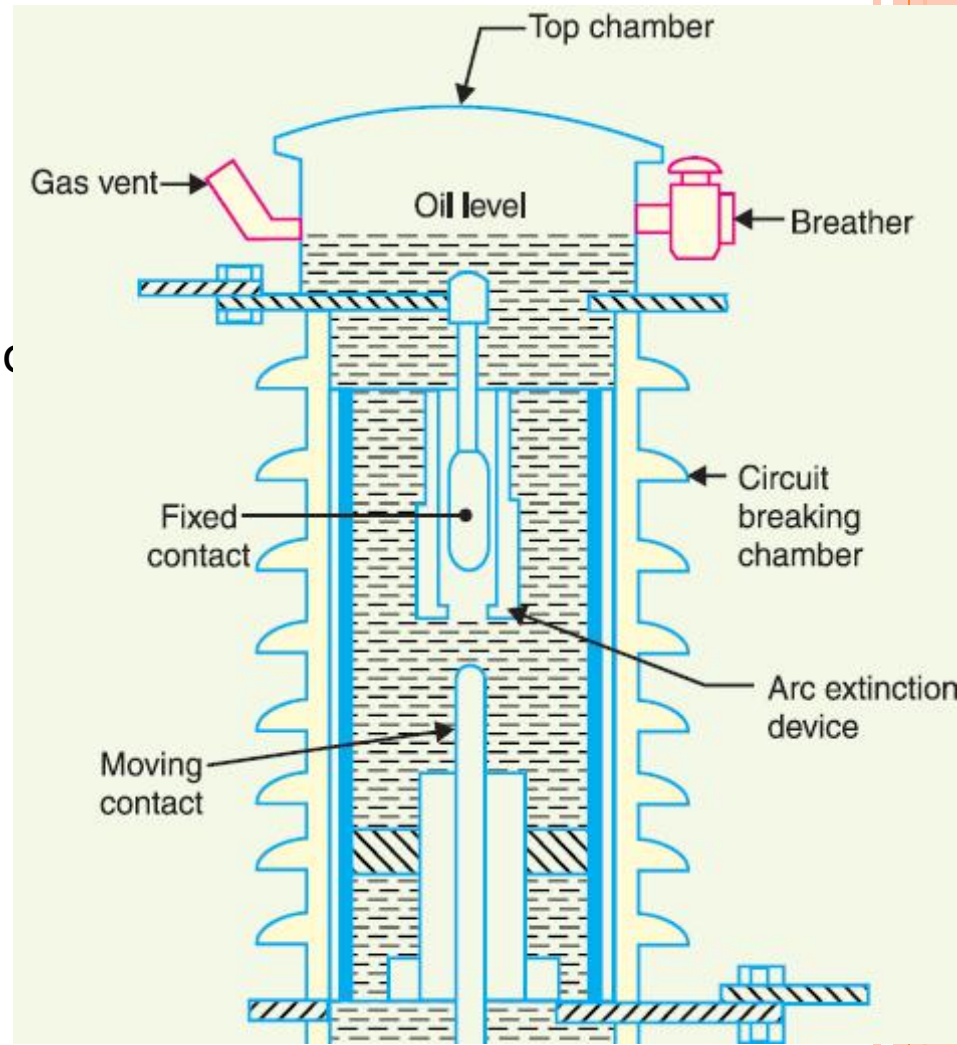
It has following parts:

(i) Fixed contacts
(ii) Moving Contacts
(iii) Turbulator

The moving contact is hollow & includes a cylinder which moves down over a fixed piston.

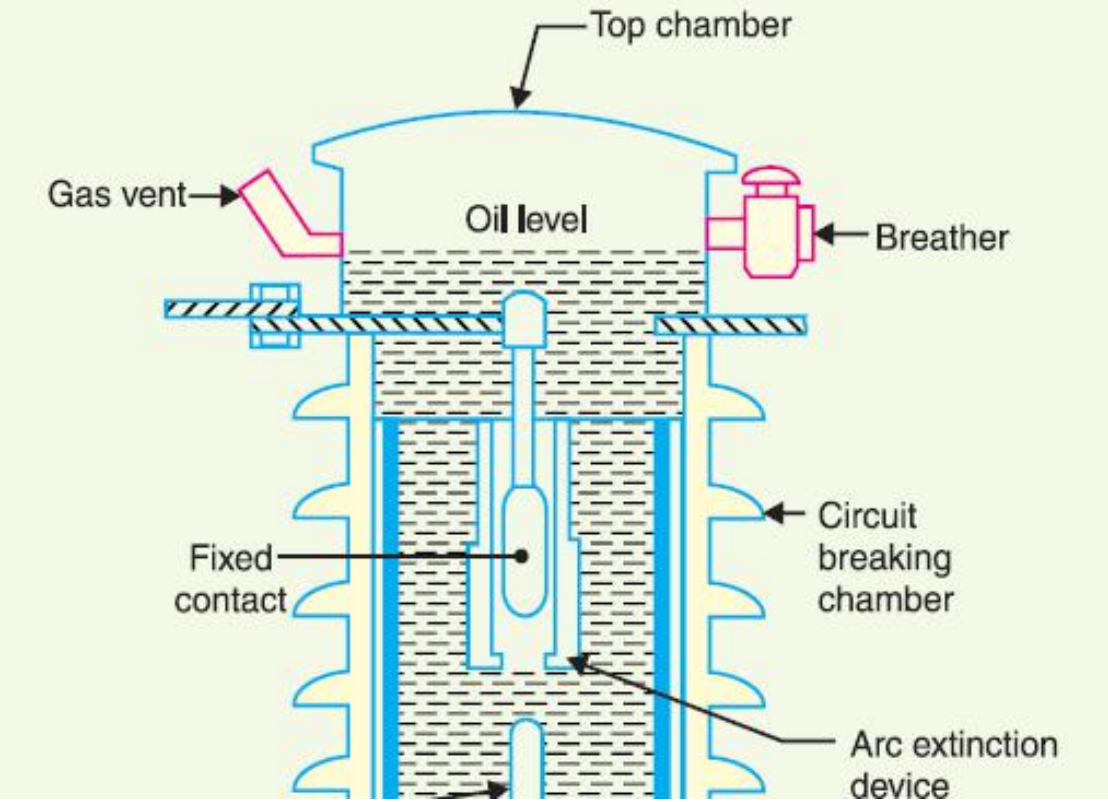
The turbulator is an arc control devic & has both axial & radial vents.

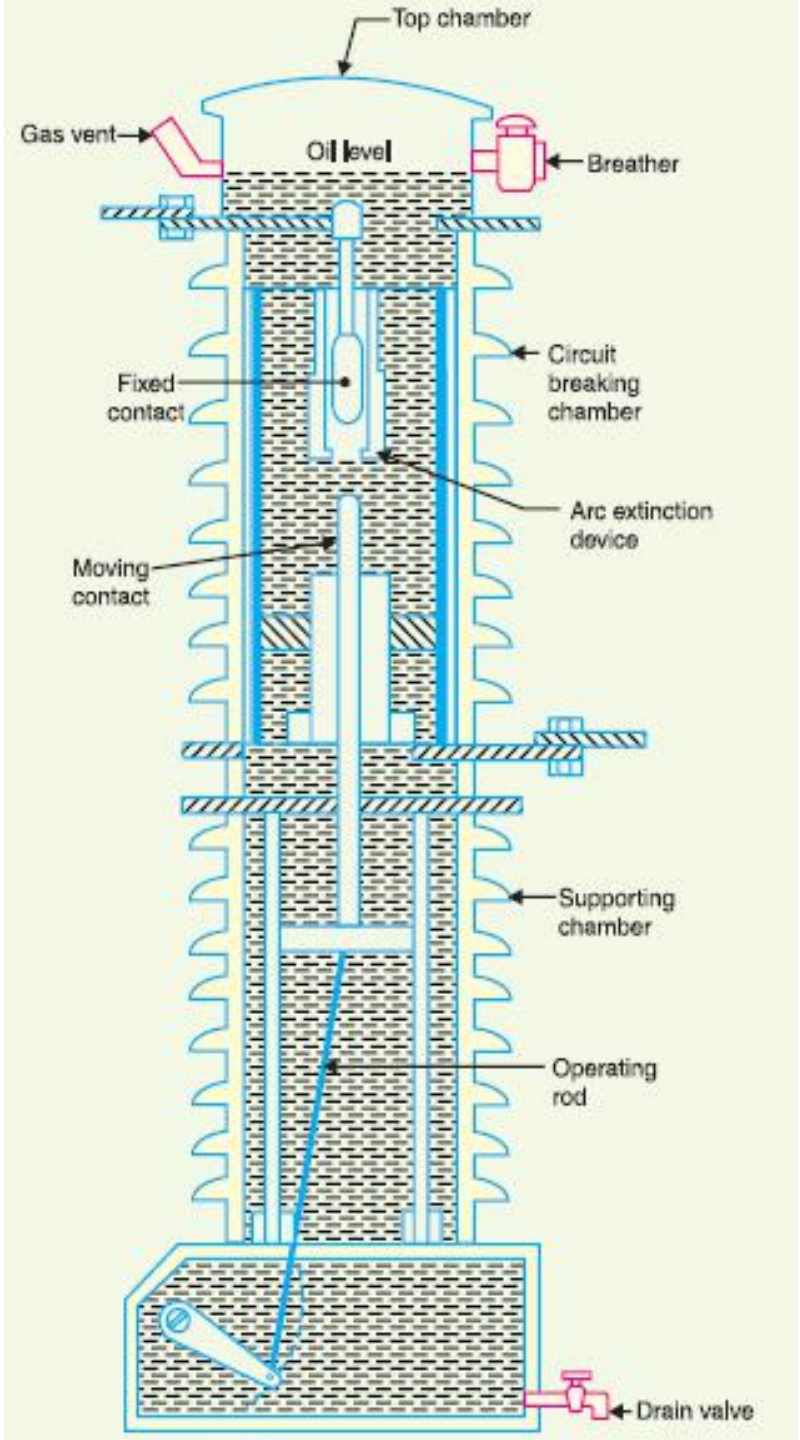
The axial venting ensures the interrupting of low current whereas radial venting helps in the interrupting of high current.



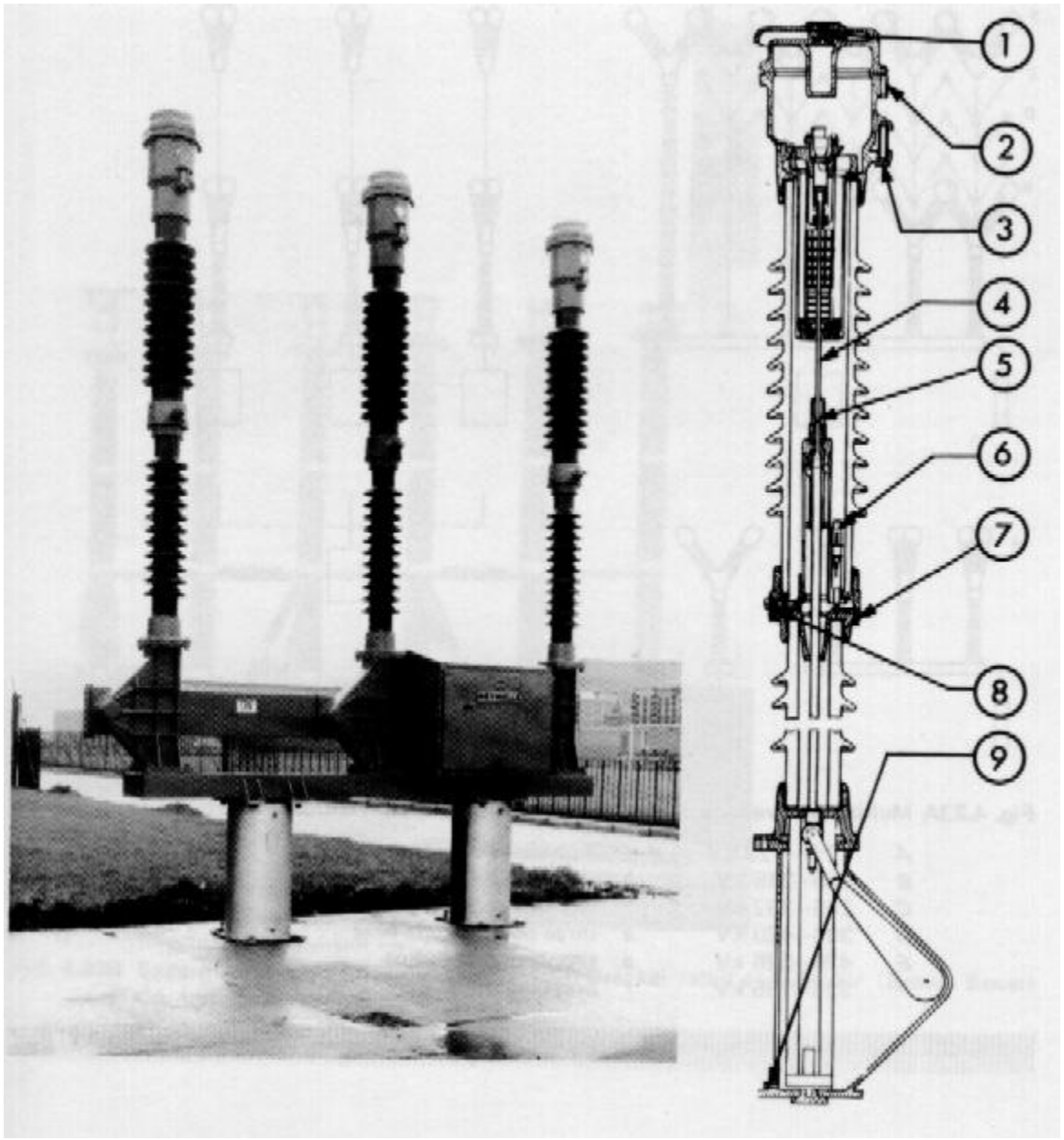
Top Chamber :

- It is a metal chamber & is mounted on the circuit breaking chamber.
- It provides expansion space for the oil in the circuit breaking compartment.
- The top chamber is also provided with a separator which prevents any loss by centrifugal action caused by a circuit breaker operation during fault conditions




Top chamber
Gas vent
Oil level
Breather
Fixed contact
Circuit breaking chamber
Arc extinction device
Moving contact
Supporting chamber
Operating rod
Drain valve

Minimum Oil Breaker



1 vent valve

2 terminal pad

3 oil level indication

4 moving contact

5 lower fixed contact

6 separating piston

7 terminal pad

8 upper drain valve

9 lower drain valve

(a) three phase circuit breaker (b) cross-section through a single phase

When a fault occurs, the moving contact is pulled down by the tripping springs & an arc is struck.

The arc energy is vaporises the oil & produces gases under high pressure.

This action constrains the oil to pass through a central hole in the moving contact & results in forcing series of oil through the respective passages of the turbulator.

A low oil circuit breaker has the following advantages and Disadvantages over a bulk oil circuit breaker.

Advantages:

It requires less quantity of oil.

It requires smaller space.

There is reduced risk of fire.

Maintenance problems are reduced.

Disadvantages:

Due to smaller quantity of oil , the degree of carbonnision is increased.

There is a difficulty of removing gasses from the contact space.

Due to high degree of carbonisation, dielectric strength of the oil is reduced.

Maintenance of Oil Circuit Breaker:

o Check the current carrying parts. If they are burnt replace them.
o Check the dielectric strength of oil.
o Check the insulation for any damage.
o The oil level should be check.
o The closing & tripping mechanism should be checked.

SULPHUR HEXAFLOURIDE(SF_6) CIRCUIT BREAKER

In such circuit breaker sulphur hexaflouride (SF_6) gas is used as the arc quenching medium.

The SF_6 is an electro – negative gas & has a strong tendency to absorb free electrons.

When arc is produced, SF_6 gas is entered in arc contact space & due to this electrons are absorbed & immobile negative ions is produced.

So dielectric strength of the medium is increased and arc is extinguish.

Properties of SF_6 Gas:

(1) **Physical properties**
(2) **Chemical properties**
(3) **Dielectric properties**

(1) Physical properties:
The gas is colourless ,non-toxic, & non harmful to health.
The gas is non-inflammable.
The gas is electronagative.
It is heavy gas having high density.

(2) Chemical properties:
The gas is chemically inert & stable upto 500ºC.
The metallic fluorides are good dielectric material.hence are safe for electrical equipment.

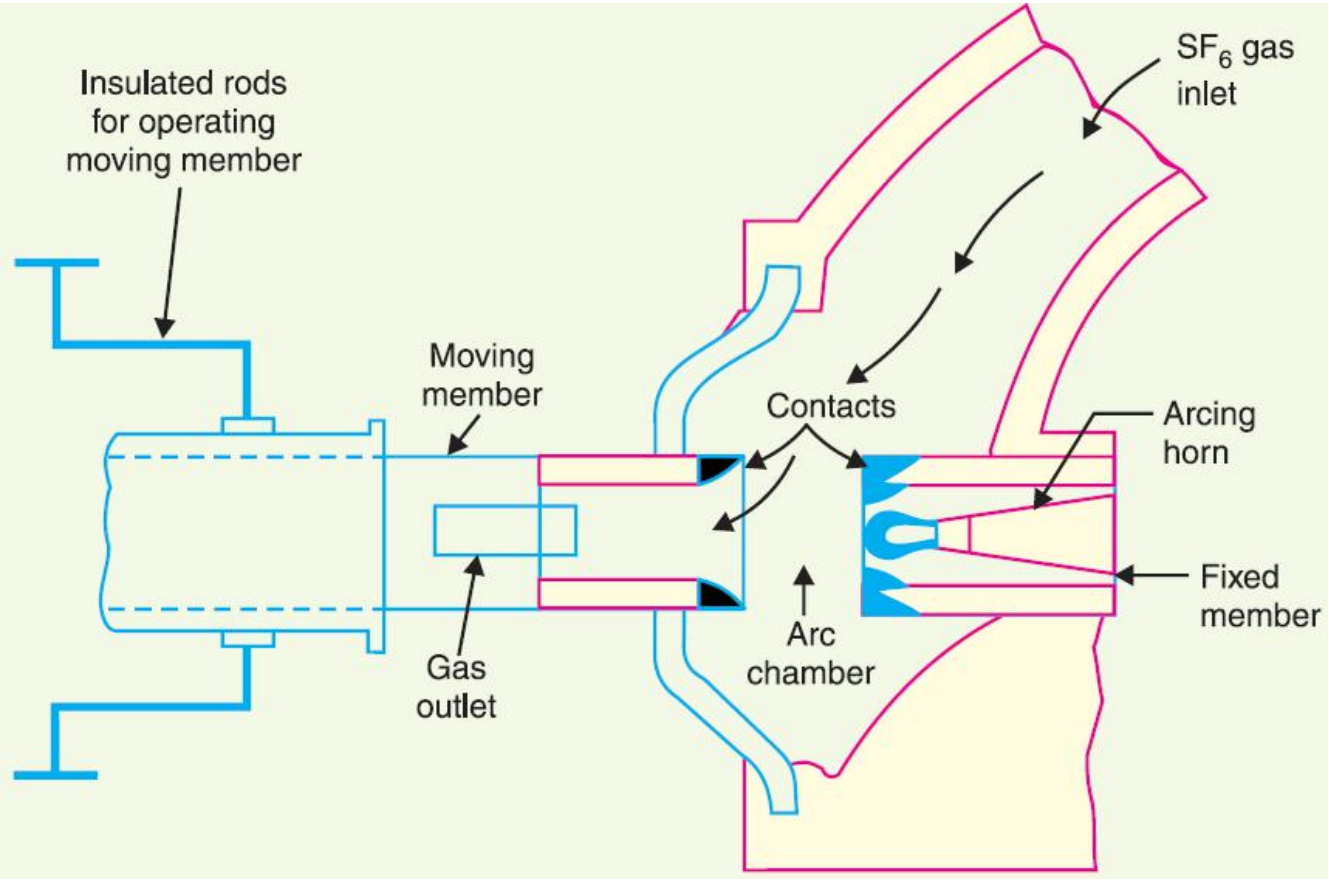
(3) Dielectric properties:
The dielectric strength of gas SF6 gas at atmospheric pressure is 2.9 times that of air & 30% less than that of dielectric oil.
At higher pressure, the dielectric strength of gas increases.

Fig shows the constructional details of SF_6 CB.

It consists of arc interruption chamber where in fixed & moving contacts are enclosed.

The chamber is filled with SF_6 gas.

The tips of fixed & moving contacts are coated tungsten arc resistance material.



Working:

During the normal working condition the contacts are in closed position which are surrounded by SF_6 gas at pressure of about 2.8 Kg/cm^2.

When the breaker operates , the moving contact is pulled apart & an arc is struck between the contacts.

The movement of the moving contact is synchronised with the opening of a valve which permits SF_6 gas at $14 Kg/cm^2$ pressure from the reservoir to the arc interruption chamber.

The high pressure flow of SF_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carries.

so the increasing the dielectric strength & causes the extinction of the arc.

After the breaker operation,the valve is closed by the action of a set of springs.

Advantages:

o The size of SF_6 breaker is smaller than conventional circuit breaker of same ratings.
o SF_6 gas is non inflammable & chemically stable.
o The breaker is silent in operation.
o Minimum maintenance required for this breaker.
o No contact replacement required.
o Ability to interrupt low & high fault currents.
o Same gas is recirculated in the circuit hence requirement of gas is small.
o Due to the superior arc quenching property of SF_6, such circuit breakers have very short arcing time.

Disadvantages:

o Sealing problem arises due to the type of construction.
o Imperfect joint lead to leakage of gas.
o The presence of moisture in the system is very dangerous.
o SF_6 breaker are costly as there is high cost of SF_6 gas.

Application:

- This type of CB is used for high power, high voltage .
- SF_6 CB are developed for voltage ranges upto 230 KV & power of 10 MVA to 20 MVA ratings.

Ratings of circuit breaker

1. Rated voltage.
2. Rated insulation level.
3. Rated frequency.
4. Rated normal current.
5. Rated short Circuit Breaking current.
6. Rated transient recovery voltage for terminal faults.
7. Rated short circuit making current.
8. Rated operating sequence.
9. Rated short time current
10. Rated supply voltage for opening & closing devices & auxiliary circuits
11. Rated peak withstand current
12. Rated pressure of compressed gas for interruption.

Rated voltage: It is a voltage of a circuit breaker which refers to higher system voltage for which it is designed.

Rated normal current: It is defined as r.m.s value of the current that can be carried by the circuit breaker continuously with temperature rise within the specified limits.

Rated frequency : The performance of circuit breaker is greatly influenced b

Rated short Circuit Breaking current: It is r.m.s value of highest short circuit current which the circuit breaker is capable of breaking under specified conditions of TRV & Power frequency voltage & expressed in kA r.m.s at constant separation.

Type	Medium	Voltage, Breaking Capacity
1 – Air break Circuit Breaker	Air at atmospheric pressure	(430 – 600) V– (5-15)MVA (3.6-12) KV – 500 MVA
2 – Miniature CB.	Air at atmospheric pressure	(430-600) V
3 – Tank Type oil CB.	Dielectric oil	(3.6 – 12) KV
4 – Minimum Oil CB.	Dielectric oil	(3.6 - 145)KV
5 – Air Blast CB.	Compressed Air (20 – 40) bar	245 KV, 35000 MVA up to 1100 KV, 50000 MVA
6 – SF_6 CB.	SF_6 Gas	12 KV, 1000 MVA 36 KV , 2000 MVA 145 KV, 7500 MVA 245 KV , 10000 MVA
7 – Vacuum CB.	Vacuum	36 KV, 750 MVA
8 – H.V.DC CB.	Vacuum , SF_6 Gas	500 KV DC

SELECTION OF CIRCUIT BREAKERS

RATED VOLTAGE	CHOICE OF CIRCUIT BREAKERS	REMARK
Below 1 KV	Air- break C B	
3.3-33KV	Vacuum CB, SF6 CB Minimum CB	Vacuum prefer red
132-220KV	SF6 CB, Air Blast CB, Minimum Oil CB	SF6 preferred
400-760KV	SF6 C B,Air Blast C B	SF6 preferred

Types of Test