5.9. MINIATURE CIRCUIT-BREAKER, MOULDED CASE CIRCUIT-BREAKERS

These are used extensively in low voltage domestic, commercial and industrial applications. They replace conventional fuses and combine the features of a good HRC fuse and a good switch. For normal operation it is used as switch. During overloads or faults, it automatically trips off. The tripping mechanism is actuated by magnetic and thermal sensing devices provided within the MCB.

Tripping mechanism and the terminal contacts are assembled in a moulded case, moulded out of thermosetting powders. They ensures high mechanical strength, high dielectric strength and virtually no ageing. The current carrying parts are made out of electrolytic copper or silver alloy depending upon the rating of the breaker. All other metal parts are of non-ferrous non-rusting type. Sufficient cross-section for the current carrying parts is provided to ensure low temperature rise even under high ambient temperature environment. The arc chute has a special construction which increases the length of the arc by the magnetic field created by the arc itself and the arc chute is so placed in the breaker that the hot gases may not come in contact with any of the important parts of the breaker.

The breaker has unit construction whereby multiple pole breakers can be made by assembly of single pole breakers.

Typical Ratings of MCB

Current Rating : 5, 10, 15, 20, 30, 40, 50, 60, Amp. also 0.5, 1, 2, 2.5, 3, 3.5, 6, 7.5, 8, 10, 12, 35, 45, 55 Amp.

Voltage Rating : 240 V/415 V AC; 50 V/110 VDC

Rupting Capacity: AC : 3 kA at 50 V (non-inductive)

1 kA at 110 V (non-inductive).

QUESTIONS

1. Describe with neat sketches the principle of medium voltage-air-break circuit-breakers.
2. Explain the arc interruption process in air-break circuit-breakers incorporating arcing horns, arc splitters, magnetic blow-out coils.
3. Describe current limiting feature of Air-break circuit-breakers.

6

Air Blast Circuit-Breaker

Introduction—Principle of ABCB—Circuit-Breaker with External Extinguishing Energy—Design Features—Multi-Unit Design—Resistance Switching—Voltage Distribution—Cross-jet Design —Technical Data—Merits—Maintenance—Compressed Air System—Generator C.B.—Summary.

6.1. INTRODUCTION

Air blast circuit-breakers were used before 1980s for 11 to 1100 kV. A compressor plant is necessary to maintain high air pressure in the air receiver.

During the period 1950-1970, Air-blast circuit-breakers were preferred for 220 kV and above. However today, SF_6 circuit-breakers are preferred for this range. For 11 kV and 33 kV applications. VCBs are preferred Air-blast Circuit Breakers have become obsolete. (1995)

6.2. 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. In some low capacity circuit-breakers the isolator is an integral part of the circuit-breaker. The circuit-breaker opens and immediately after that the isolator opens, to provide additional gap.

In EHV switch-yards of today, isolators are generally independently mounted.

Fig. 6.1 shows one pole of the EHV air blast circuit-breaker. In the complete assembly there are three identical poles.

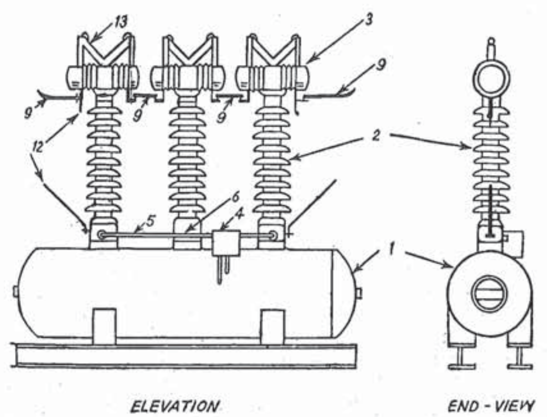


Fig. 6.1. (*a*) One pole of an extra-high voltage air blast circuit-breaker.

Description. High pressure air, at a pressure between 20 to 30 atm is stored in the Air reservoir (Item 1 in Fig. 6.1). Air is taken from compressed air system.

Three hollow insulator columns (Item 2) are mounted on the reservoir with valves (6) at their base. 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. Since three exists a very high voltage between the conductors and the air reservoir, the entire arc extinction chamber assembly is mounted on insulators.

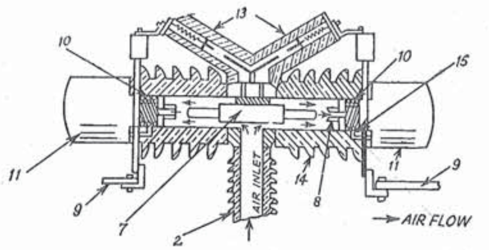


Fig. 6.1. (*b*) Details of (3) Double arc extinction chamber.

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 outlet	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 extinction chamber	3	(Assembly)
2. Hollow insulator assembly	3	Steatite
1. Tank air reservoir (receiver)	1	Boiler plate steel

The details of the double arc extiction chambers (3) arc shown in Fig. 6.1 (*b*). Since there are three double arc extinction poles in series, there are six breaks per pole. Each arc extinction chamber [Fig. 6.1. (*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.

The operating mechanism (3) operates the rod (5) when it gets a pneumatic or electrical signal. The valves (6) open so as to send the high pressure air in the hollow of the insulator. The high pressure air rapidly enters the double arc extinction chamber [*Air inlet* in Fig. 6.1(*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 (6) is turned so as to close connection between the hollow of the insulator and the reservoir. 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.

Air blast circuit-breakers were preferred for Arc Furnace Duty and traction system, because they were suitable for repeated duty. Now vacuum circuit-breakers are preferred for these duties upto rated voltage of 33 kV.

In multi-unit breaker grading capacitors are connected across the interrupter unit for the equal distribution of voltage between the units. Closing resistors are connected across the interrupter units for limiting the over voltages during closing operation. Opening resistors are connected across the interrupter units to make the circuit-breakers restrike free. Now, single pressure puffer type SF_6 CB is preferred for 132 kV, 220 kV, 400 kV, 765 kV applications.

6.3. PRINCIPLE OF ARC QUENCHING IN ABCBs

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 ionized gases along with it and assists arc extinction. Within one or two cycles the arc is extinguished by the air blast and the arc extinction chamber is filled with 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 [Fig. 6.2. (*a*), (*b*), Sec.7.5)]

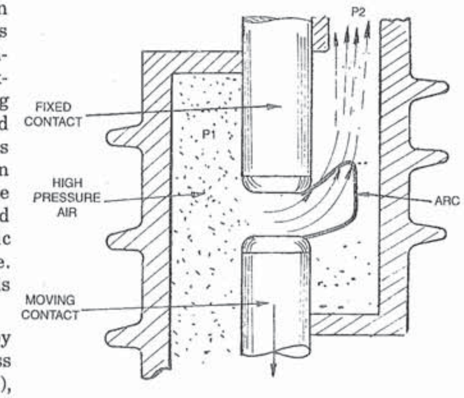


Fig. 6.2 Flow of air in Air-blast C.B.

In the axial blast type air flow Fig. 6.2 (*a*) the flow air is longitudinal along the arc. (Refer Sec. 4.11 and 7.5).

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, exit area of nozzle, and is influenced by the diameter of the arc itself.

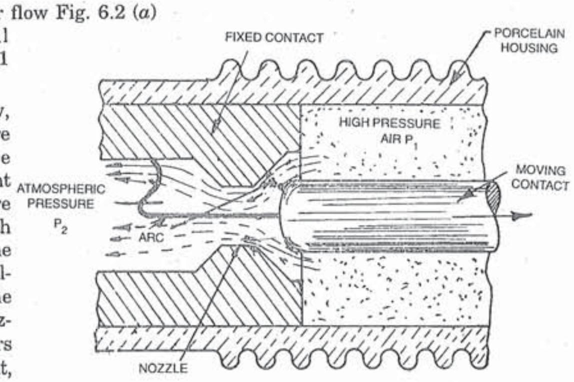


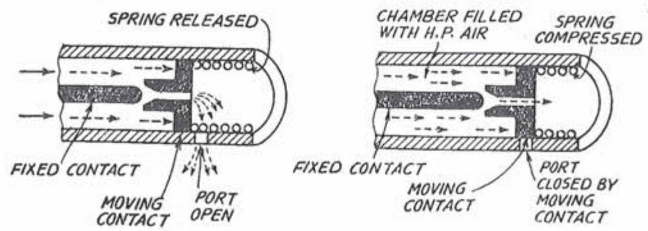
Fig. 6.2 (*a*) Axial Flow.

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.

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 with standing the transient recovery voltage.

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. 6.3).



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.

Fig. 6.3. (*a*) Sequence of operation in ABCB.

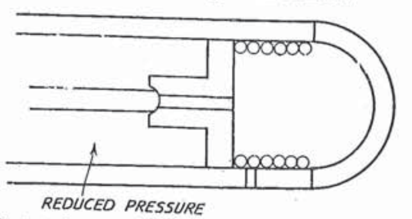


Fig. 6.3. (*b*) Contact close by spring pressure against reduced air pressure.

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.

6.4. CIRCUIT-BREAKERS WITH EXTERNAL EXTINGUISHING ENERGY

If the pressure generated in the arc extinction chamber is derived from arc current *e.g.*, by decomposition of oil in oil circuit breaker, the circuit-breaker is said to be of internal energy source. If the pressure is independent of arc current the circuit-breaker is said to be of external energy source. The behaviour of these two types are inherently different.

In the air blast circuit-breakers that air pressure used for the arc interruption is constant and does not depend on the arc current. The air pressure is of such magnitude that it can break rated breaking current (say 40 kA) satisfactory at natural zero. High pressure ($60 kg/cm^2$) are used for breakers above 400 kV.

The arcing time does not change appreciably for lower magnitudes of currents as the air pressure is independent of arc current. Now consider that the breaker has to interrupted small currents

(say 10 A). For the current the air pressure used for the arc interruption is too high, the current gets chopped out before reaching natural zero. This current chopping gives rise to high restriking voltage. The resistance of contact space being high, the contact space being high the contact space is not likely to break down. However resistance switching should be employed.

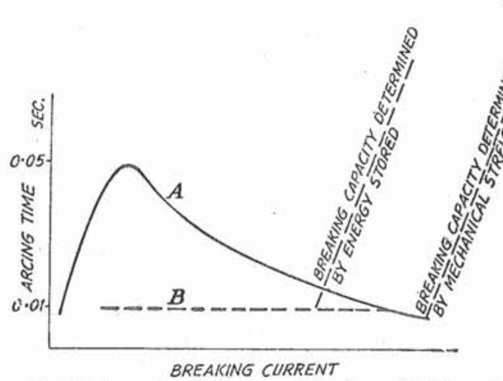


Fig. 6.4. Comparison between circuit-breakers with *A* internal source of extinguishing energy and *B* external source of extinguishing energy.

The arcing time of ABCB is almost independent of arc-current [Fig. 6.4]. Whereas in oil current breakers the arcing time is more for lower currents [Fig. 6.3 (*a*)] and the restriking voltages are damped out by contact space of law dielectric strength.

In the circuit-breakers with external energy source the breaking capacity of the unit is determined by the pressure of extinguishing medium. In circuit-breakers with internal energy source the capacity limit is determined by the design features.

6.5. 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.

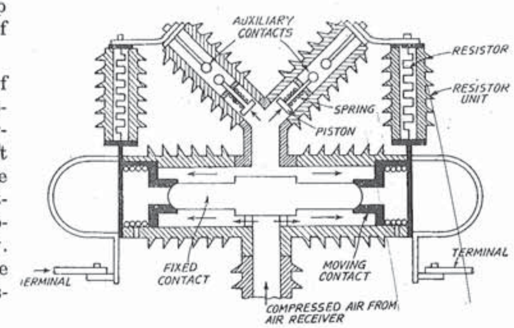


Fig. 6.5. Configuration of switching resistors.

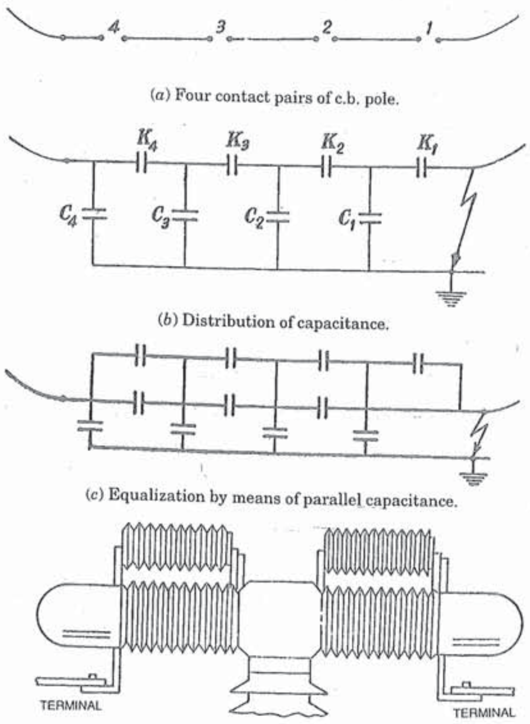
Fig. 6.5 shows another popular arrangement used for a double arc extinguishing chamber explained in section 2.6. During the opening operation, air is admitted in the arc extinguishing chamber. It separates main contacts and pushes the auxiliary contacts. The auxiliary contacts close, thereby the resistors 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 non-linear characteristics, similar to those used in the lightning arresters were used for resistance switching.

These consist of 'Silicone-carbide, bound by inorganic binders subjected to head treatment. During high current, non-linear resistor offers low resistance. Thus the main arc currents 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.

6.6. VOLTAGE DISTRIBUTION IN MULTI-BREAK CIRCUIT-BREAKERS (ABCB-MOCB, SF_6)

The voltage distribution should be even, between the gaps in series. If not, the breaking capacity shared by the different gaps will be unequal. The unequality of voltages and breaking capacity occurs mainly at the instant of recovery voltage, when the potential across the contact spaces is determined by capacitance between contact members and between contact and earth.

These potentials may vary according to the kind of short-circuit but will be least even when the fault involves earth (*e.g.*, L-G fault). In Fig 6.6 (*a*), 4 contact pairs 1 to 4 have been shown. Fault occurs near to the contact 1. The capacitances between the contacts are K_1, K_2, K_3, K_4 respectively and capacitances between contacts and earth are C_1, C_2, C_3, C_4 respectively. Because of the unsymmetry, the capacitances do not get equally charged and the recovery voltage is least over C_1 and



(*a*) Four contact pairs of c.b. pole.

(*b*) Distribution of capacitance.

(*c*) Equalization by means of parallel capacitance.

(*d*) External appearance

Fig. 6.6 Capacitors for voltage grading in multi-break breaker.

To equalize these voltages capacitances are connected across contact space as shown in Fig. 6.6 (*a*) by *C, C, C, C*. The shunt capacitor *C* is much larger than the natural capacitance in order to nullify the effect of the unequal capacitance of contact spaces. These capacitors are rigidly connected across the breaker arc extinction chamber as shown in Fig. 6.6 (*d*). The value of grading capacitors varies between 1200 pico-farads and 1650 pf depending upon number of breaks per pole and capacitance per break.

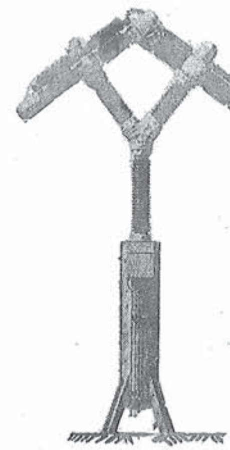


Fig. 6.7. One pole of an EHV Air Blast Circuit Breaker with four interrupters per pole. *Courtesy : Brown Boveri.*

6.7. REDUCING SWITCHING OVER-VOLTAGES BY PRE-CLOSING RESISTOR (Ref. Sec. 18.8)

The design of lines rated 420 kV and above is influenced by switching overvoltages. The switching overvoltages can be minimised by improving the design of circuit breakers. The features desirable for EHV and UHV circuit breakers are the following:

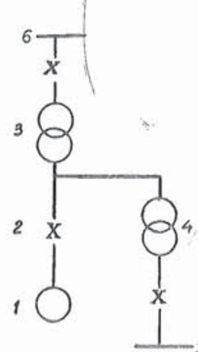
1. Pre-insertion of closing resistors in parallel with main contacts. This is either single stage or multi-stage.

2. Simultaneous closing three poles.

3. Simultaneous closing lines at both ends. The closing of line is first initiated through pre-closing resistors. Shortly after this, the pre-closing resistors are shunted out. The optimum value of pre-closing resistors for airblast circuit breakers is about 0.5 to 2 times the voltage of surge impedance of the line. Better damping effect is achieved by multi-stage pre-closing. As per recent ICC specifications, overvoltage factors less than 1.7 have been recommended for system above 550 kV. Such condition can be achieved by employing two-stage closing. In first stage a high resistance comes into circuit, in the second stage low resistance comes into circuit.

6.8. GENERATOR CIRCUIT BREAKERS

Development of Generator Breakers has brought about a significant change in the layout of generator connections. Generator circuit breakers are indoor, metal-enclosed air-blast circuit breakers suitable for connection between generator and its main transformer. (The typical 22 kV, 3500 MVA). Ref. Sec. 17.61. After 1985, SF_6 C.B.s have been developed and used for Generator Circuit-breakers.



1. High capacity generator
2. Generator circuit breaker
3. Main Transformer
4. Unit-Auxiliary Transformer
5. Auxiliary-bus
6. EHV bus

Fig. 6.8 Use of Generator Circuit Breaker.

6.9. COMPRESSED AIR SYSTEM FOR ABCB

The EHV-ABCB's are outdoor equipment. The air pressure in the receivers of the circuit breaker is of the order of 20–30 kgf/cm^2. The local receivers are of such a size that the air pressure is maintained for some 4 to 12 repeated operations. When the pressure in the receiver of the breaker reduces below a certain value [say 20 kg/cm^2] the pneumatic valves automatically open and air is let into the receivers from compressed air system of a higher pressure [30 kgf/cm^2 to 40 kgf/cm^2], and the pressure in the air receiver is maintained a desired value.

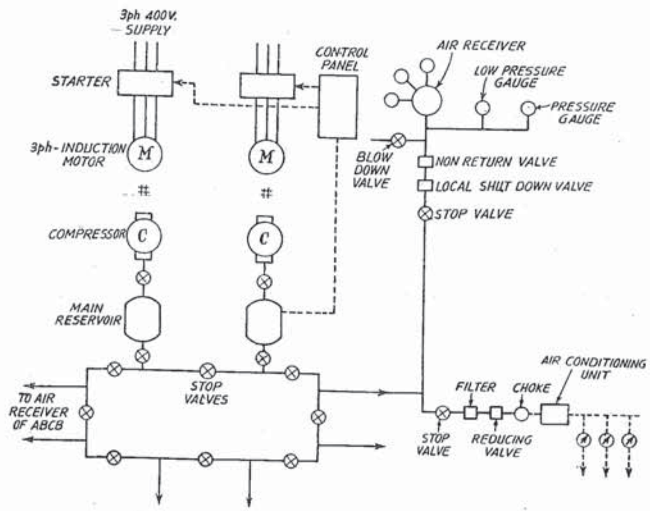


Fig. 6.9 Schematic diagram of compressed air system.

7

Sulphur Hexafluoride (SF_6) Circuit-Breaker and SF_6 Insulated Metalclad Switchgear (GIS)

Part I—Properties of SF_6 Gas—Physical properties—Chemical properties—Dielectric properties—Arc extinguishing properties of SF_6 gas.
Part II—Outdoor High Voltage SF_6 Circuit-Breakers—Type of designs—Single pressure puffer type SF_6 Circuit-breakers—Double pressure dead tank type SF_6 Circuit-breaker—Merits of SF_6 Circuit-breakers—Some demerits—SF_6 filled load-break switches—Auxiliaries and accessories.
Part III—SF_6 Insulated Metalclad Switchgear—Introduction—Advantage—Demerits—design aspects—Busbars—Isolators—Earthing switch—Circuit-breakers Components—Gas systems—Typical Ratings—Summary.

7.1. INTRODUCTION

Sulphur hexafluoride (SF_6) is an inert, heavy gas having good dielectric and arc extinguishing properties. The dielectric strength of the gas increases with pressure and is more than that of dielectric of oil a pressure of 3 kgf/cm^2. SF_6 is now being very widely used in electrical equipment like high voltage metal enclosed cables; high voltage metalclad switchgear, bushings, circuit-breakers, current transformers, etc. This gas liquefies at certain low temperatures, the liquefaction temperature increases with pressure. This gas is commercially manufactured in many countries and is now being extensively used by electrical industry in Europe, U.S.A. and Japan.

Several types of SF_6 circuit-breakers have been developed by various manufactures in the world during last fifteen years, for rated voltages from 3.6 to 760 kV.

SF_6 gas insulated-metalclad switchgear comprises factory assembled metal clad, sub-station equipment like circuit-breaker, isolators earthing switches bus-bars etc. These are filled with SF_6 gas. Such sub-stations are compact and are being favoured in densely populated urban areas.

Sulphur hexafluoride gas is prepared by burning coarsely crushed roll sulphur in fluorine gas, in a steel box, provided with staggered horizontal shelves, each bearing about 4 kg of sulphur. The steel box is made gas-tight. The gas thus obtained contains other fluorides such as S_2F_{10}, SF_4 and must be purified further SF_6 gas is generally supplied by chemical firms. The cost of gas is low if manufactured on a large scale.

The gas is transported in liquid form in cylinders. Before filling the gas, the circuit-breaker is evacuated to the pressure of about 4 mm of mercury so as to remove the moisture and air. The gas is then filled in the circuit-breaker. The gas can be reclaimed by the gas-handling unit.

Part I—Properties of SF_6 gas

7.2. PHYSICAL PROPERTIES OF SF_6 GAS

— Colourless.
— Odourless.
— Nontoxic, Pure SF_6 gas is not harmful to health.