Changes for the Better

MITSUBISHI ELECTRIC

SF_6-GAS CIRCUIT BREAKERS FOR USE IN METALCLAD SWITCHGEAR

Type

SFG

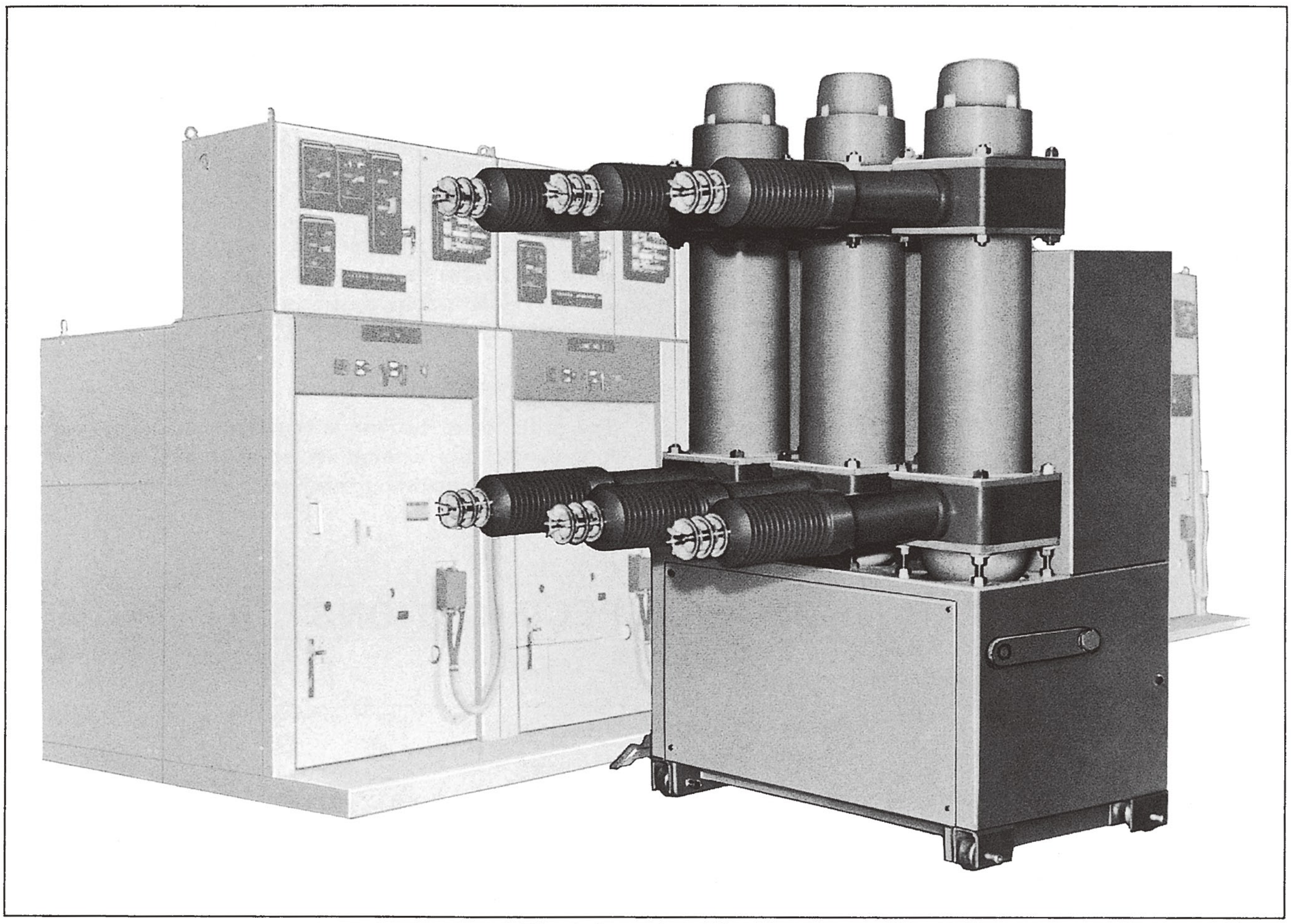


Fig. 1 Type 30-SFG-25A

Sulphur hexafluoride gas (SF_6) is advantageous for power circuit breakers because of its excellent arc-quenching properties and high electrical insulating characteristics. At voltages above 72kV, SF_6-gas circuit breakers are well established, more than 15 years, and have commanded a significant proportion of sales in markets around the world.

SF_6 switchgear up to 500kV, using puffer-type (single-pressure) circuit breakers, is manufactured at one end of the range, and switchgear in the medium voltage (up to 36kV) range is available at the other.

Mitsubishi Electric's Type SFG, SF_6-gas circuit breakers for 3.6~36kV were accordingly developed based on the wealth of experience obtained with EHV breakers. These breakers guarantee the high level of performance required for the reliable operation of rapidly growing electric power transmission and distribution systems.

The interrupting capacity is rated at 25~63kA and not only abnormal short-circuit condition but also cable charging current and no-load transformer exciting current can be successfully cleared. Type SFG breakers are withdrawable and front-operated for convenient use in metalclad cubicles. Breakers are operated by a rapid-action stored-energy (spring) mechanism and the three arcing chamber columns are of the grounded tank type for a high degree of safety and space saving.

Main ratings are:

Rated voltage	3.6/7.2/12/24/36kV
Rated breaking current	25~63kA
Rated continuous current	630~4000A
Rated frequency	50/60Hz

FEATURES

1. Superior Interrupting Capabilities

Owing to the excellent current-interrupting ability of SF_6 gas, these breakers can successfully interrupt such abnormal short circuits as out-of-phase conditions and two-phase simultaneous ground faults on both sides of the breaker, as well as normal fault conditions.

2. Low Overvoltages in Small Current Interruption

The peculiar properties of SF_6 gas for a small current arc keep overvoltage to a minimum.

In interrupting a magnetizing current, less than twice the applied voltage is observed, and in charging-current interruption neither restrike nor reignition occurs even when line-to-line voltage is applied for non-grounded systems.

Thus insulation coordination with the breakers can be easily realized, and no surge absorber is necessary in any practical circuit or system configuration.

3. High Availability

Since the breakers are provided with a pressure gauge and pressure switch, the pressure of the SF_6 gas can be checked at any time.

4. Simple Structure and Compact Size

The structure is extraordinarily simple, resulting both in highly reliable performance and minimal inspection and reassembly.

Compact construction and small dimensions result in switchgear of space-saving design. For instance, a 36kV switchgear unit is only two square meters (1.2 x 1.65m) in area.

5. High Level of Safety

SF_6 gas is physically nontoxic and noncombustible, there is absolutely no insulating oil present, and the arcing chamber column is of the grounded tank type. Therefore there is no danger to personnel and no fire hazard.

6. Easy Operation

Breakers are withdrawable and interchangeable, for faster, easier replacement and maintenance. The circuit breakers are fully interlocked to ensure that faulty switching is impossible during insertion or withdrawal.

7. Low Maintenance Costs

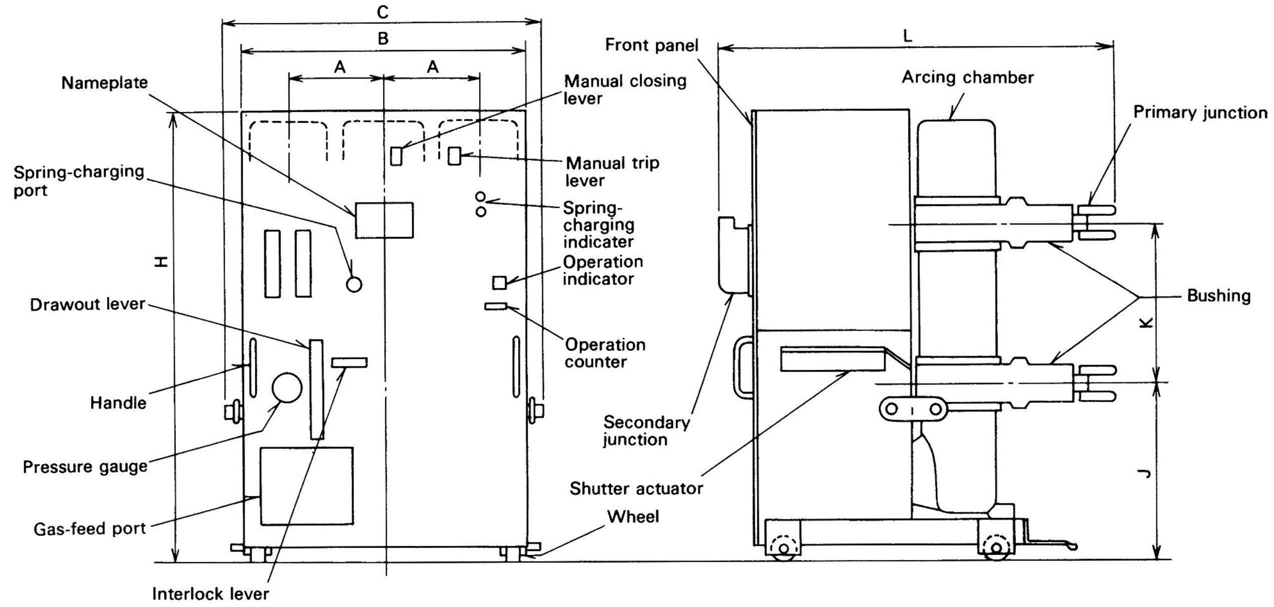
The principle of current interruption in SF_6 gas ensures long contact life without replacement and no deterioration of the extinguishing medium.

RATINGS AND SPECIFICATIONS

Table 1 Standard Ratings and Specifications

Type			6-SFG-40	6-SFG-63	10-SFG-40	10-SFG-50	20-SFG-25A	20-SFG-40A	30-SFG-25A	30-SFG-40A
Rated voltage		(kV)	3.6/7.2		12/13.8		24		36	
Rated continuous current		(A)	630/1250 2000 3150 4000	1250 2000 3150	630/1250 2000 3150 4000	1250 2000 3150	630 1250 2000 3150	1250 2000 3150	630 1250 2000 3150	1250 2000 3150
Rated frequency		(Hz)	50/60							
Rated interrupting current		(kA)	40	63	40	50	25	40	25	40
Rated closing current		(kA)	100	160	100	125	63	100	63	100
Rated short-time (3 sec) current		(kA)	40	63	40	50	25	40	25	40
Rated opening time		(sec)	0.05							
Rated closing time		(sec)	0.1							
Rated closing voltage		(VDC)	48/110/220							
Current of closing coil		(A)	5 (at 110VDC)							
Rated tripping voltage		(VDC)	48/110/220							
Current of tripping coil		(A)	5 (at 110VDC)							
Operating duty			0 – 3 min – CO – 3 min – CO							
Applied standards			IEC Pub 56, BS 5311, ANSI C 37, JEC 2300							
Low-frequency withstand voltage		(kV)	27		36		60		80	
Inpulse withstand voltage		(kV)	60		95		125		170	
Auxiliary contacts			5NO 5NC							
SF_6-gas pressure at 20°C (MPa)	Normal		0.5							
	Gas-feed alarm		0.45							
	Lock out		0.4							

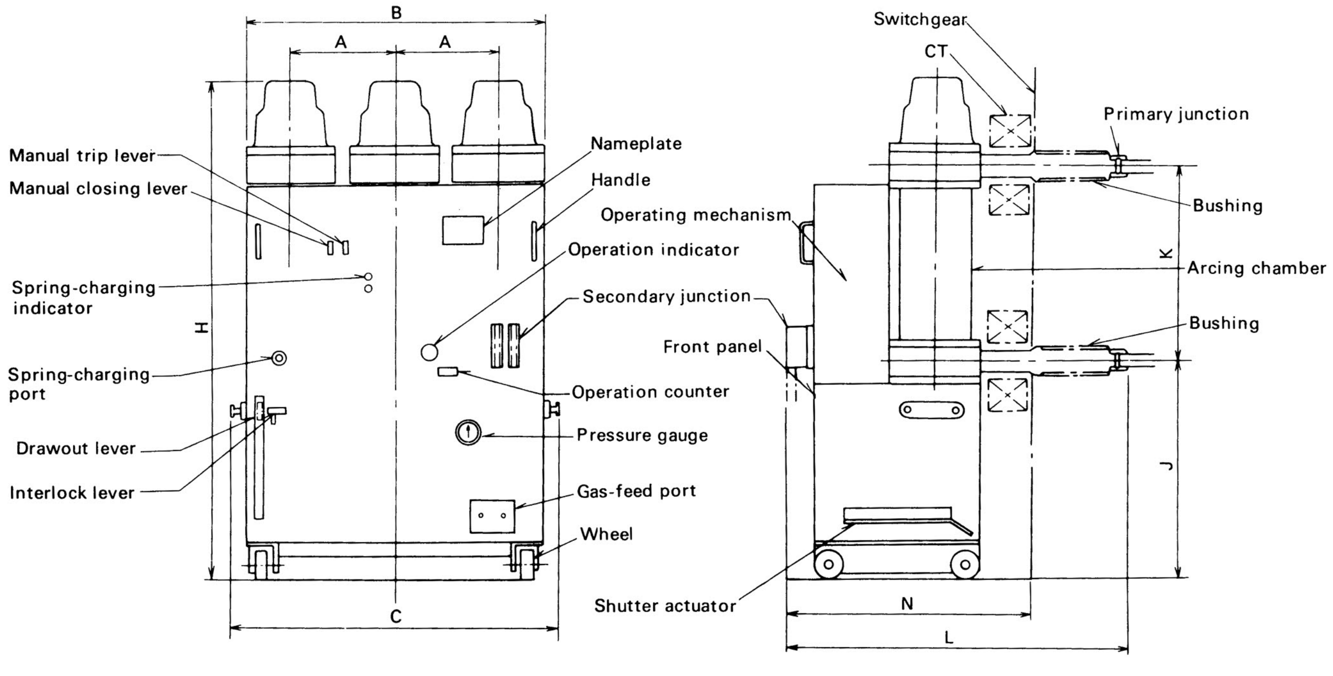
OUTLINES AND DIMENSIONS



Key

Type	Rated interrupting current (kA)	Rated current (A)	Approximate dimensions (mm) A	B	C	H	J	K	L	Weight (kg)
6-SFG-40	40 (250/500MVA)	630/1250	200	605	680	985	385	350	850	260
		2000	200	605	680	985	385	350	850	270
		3150	250	755	830	1040	400	400	850	380
		4000	250	755	830	1040	400	400	850	400
6-SFG-63	63 (390/785MVA)	1250/2000	250	755	830	1200	400	500	858	475
		3150	250	755	830	1200	400	500	858	500
10-SFG-40	40 (800MVA)	630/1250	200	605	680	985	385	350	850	260
		2000	200	605	680	985	385	350	850	270
		3150	250	755	830	1040	400	400	850	380
		4000	250	755	830	1040	400	400	850	400
10-SFG-50	50 (1000MVA)	1250/2000	250	755	830	1200	400	500	858	475
		3150	250	755	830	1200	400	500	858	500

Fig. 2 Outlines and dimensions (rated voltage 3.6, 7.2, 12kV class)



Key

Type	Rated interrupting current (kA)	Rated current (A)	Approximate dimensions (mm)								Weight (kg)
			A	B	C	H	J	K	L	N	
20-SFG-25A	25 (1000MVA)	630	300	840	920	1360	610	540	985	713	410
		1250	300	840	920	1360	610	540	985	713	410
		2000	300	840	920	1370	610	540	985	713	430
		3150	300	840	920	1380	610	540	985	713	450
20-SFG-40A	40 (1500MVA)	1250	300	840	920	1450	610	540	985	713	440
		2000	300	840	920	1460	610	540	985	713	460
		3150	300	840	920	1470	610	540	985	713	480
30-SFG-25A	25 (1500MVA)	630	300	840	920	1370	610	540	1140	795	440
		1250	300	840	920	1370	610	540	1140	795	440
		2000	300	840	920	1375	610	540	1140	795	470
		3150	300	840	920	1380	610	540	1140	795	490
30-SFG-40A	40 (2500MVA)	1250	300	840	920	1460	610	540	1140	795	470
		2000	300	840	920	1465	610	540	1140	795	500
		3150	300	840	920	1470	610	540	1140	795	520

Fig. 3 Outlines and dimensions (rated voltage 24, 36kV class)

CONSTRUCTION AND OPERATION

1. Arcing-Chamber Column

The interrupting unit of each column is enclosed by a grounded, metallic tank as shown in Figs. 4 and Fig. 5. The SF_6 gas completely fills the column at the pressure of 0.5MPa and is connected by piping on the bottom casing through each column to the control devices.

The chamber of each column contains one puffer-type breaking unit, consisting of a fixed contact, moving contact, arcing contact and a pair of pistons and cylinders. The design of the arcing-chamber columns permits easy access to and replacement of the current-carrying components.

At the commencement of the breaking cycle, the moving contact is pulled down by the insulation rod to open the contact, simultaneously compressing the gas contained in the cylinder (A in Fig. 5) to generate temporary high pressure.

The compressed gas is driven into the upper area where the arc is drawn between the upper fixed contact and the lower moving contact (inset B). A polytetrafluor-ethylene nozzle concentrates the gas flow to the arc, resulting in very effective arc extinction. After breaking, the moving contact is located in the open position as shown in inset C.

In closing, the insulating rod forces the moving contact upward to the closed position, evacuating the gas into the cylinder via the nozzle to prepare for subsequent opening. The insulation rod is connected to a sliding rod that passes through a sliding seal located at the bottom of the casing.

The sliding rods of each pole are linked to a connecting lever, which is rotated by the operating mechanism to close or open the contacts of the three poles simultaneously.

2. Operating Mechanism

Operation is by a stored-energy (spring) mechanism shown in Fig. 6. The main parts of the mechanism are assembled in a frame which is mounted on the truck.

Sufficient energy for one closing operation is stored by charging the closing spring by means of either an electric motor or a manual crank handle. With the spring loaded, the breaker can be closed and opened either mechanically or electrically.

During closing operation, the closing spring is released and the tripping spring is charged to prepare for subsequent opening.

The closing spring is recharged after every closing operation. In instantaneous close-open duty, tripping occurs with normal speed and full stroke after the completion of closing. Manual charging, closing and opening can be accomplished easily by an operator standing in front of the breaker. By means of these procedures, breakers can be operated with normal contact speed even if the control power source is lost.

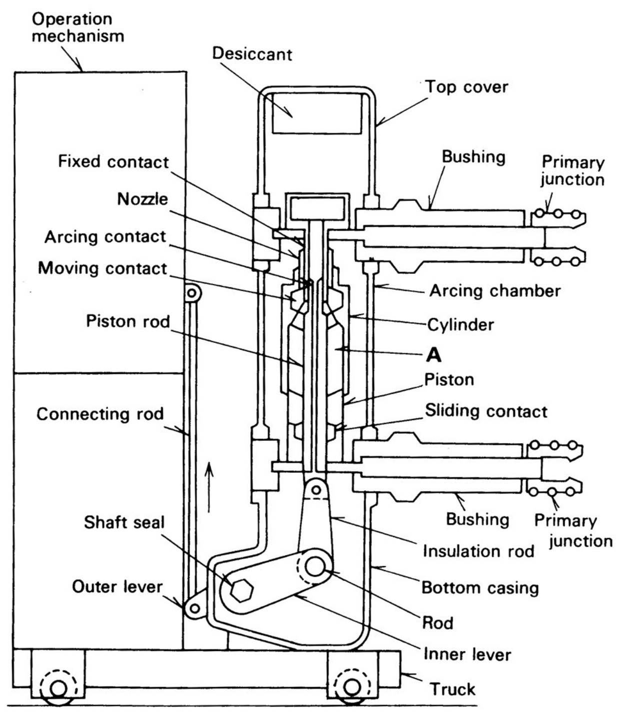


Fig. 4 Arcing-chamber column (rated voltage 3.6, 7.2, 12kV class)

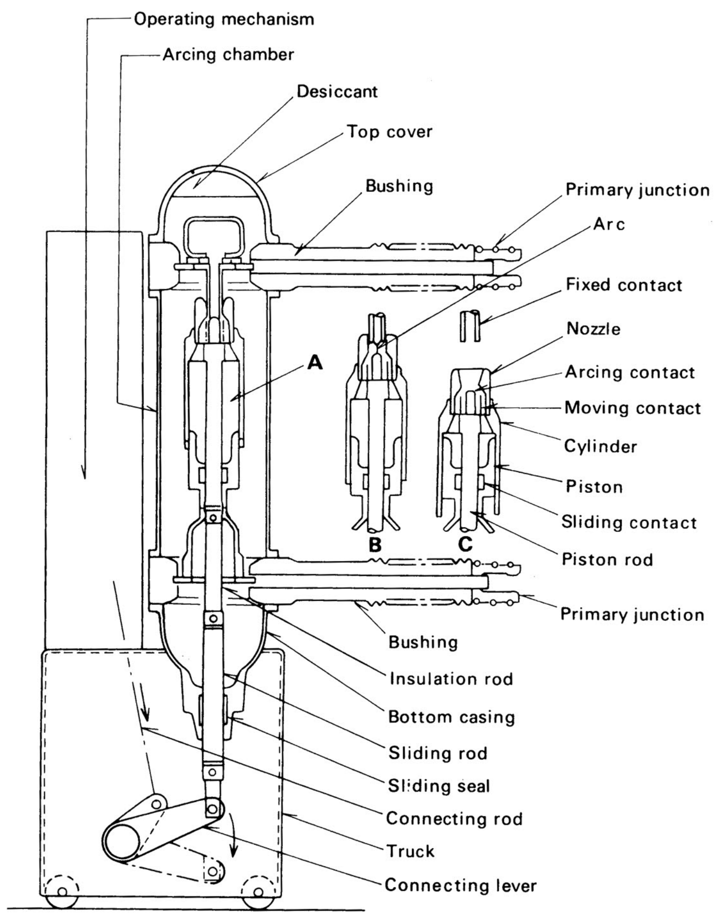


Fig. 5 Arcing-chamber column (rated voltage 24, 36kV class)

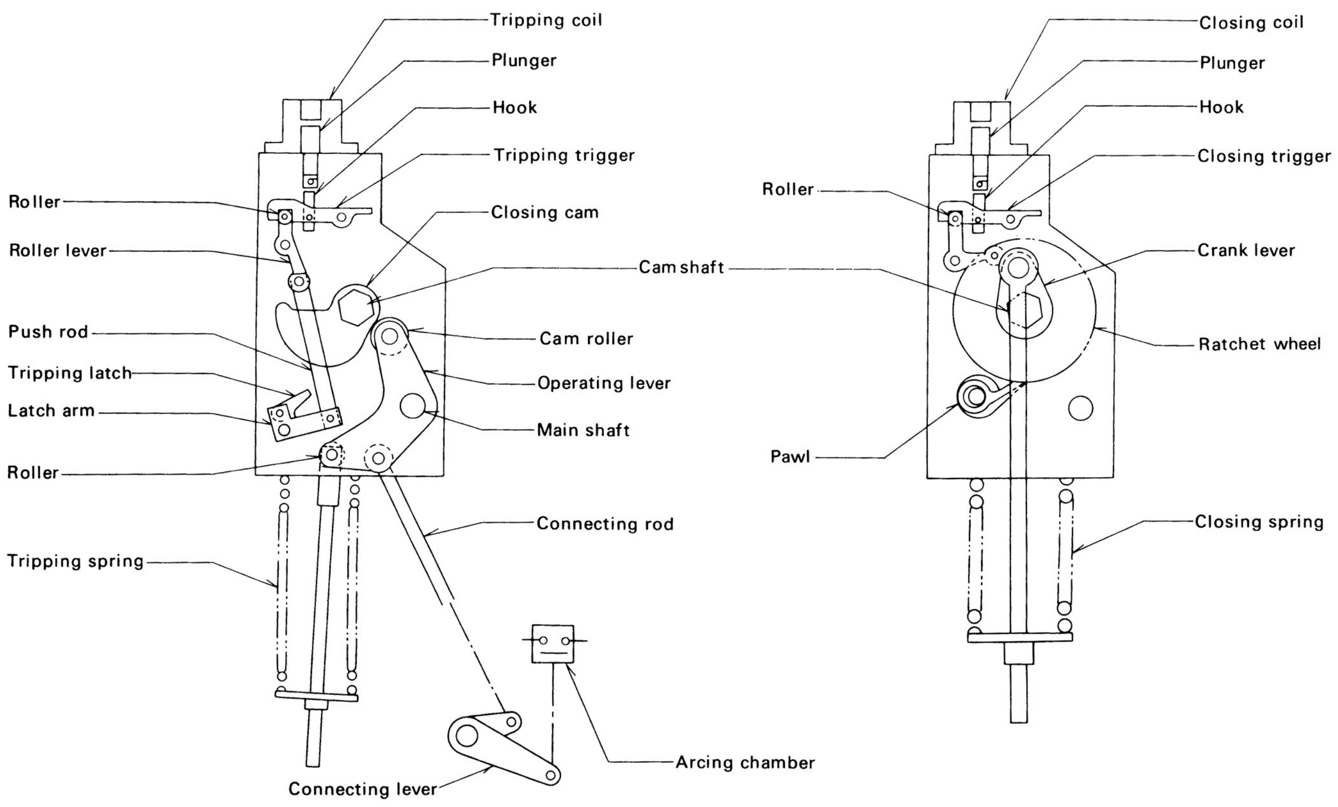


Fig. 6 Schematic of operating mechanism

3. Control Devices

As shown in Fig. 7, control devices such as auxiliary relays, secondary junctions, auxiliary switch and pressure switch are mounted on a panel located on the breaker truck and are enclosed with a cover as well as operating mechanism.

Secondary wiring of the breaker is connected manually at the secondary junction. The control circuit is diagrammed in Fig. 8.

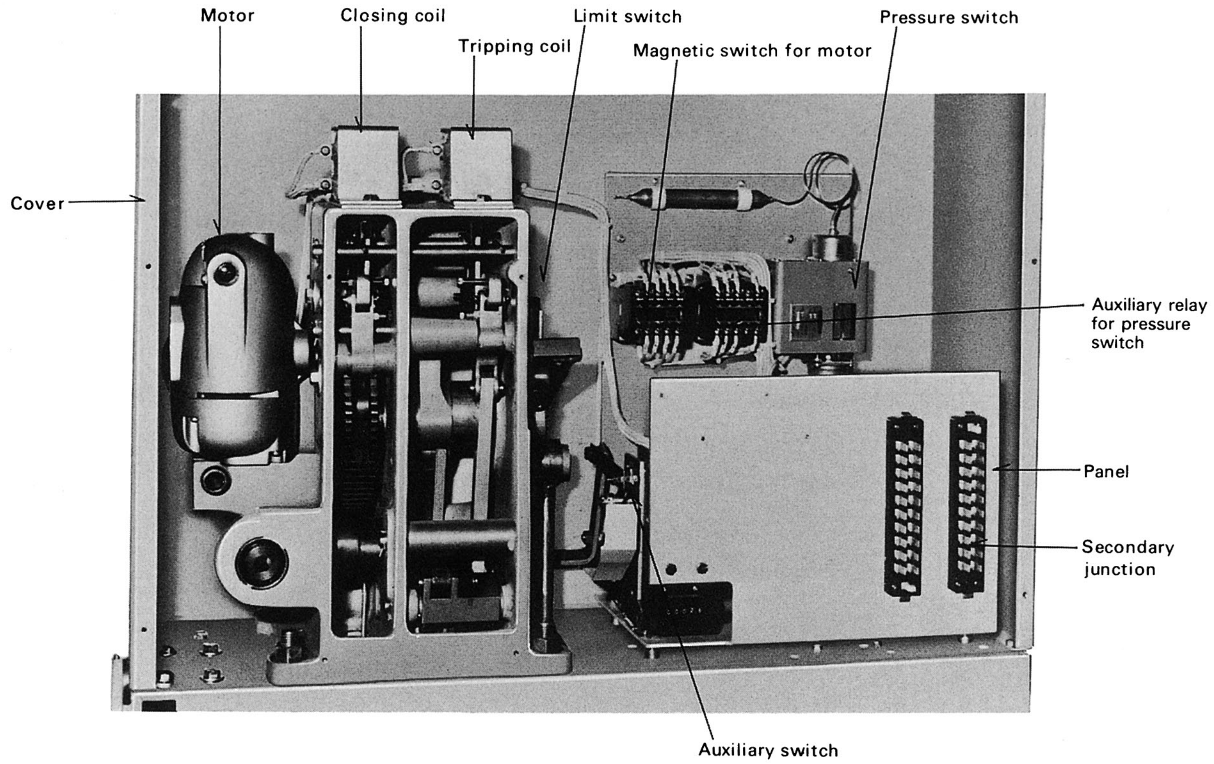
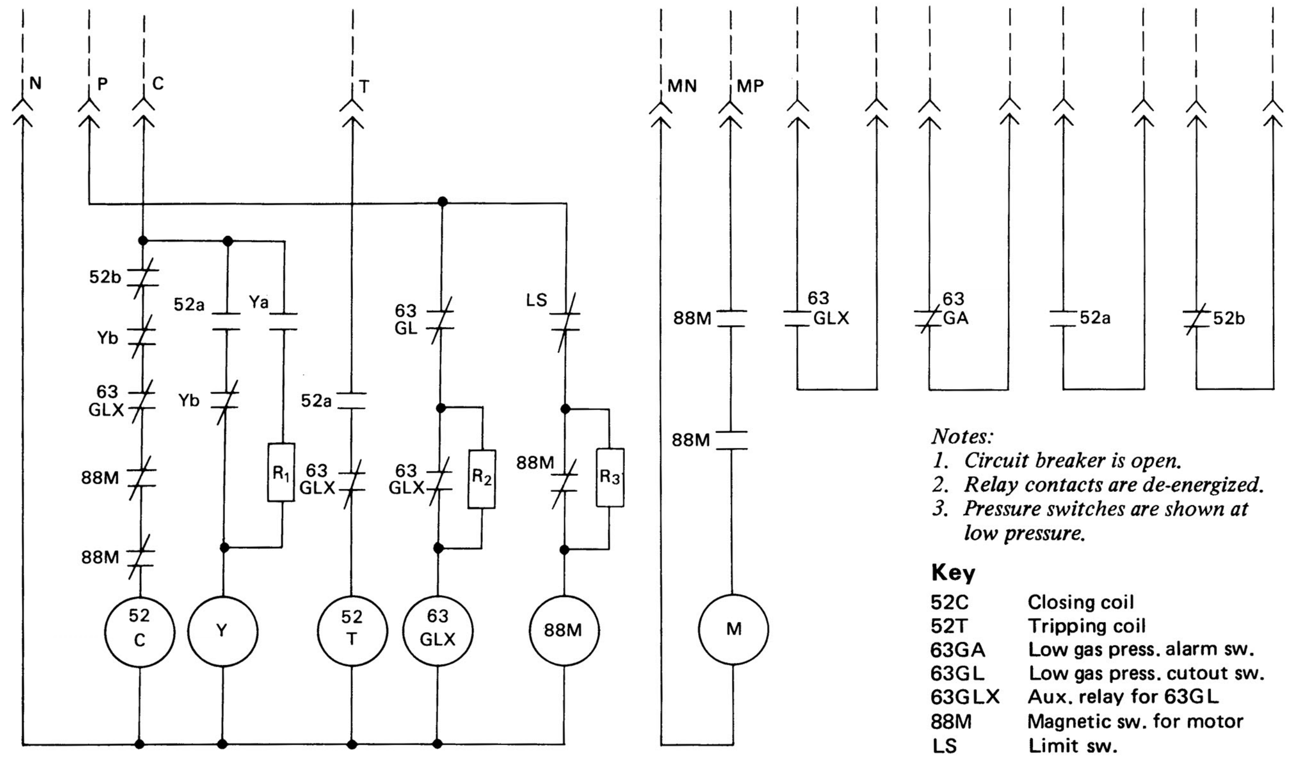


Fig. 7 Operating mechanism and control devices



Notes:
1. *Circuit breaker is open.*
2. *Relay contacts are de-energized.*
3. *Pressure switches are shown at low pressure.*

Key

52C	Closing coil
52T	Tripping coil
63GA	Low gas press. alarm sw.
63GL	Low gas press. cutout sw.
63GLX	Aux. relay for 63GL
88M	Magnetic sw. for motor
LS	Limit sw.
M	Motor for spring charge
R_1	Resistor
R_2	Resistor
R_3	Resistor
Y	Magnetic sw.

Fig. 8 Control-circuit diagram

4. Gas Density Control

The pressure-temperature characteristics of SF_6 gas are illustrated in Fig. 9. The gas pressure switch is temperature-compensated to follow the constant-density line. The SF_6 gas is introduced at the normal pressure of 0.5 MPa at 20°C and the gas-feed alarm is set to operate at 0.45MPa at 20°C. The breaker is locked out if gas pressure should fall to 0.4MPa at 20°C.

Since all ratings are guaranteed above the lock-out pressure line, the breaker is able to operate satisfactorily even when the gas-feed alarm is set. If necessary gas can be supplied through the gas-feed port shown in Figs. 2 and 3 without suspending the service.

Immediate gas supply is not necessary, as the gas density is maintained for a very long period even after the gas-feed alarm is energized. Gas density is very low and liquefaction is no problem above minus 35°C.

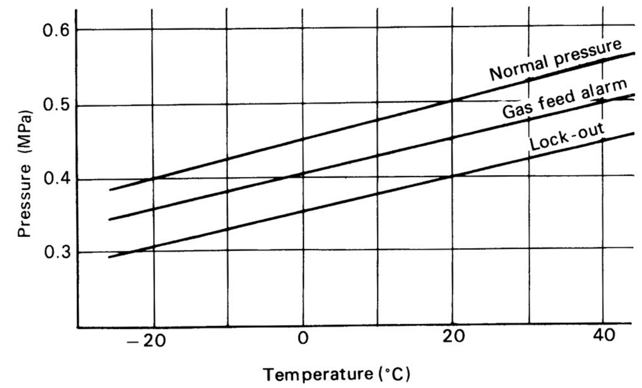


Fig. 9 Pressure-temperature characteristics of SF_6 gas at constant specific volume

5. Interlocks

The breaker is provided with a complete system of interlocks. The drawout mechanism cannot be operated unless the breaker is open, insuring that the breaker position can be changed only when the breaker is open.

Otherwise the breaker cannot be closed at any point between the fully connected and disconnected positions. In addition, the breakers of the same rated continuous current are interchangeable to each other's switchgear panel, but the breakers are prevented from joining with panels of a different rating.

APPENDIX: PROPERTIES OF SF_6 GAS

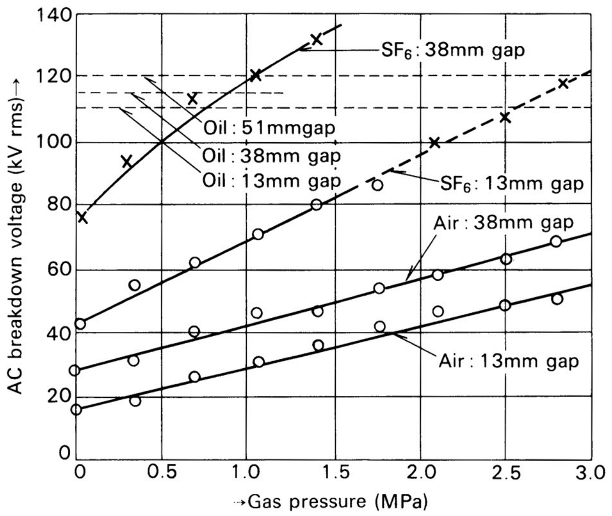
1. Physical Properties

Sulphur hexafluoride gas has excellent interrupting and insulating properties. Chemically, it is one of the most stable compounds and in the pure state and under normal service conditions it is inert, nonflammable, nontoxic, and odorless.

The physical properties of SF_6 gas appear in Table 2, which shows that its density is about 5 times that of air. The insulating strength is about 2~3 times that of air, and it exceeds that of oil at 0.3MPa pressure, as shown in Fig. 10. The pressure-temperature characteristics of SF_6 gas at constant specific volumes are shown in Fig. 9.

Table 2 Typical Physical Constants of SF_6

Material	SF_6	Air
Molecular	146.07	28.8
Melting point (°C)	−50.7	—
Dielectric constant at 25°C, 1 atm.	1.002	1.0005
Density at 20°C, (g/ℓ) at 0MPa	6.25	1.166
at 0.1MPa	12.3	
at 0.5MPa	38.2	
at 1MPa	75.6	
at 1.5MPa	119.0	
Thermal conductivity at 30°C (cal/sec·cm°C)	3.36×10^{-5}	5.12×10^{-5}
Specific heat ratio	1.07	1.4
Specific heat at constant 1 atm., 25°C (Cp cal/mol °C)	23.22	6.85
Solubility: In oil (cc's per cc of oil)	0.297	—
Solubility: In H_2O (cc's per cc of H_2O)	0.001	—
Solubility: Of H_2O in SF_6 (% weight at 30°C)	0.035±0.010	—



Note: x : Applied to 76mm-diam. plate electrode
o : Applied to 13mm-diam. sphere electrode

Fig. 10 Examples of AC breakdown voltage vs. gas-pressure characteristics of SF_6 gas and air on nickel-plated brass electrodes

2. Toxicity

White mice placed in an atmosphere of four parts SF_6 to one part oxygen for a period of 24 hours were found to have suffered no ill effects.[1,2]

Actually, no problems of personnel safety have arisen in either routine shop manufacture or laboratory development work, and never have any special masks, gloves, or protective devices been required.

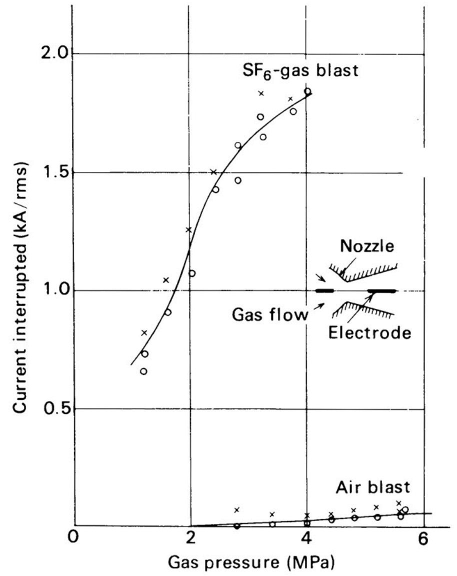
1. D. Lester: "General consideration of toxicity of gaseous dielectrics," AIEE, Tr, Part III, p. 1183 (1957).
2. Complete rendu des discussions, S.F.E. 8è serie, tome III. n° 34, p. 547 (Oct. 1962).

3. Arc-Quenching Ability

Although a fundamental explanation for the arc quenching effectiveness of SF_6 gas still lags somewhat behind its application, remarkable progress has been made in developing an adequate theory. The phenomenon that apparently explains the superior arc-interrupting abilities of this gas is the effect of negative ion formation by electron capture on electric discharges. Certain molecules offer an attraction for free electrons, and combine with the electrons to form negatively charged ions. Gases made up of molecules with this electron-attracting characteristic are known as electro-negative gases. Both the insulating and arc-quenching abilities of SF_6 are strongly affected by this electron-trapping action.

It has been verified that plain-break contacts drawing AC arcs in SF_6 can interrupt about 100 times more current than in air at a given voltage. Fig. 11 shows the comparison of the arc-quenching ability of SF_6 with that of air using the same axial blasting nozzle.

The basic requirement of an AC arc-interrupting medium is not primarily high dielectric strength, but rather a high rate of recovery of dielectric strength. This requirement can alternatively be expressed as a high rate of loss of arc-path conductance as the alternating current passes through zero. This rate of change in conductance is generally measured in terms of the time constant of the medium. The extremely fast capture of free electrons in the arc path through the electro-negative process is believed to explain the extremely low time constant of SF_6, which is only a fraction of that for air, as indicated in Fig. 12. Another peculiar characteristic of the arc in SF_6 is that it is quite stable down to the small magnitude of the current near zero point, although the rate of insulation recovery after current zero is very high. Thus an SF_6 interrupter does not cause current chopping, which would induce harmful overvoltage.



Note: Test voltage is 12kVrms. O = success, X = failure.

Fig. 11 The arc-quenching ability of an interrupter using SF_6 gas blast in comparison with one using air blast

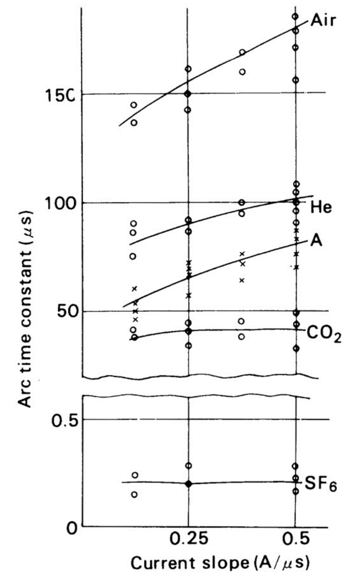
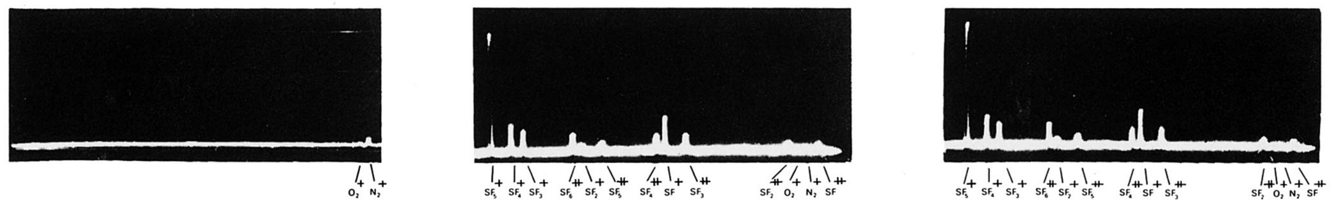


Fig. 12 Arc time constant vs. current-slope characteristics of various gases

4. Deterioration of SF_6 Gas Due to Arcing

It has been found that the deterioration or decomposition of SF_6 due to arcing is practically negligible for use in circuit breakers. It is true that SF_6 decomposes when exposed to the arc, producing lower fluorides of sulphur, such as SF_2 and SF_4, but these are very unstable and immediately recombine to SF_6 in the extremely short time of 10^{-3} sec. Therefore, as shown in Fig. 13, the gas spectra produced by a mass spectrometer before and after many high-current-interrupting tests clearly indicate that the physical component of the gas after the test is exactly the same as before.

Some metallic fluorides are formed during arcing. These fluorides, which distribute themselves as a fine powder in the arc chamber, have high resistivity and therefore cause no insulation trouble. The complete absence of carbon in SF_6 is a major advantage as an arc-interrupting medium.



a) Background spectrum **b) Spectrum before type testing** **c) Spectrum after type testing**

Note: O_2^+ and N_2^+ lines are background spectrum lines of the ions remaining in the ionization chamber of the mass spectrometer and do not indicate the existence of O_2 or N_2 in SF_6 gas.

Fig. 13 SF_6-gas spectra by mass spectrometer before and after type testing

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