UDC 621. 314. 57. 064. 242

SINGLE PRESSURE-TYPE 72kV F-CIRCUIT BREAKERS

Hiroyoshi Kawabata

Takasuke Kodama

Kawasaki Factory

I. INTRODUCTION

The excellence of SF_6 gas has been recently noticed as an arc-quenching medium. The manufacturing process of the SF_6 gas circuit breaker is now firmly established. We, in the spring of last year, developed a 300 kV 25G VA F-circuit breaker and then a 168 kV 10 GVA also. These breakers have already undergone the type tests for various electric power companies and the F series is being completed. Our good success in the practical application of SF_6 gas circuit breakers is based largely on the fundamental researches for SF_6 gas carried out in Siemens Ltd., Germany, and in our Central Research Laboratory. When using SF_6 gas circuit breaker, there are several problems concerning with measuring and detecting gas leaks and controlling the amount of water in the gas. Although very high level required to solve the problems, we have overcome these difficulties.

We have two types of SF_6 gas circuit breakers, the single-pressure type and the double pressure type, depending on the arc quenching process. In the case of the double pressure type, the SF_6 gas is sealed in a high pressure section and a low pressure one. In such a breaker, the high pressure gas blows against the arc by means of a blast valve. The quenching gas pours into the low pressure section. After breaking a current the gas in the low pressure section is pumped up to the high pressure section by means of a compressor. In case of the single pressure type the SF_6 gas is sealed in the breaker at only one pressure level. On the breaking process the cylinder behind the movable contact momentarily compresses the gas. This compressed gas blows against the arc and extinguishes it. This type of the breaker is also called puffer type.

We also has developed a 72/84 kV single pressure type F-circuit breaker and completed the type tests of this breaker for the various electric power companies. At about the same time, 72 kV 3.5 GVA 1,200 A indoor draw-out type single pressure type F-circuit breakers were manufactured. This article contains the construction and test results of this breaker. In August 1970, we already have the orders over 60 sets of single pressure type and over 50 sets of double pressure type F-circuit breakers.

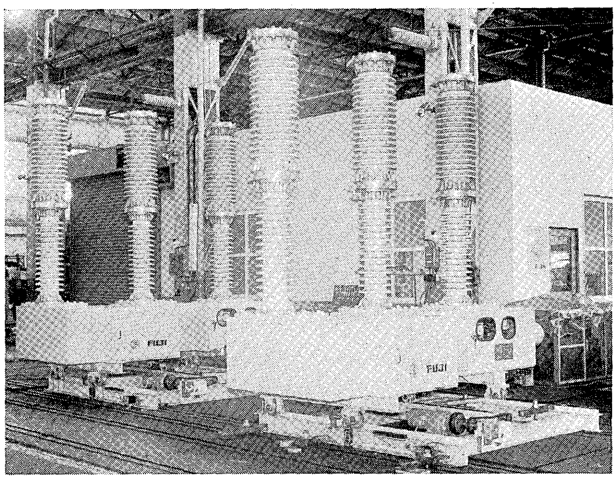


Fig. 1 Fuji F-circuit breaker 72/84 kV 2,000 A 3,500 MVA

II. RATINGS

The ratings of this indoor type single pressure F-circuit breaker are as follows.

Rated voltage :	72/84 kV
Insulation level :	350/400 kV
Rated current :	2,000 A
Rated frequency :	50/60 Hz
Rated breaking capacity :	3,500 MVA
Rated breaking time :	5～
Rated gas pressure :	5 kg/cm²·g (20°C)
Rated compressed air pressure :	15 kg/cm²·g
Rated control voltage :	DC 100 V
Basic standard :	JEC 145

III. FEATURES

Since we also use SF_6 gas in the single pressure type as the arc quenching medium, the features are the same as those of the double pressure model introduced previously.

1) Excellent breaking and insulation characteristics:

Unlike air circuit breakers, this circuit breaker can interrupt fault current with a severe rate of rise of restriking voltage such as short-line, out-of-phase and multiple faults.

2) Contacts do not wear much and are maintenance free:

Since the arc voltage in the SF_6 gas in about 1/10 that in air, the arc energy is much less than in the air-blast types and there is no oxygen present. Therefore, there is very little contact wear due to the lack of burning damage and the contacts do not need to be checked for long periods.

3) Completely enclosed construction:

The joint parts of the SF_6 gas sealing section are specially finished and protective tools are provided so that there is no damage to these parts during processing or transportation. A leak detector is used with an accuracy of 10^{-8} so that almost complete air-tightness can be maintained. The actual amount of leakage is only a few percent over a period of fifty years.

4) Rated breaking is possible without compressed air:

Drive energy is supplied by a spring during breaking and by compressed air during closing. Therefore, breaking operations are not effected even when there is no compressed air and rated breaking is insured. Since the compressed air and SF_6 gas system are completely separated, there is no influence whatsoever on the breaking characteristics due to the presence or absence of compressed air.

This single pressure F-circuit breaker differs in the following points from the double pressure type.

(1) Construction is simple:

Since this single pressure breaker contains SF_6 gas at a constant pressure and high pressure gas occurs only during breaking, the gas circuits are extremely simple. In other words there is no need for a high pressure gas tank or blast and exhaust valves to blast the gas against the arc. Since high pressure gas is created only for operation, a gas compressor is not needed to create high pressure gas. The construction can thus be very simple.

(2) Small gas volume:

Since the gas circuit is compact, the volume of SF_6 gas sealed in the breaker can be kept to a minimum and therefore it is possible to make checks without

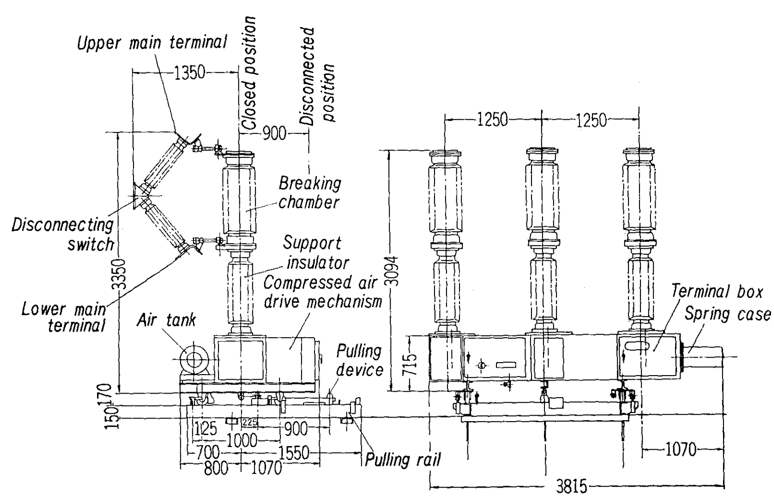


Fig. 2 Outer view of RF951 (Indoor type)

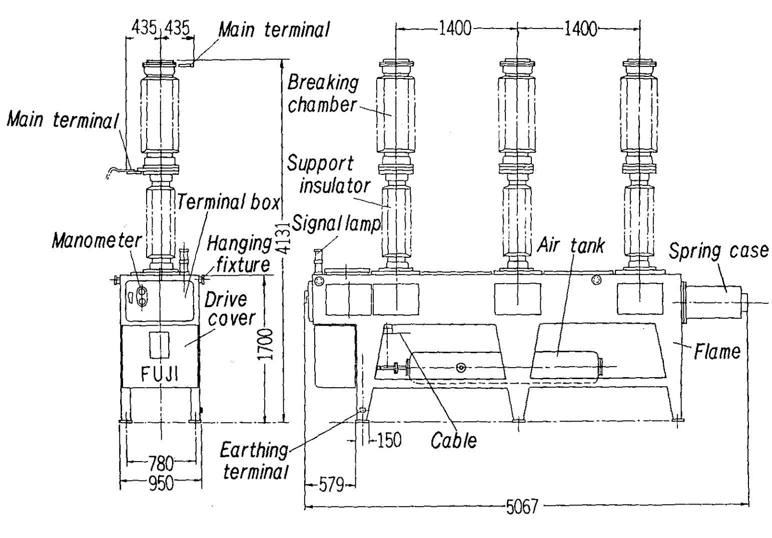


Fig. 3 Outer view of RF951 (Outdoor type)

reusing the gas.

(3) Indoor draw-out type:

Since the breaking chamber is perpendicular, the breaker can be pulled when a disconnecting switch is attached. Manual or automatic pulling is possible.

IV. CONSTRUCTION AND OPERATION

Fig. 2 is an outer view of this breaker. This is an indoor type movable model pulled by a motor. *Fig. 3* shows the outdoor frame attachment model in which the frame and the lower part of the drive mechanism forms a single compact unit.

In both the indoor and outdoor types, the breaking chambers and support insulators are arranged perpendicular to the base which contains the lower part of the drive mechanism.

1. Quenching Principle

Fig. 4 illustrates the arc quenching principle of the F-circuit breaker. During breaking, the puffer cylinder moves to the right, and a gap is created between the movable and stationary contacts.

At the same time, the puffer gas in the space surrounded by the movable cylinder and fixed piston is compressed. In this way, high pressure gas arises in the cylinder and this gas flows against the arc. After the arc is extinguished the insulation between the poles is maintained by the gas under the rated sealing pressure.

During closing, the moving cylinder is moved to the left, opposite to the direction for breaking. The puffer chamber gas is brought in from the surroundings and the breaker is ready for the next breaking operation.

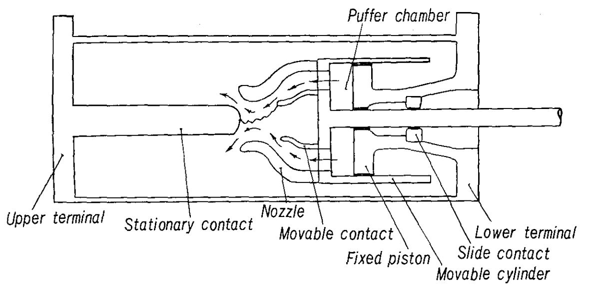


Fig. 4 Principle of arc quenching

2. Construction

Fig. 5 is a sectional diagram of the breaking chamber and the support insulator. A protective cylinder is placed inside the breaking chamber to protect the inner surface of the breaking chamber insulator against arcs. There is a filter in the space between the breaking chamber and the support insulator. This filter absorbs the small amount of decomposed materials arising in the breaking chamber so that such materials can not get into the support insulator.

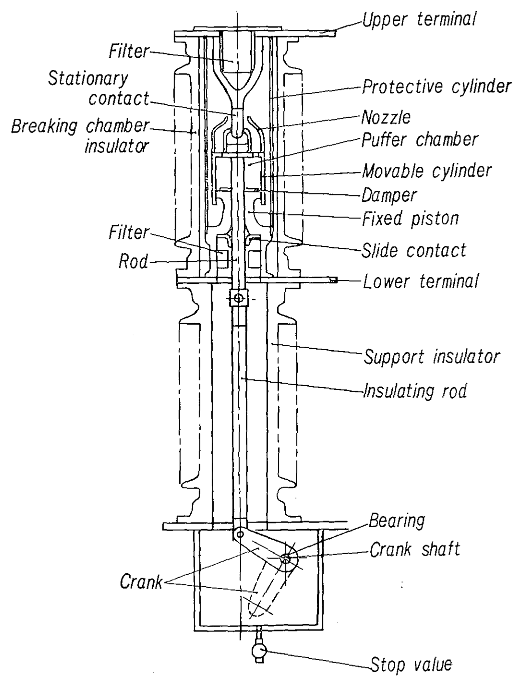
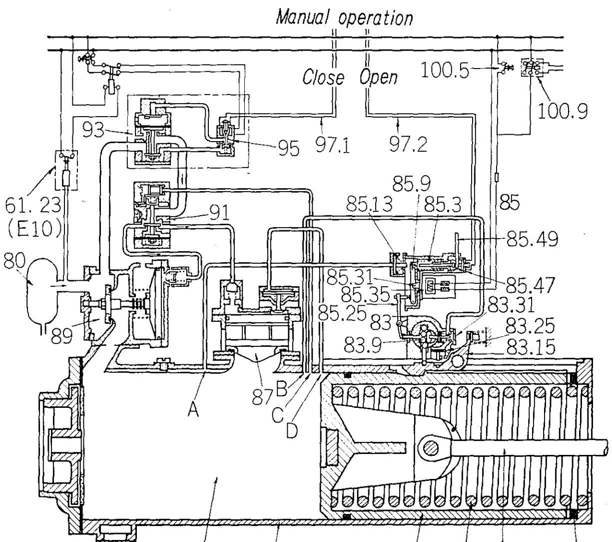


Fig. 5 Section of breaking chamber and support insulator



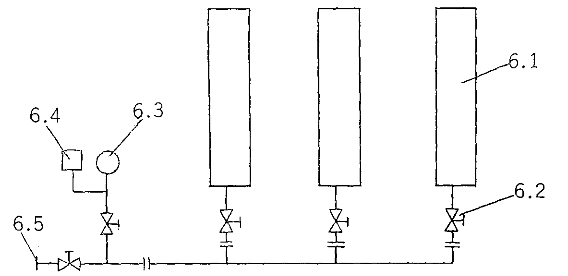
61.23 Pressure switch
80 Air tank
81 Pneumatic operating mechanism
81.19 Cylinder
81.21 Piston
81.27 Main spring
81.29 Piston rod
81.33 Damper
83 Tripping mechanism
83.9 Roller
83.15 Ratchet lever
83.25 Piston
83.31 Piston
85 Tripping device
85.3 Compression spring
85.9 Lever
85.13 Piston
85.25 Tripping lever
85.35 Tripping lever
85.31 Sticking piece
85.35 Tripping magnet
85.47 Piston
85.49 Manual tripping lever
87 Exhaust valve
89 Operating valve
91 Locking valve
93 Closing valve
95 Closing electromagnetic valve
97.1 Piping for manual closing
97.2 Piping for manual tripping
100.5 Control switch
100.9 Protection contactor

Fig. 6 Section of air drive

The lower frame contains the breaking spring, compressed air drive mechanism, dashpot and control box. The compressed air drive mechanism is exactly the same as that in the 168 kV double pressure F-circuit breaker. A cross-sectional view of this drive mechanism is shown in *Fig. 6*.

3. Gas Cycle

The gas cycle is shown in *Fig. 7*. The SF_6 gas is sealed inside the breaking chamber insulator and the support insulator and there is 3-phase connection with the base part of the breaker by means of tubes. If ever gas leaks should occur, a pressure drop would be detected by the pressure switch with temperature compensator. An alarm would be given and at the same time the breaker operation would be locked. During attachment or disassembly checks, the SF_6 gas is supplied and sealed.

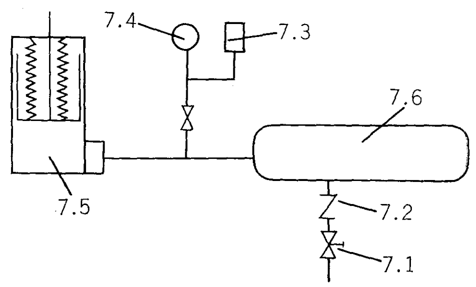


6.1 Breakipg chamber and support insulator
6.2 Stop valve
6.3 Manometer
6.4 Pressure switch with temperature compensator
6.5 Gas supply port

Fig. 7 Diagram of gas cycle

4. Air Pipe System

The air pipe system is shown in *Fig. 8*. The compressed air used for closing operation is stored in the air tank attached to the breaker base. The pressure of the compressed air is monitored by the pressure switch and when the pressure drops below the specified value, a warning is given and closing operation is locked.



7.1 Stop valve
7.2 Check valve
7.3 Pressure switch
7.4 Manometer
7.5 Compressed air drive mechanism
7.6 Air tank

Fig. 8 Diagram of air pipe system

5. Operation

1) Breaking

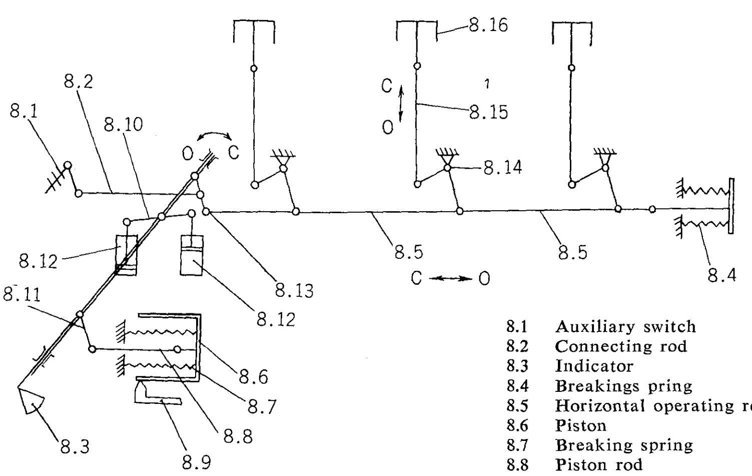
The operating mechanism is as shown in *Fig. 9*. The breaking instruction excites the tripping magnet of the compressed air drive device and the rollers aligned in series with the tripping mechanism are thrown out of position. This disturbs the relation between the breaking spring and the ratchet lever. The spring is then released, and the horizontal drive rods in the lower drive mechanism move. This movement is transferred to the insulated drive rod via the bearing; the movable contact and the movable cylinder are moved downwards and breaking occurs.

2) Closing

The closing signal excites the closing magnetic valve, the drive valve is operated and compressed air is sent into the drive mechanism cylinder. The movement of the drive piston is transferred to the lower drive mechanism, the breaking spring is compressed and the horizontal drive rod is moved in the reverse direction to that during breaking. This movement causes the insulated drive rod to move upwards because of the bearing. The movable contact then moves up and closing is completed.

V. TEST RESULTS

Before this F-circuit breaker was delivered, it was subjected to certain type and reference tests in ac-



8.1 Auxiliary switch
8.2 Connecting rod
8.3 Indicator
8.4 Breakings pring
8.5 Horizontal operating rod
8.6 Piston
8.7 Breaking spring
8.8 Piston rod
8.9 Ratcnet lever
8.10 Dash pot crank
8.11 Drive crank
8.12 Dash pot
8.13 Operating crank
8.14 Bearing
8.15 Insulatd operating rod
8.16 Moveable cylinder

Fig. 9 Diagram of drive mechanism

Table 1 Results of Interruption

Type of test	Duty	Type		Test pressure (atg)	Test voltage (kV)	Recovery voltage (%)	Breaking current (kA)	Arc time (~)	Restriking voltage: Peak value (kV)	Restriking voltage: Frequency (kHz)	Restriking voltage: Rate of rise of restriking voltage (r.r.r.v.) (kV/μs)	Remarks
Terminal fault	O-1min-O-3min-O	10%	Single phase direct	4	75	103	2.83	0.81~0.83	155	4.7	1.46	
	O-1min-O-3min-O	30%	Weil synthetic test circuit	4	77.2~78.2	106~107	9.5	0.98~1.00	153	4.7	1.44	
	O-1min-O-3min-O	60%	Weil synthetic test circuit	4	77.2~78.3	106~107	17.5	0.97~1.00	153	5.3	1.62	
	O-1min-CO-3min-CO	110%	Weil synthetic test circuit	4	90~91	123~125	30.7	1.10~1.15	178	4.7	1.67	
Multiple faults	O-1min-O-3min-O	87%	Weil synthetic test circuit	4	96.8~101	115~120	25.0	1.09~1.15	192	2.7	1.04	
Out-of-phase fault	O-3min-O	50%	Weil synthetic test circuit	4	139	2.87E	14.5	1.07~1.14	246	2.9	1.43	
Short line fault (SLF)	O-3min-O	60%	Weil synthetic test circuit	4	52.5~53	108~109	15.2	1.05~1.09	47	41	3.8	
	O-3min-O	75%	Weil synthetic test circuit	4	56.5~58	116~119	19.0	1.26	30	83	4.7	
	O-3min-O	90%	Weil synthetic test circuit	4	52~53	107~109	22.0	1.03~1.05	12	167	5.3	
Inductive small current	0	—	Single phase direct	6	73	109	22.5	0.23~0.63	—	—	—	Over voltage coefficient less than 1.06
Line charging current	0	—	Single phase direct	4	84	240 kV	10.3	0.19~0.58	—	—	—	

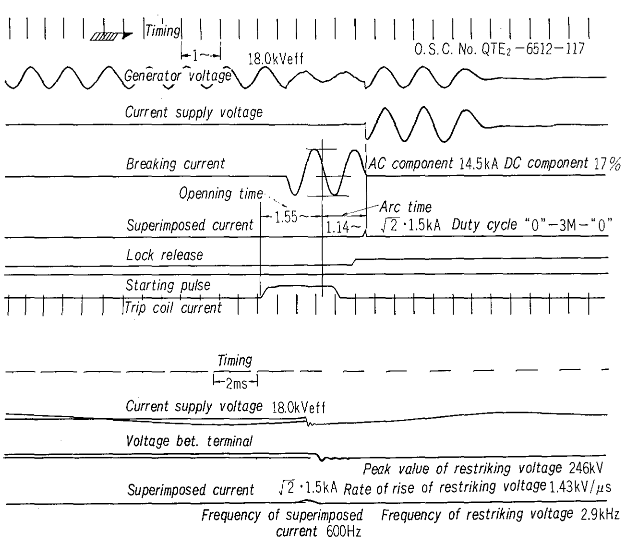


Fig. 10 **Oscillogram of out-of-phase interruption**

cordance with JEC 145 and power standard B112. Good results were achieved in all the tests as can be seen from those results given in *Table 1*. It was confirmed that there was excellent insulation at the peak value of the restriking voltage which is a feature of SF_6 gas circuit breakers. *Fig. 10* shows a typical oscillogram.

In the flash-over test when the gas pressure was the lock pressure, it was evident that the flash-over voltage had sufficient tolerances in respect to the test voltages both between the poles and to ground. The flash-over voltage at atmospheric pressure was determined considering the case of an abnormal drop in the gas pressure. The results confirmed that there was sufficient withstand both between the poles and to ground for the phase voltage and 80.5 kV.

VI. CONCLUSION

This article has described the single pressure type F-circuit breaker. Fuji Electric is now completing the F series of single and double pressure breakers, arranging production systems and putting the breakers into mass production. It is expected that the demands for SF_6 gas circuit breakers will continue to increase in the future.

The authors would like to thank all those who cooperated and assisted in conducting the various tests and well as those who cooperated in the plant where the breaker was installed. It is hoped that general user will cooperate in the future development of SF_6 gas circuit breakers.