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300 kV 20 GVA 4,000 A F-SCHALTER

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I. INTRODUCTION

In 1969, Fuji Electric completely assimilated the Siemen's techniques concerning SF_6 gas circuit breakers and started domestic production of HF 904 type F-Schalter with ratings of 300/240 kV, 25/20 GVA 4,000/2,000 A. In July, type tests by the major power companies were completed. In October of the same year, HF 902type 168/204 kV, 10/12 GVA, 4,000/2,000 A F-Schalter in which two of the same breaking units as used in HF 904 type are connected in series was completed and also underwent power company type tests. In May, 1970, the first HF902 which was ordered by Fukuyama Steel Mills of Nippon Kokan Co. Ltd. was exhibited and inspected by 200 visitors.

These double pressure type F-Schalter follow the 72/84 kV, 10/12 GVA, 2,000 A puffer type F-Schalter for which there has been many orders and production is now on the increase. HF912 series of F-Schalter with ratings of 300/240 kV, 20/15 GVA and 4,000/2,000 A are now being manufactured after having passed power company type tests. These breakers have unit voltages of 140 kV which is higher than the 70 kV of HF 904 type and HF902 type. The voltage per breaking point is the highest in the world. The concepts behind the design of the operation mechanism and gas pressure control system are the the same as those for HF904 type and 902 type but the 4 unit breaking of HF904 of the same rating is handled by only 2 units. These are revolutionary breakers effectively utilizing the excellent arc quenching capabilities of SF_6 gas. Naturally all breaking conditions under short line faults completely satisfy the specifications in JEC standards.

From the viewpoint of practicability, new methods are used for construction and quality control. To prevent the SF_6 gas leak, carefully sealed piping is tested with a leak detector with the sensibility of 10^{-8} SF_6 gas density. Reliability is therefore very high and these breakers can be recommended with confidence.

In this article, the rating and construction of recently completed HF912 type F-Schalter will be discussed and summary date of interrupting tests will be given.

II. F-SCHALTER RATINGS

The ratings of 300 kV F-Schalter are given in *Table 1*, the ratings of the accessories in *Table* 2 and the quantities of SF_6 gas and created values in *Table 3*. Fuji double pressure type F-Schalter has low pressure and high pressure sides of SF_6 gas circulating via

Table 1 **Ratings of 300 kV F-Schalter**

Type	HF 912M/250/2000D/4000D (for salt contamination proof type)	HF 912 L/200/2000D/4000D (for salt contamination proof type)
Rated voltage	300 kV	240 kV
BIL	1,050 kV	900 kV
Rated current	4,000/2,000 A	4,000/2,000 A
Rated frequency	60/50 Hz	60/50 Hz
Rated interrupting current	38.5 kA	36.1 kA
Rated interrupting capacity	20 GVA	15 GVA
Rated frequency of restriking voltage	1.8 kHz	2.0 kHz
Rated making cuurent	105 kA	98.5 kA
Rated short time current	38.5 kA	36.1 kA
Rated opening time	0.035 s	0.035 s
Rated interrupting time	3∿	30∿
Rated making time	0.12 s	0.12 s
Rated duty cycles	Normal duty and high speed auto-reclosing	Normal duty and high speed auto-reclosing
SF_6 gas pressure	19/2 kg/cm²·g	19/2 kg/cm²·g
Rated operating pressure	15 kg/cm²·g	15 kg/cm²·g
Rated closing control voltage	DC 100 V	DC 100 V
Rated opening control voltage	DC 100 V	DC 100 V
Permissible salt contamination density	One line ground Breaking unit insulator: 0.04 mg/cm² Supporting insulator: 0.035 mg/cm²	One line ground Breaking unit insulator: 0.036 mg/cm² Supporting insulator: 0.046 mg/cm²
SF_6 gas quantity	150 kg	145 kg
Weight of F-Schalter	11,500 kg	11,000 kg
Applied Standard	IEC JEC 145	

***Table 2* Ratings of accessories**

Part	Application	Value
Pneumatic operating mechanism	Rated operating voltage	15 kg/cm²·g
	Closing-lock pressure	12.7 kg/cm²·g
	Capacity of air reservoir	450 *l*
	Air consumption volume while closing	360 *l*
	Control voltage	DC 100 V
Gas compressor	Rated voltage	AC 220/200 V
	Motor	2 kW
Heater	High pressure side of SF_6 gas	Normal use 2 kW For extla cold regions 6 kW

***Table 3* Quantity of SF_6 and created values of gas control**

	Item	HF 912 For auto-reclosing (3 poles)	HF 912 For nominal use (3 poles)
Quantity	Rated gas pressure	19.0/2.0 kg/cm²·g	19.0/2.0 kg/cm²·g
	Amount of SF_6 gas charged	150 kg	150 kg
	High pressure part volume	744 *l*	744 *l*
	Low pressure part volume	1,023 *l*	1,023 *l*
	Pressure drop during one operation	max. 1.2 kg/cm²·g	max. 1.2 kg/cm²·g
	H-L balancing pressure	10.7 kg/cm²·g	10.7 kg/cm²·g
Setting	Operation-lock pressure (pressure switch)	High pressure E5: 14.5L–15.3R Low pressure E31: 4.7L–4.3R	High pressure E5: 14.5L–13.5R Low pressure E32: 3.8L–3.4R
	Reclosing-lock pressure (pressure switch)	High pressure E7: 17.8–18.6R Low pressure E4: 2.8L–2.5R	—
	Common use for operation-lock and reclosing lock (pressure switch)	High pressure E6: 15.6L–16.4R	High pressure E6: 15.6L–16.4R
	Pressure drop alarm (pressure switch)	Low pressure E1: 1.5 on–1.8 off	Low pressure E1: Same as left
	Gas compressor start (pressure switch)	Low pressure E2: 23 on–20 off	Low pressure E2: Same as left
	Pressure switch change (thermostat)	High pressure E8: 20°C {E7 E6, E6 E5} 24°C {E5 E6, E6 E7}	High pressure E8: 20°C E6→E5 24°C E5→E6
	Heater (thermostat)	Up Down T21 21° off–15° on T1 70° off–65° on	Up Down T22 21° off–15° on T1 70° off–65° on
	Safety valve	High pressure Discharge to low pressure part at 25 kg/cm²·g	High pressure Same as left
	Breaking plate	Law pressure Discharge to atmosphere at 15~16.5 kg/cm²·g	Low pressure Same as left

a gas compressure. The construction is of the closed cycle type. The rated pressure for normal duty and auto-reclosing is 19 kg/cm²·g (high pressure) and 2 kg/cm²·g (low pressure). The operation-lock pressure for high speed auto-reclosing is the same as that

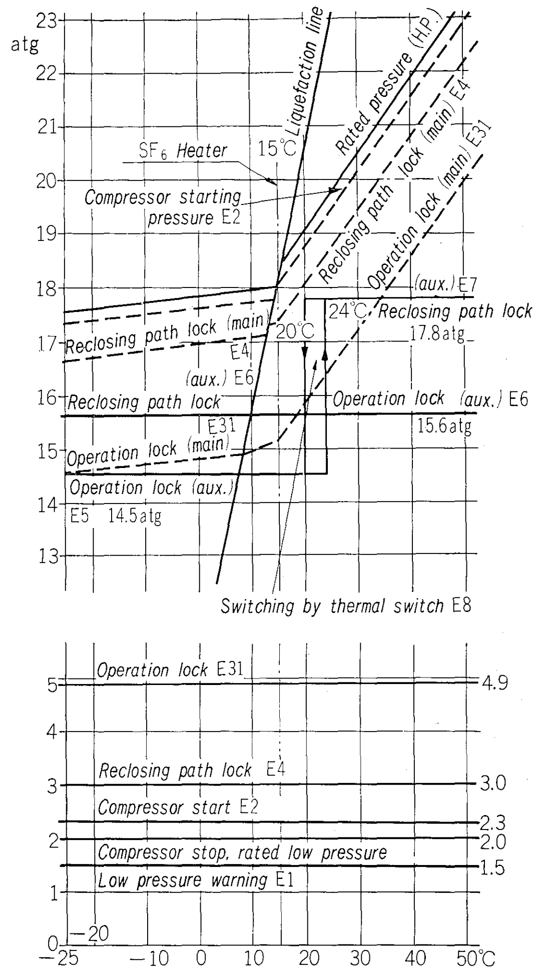


Fig. 1 Pressure vs. temperature characteristics of SF_6 system (for high speed reclosing)

for normal duty. Therefore the number of CO cycles from the rated pressure are 4 for auto-reclosing and for normal duty when the gas compressure is not operating. *Fig. 1* shows a gas control chart for high speed reclosing.

III. F-SCHALTER CONSTRUCTION AND FEATURES

An outer view of HF912 F-Schalter with one pole is shown *Fig 2*. *Figs. 3* and *4* are outline drawings of 3 pole breakers with and without reinforcing insulators respectively. *Fig. 5* shows a sectional view of a one pole breaker. Since these breakers are for high voltages, the pole-to-pole distance is a standard 5 m for 300kV (4 m for 240kV). For economy, the supporting insulators are arranged vertically on independent breaker bases. On top of these insulators, two breaking units are arranged at right angles to the pole-to-pole direction. The equalizing capacitors are attached horizontally directly under the breaking unit insulators and are fixed firmly to a case containing a link mechanism known as the breaker head for driving the moving contact, a cam mechanism for raising the blast valve and an interrupting spring. A high pressure gas tank is attached to the top of

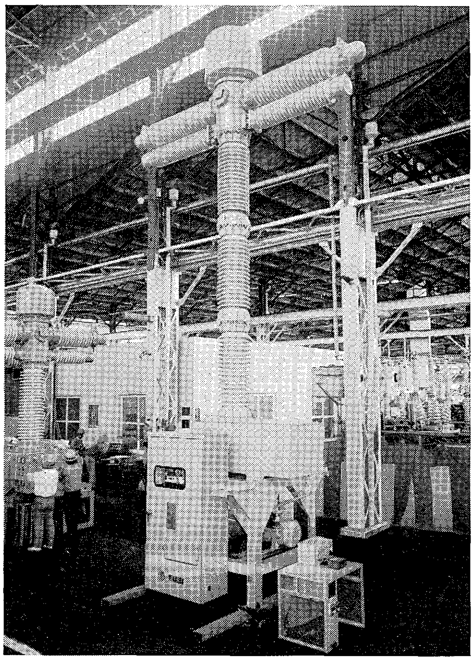


Fig. 2 F-Schalter 300 kV 20 GVA 4,000 A

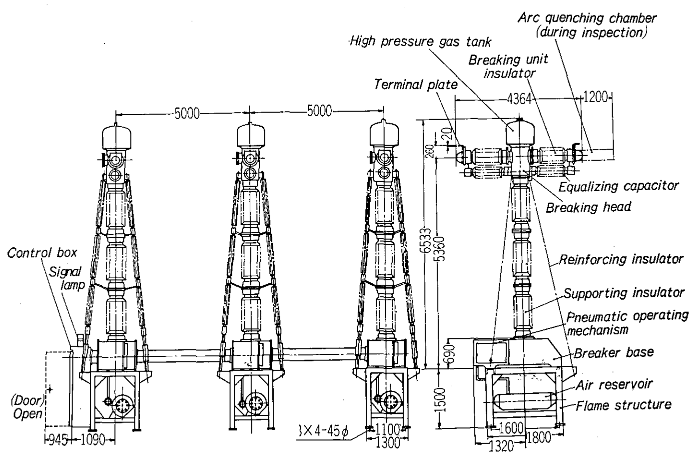


Fig. 3 Outline of 300 kV F-Schalter

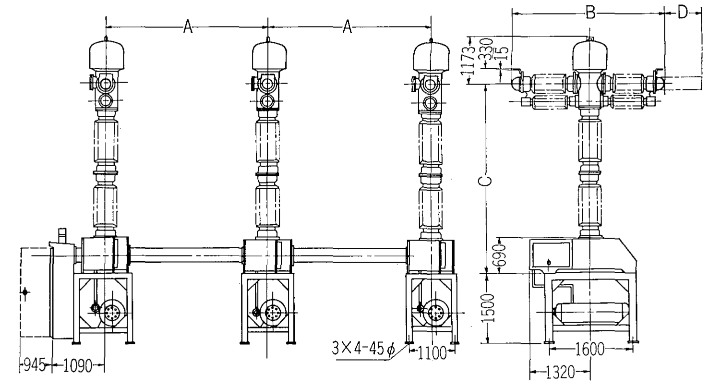
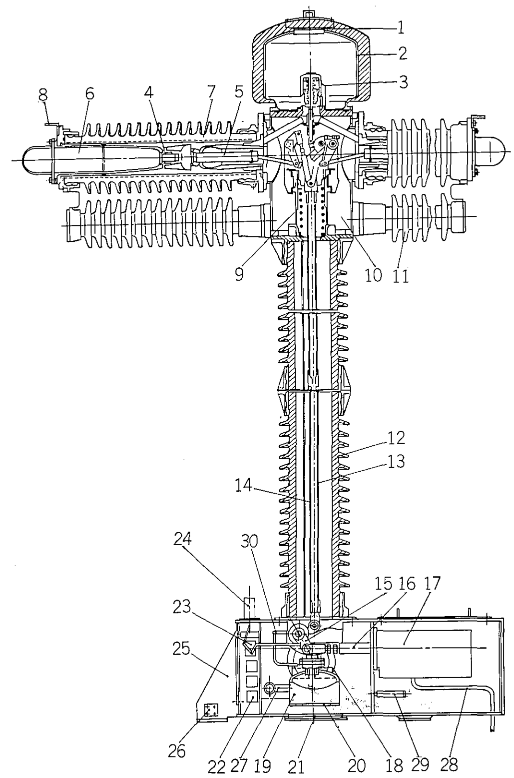


Fig. 4 Outline dimensions of Type HF912 SF_6 gas circuit breaker



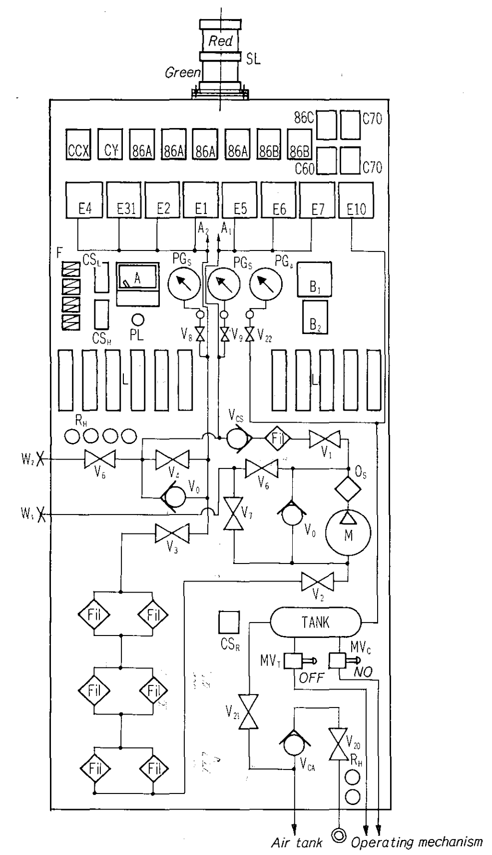
1. Inspection cover
2. High pressure bonnet
3. Blast valve
4. Fixed contact
5. Moving contact
6. Buffer chamber
7. Breaking unit insulator
8. Terminal plate
9. Interruting plate
10. Breaking head
11. Equalizing capacitor
12. Supporting insulator
13. Insulated operating rod
14. High pressure piping
15. Crank
16. Operating rod
17. Pneumatic operating mechanism
18. Dash pot
19. Heater box
20. Gas heater
21. Inspection window
22. Thermostat
23. Auxiliary switch
24. Signal lamp
25. Breaker case
26. Grounding terminal
27. High pressure piping
28. Air piping
29. Space heater
30. Low pressure piping

Fig. 5 Sectional view of F-Schalter

this case. Under normal conditions, high pressure gas is stored in this tank and high pressure SF_6 gas is supplied from the high pressure gas reservoir inside the breaker base at ground potential via an insulated tube. This high pressure gas is liquified under the liquifaction curve conditions shown in *Fig. 1* but the liquified gas is returned to the high pressure gas reservoir in the lower part via the insulated tube. A gas heater is located in the high pressure gas reservoir and this heater vaporizes the liquified gas which is once again supplied to the high pressure gas tank. Generally, there is only one high pressure gas reservoir for 3 poles but in F-Schalter for the very cold region there is one reservoir for each pole.

The high pressure gas system which comes into direct contact with the arc quenching medium has all parts exposed to the air covered with heat insulation material in order to prevent gas liquification caused by the cooling effect of the air. A protective cover is provided over that heat insulation material in the high pressure gas tank and there is a double wall of heat insulation materials covering high pressure gas reservoir. Because of these measures, the capacity of the gas heater can be rather low, which is a big feature of these breakers.

There is a blast valve inside the high pressure gas tank and the high pressure gas is kept separate from the low pressure part by this valve. When a breaking command is given, the operating mechanism in the breaker base operates, and the operation movement is transferred via the link mechanism to the insulated operating rod inside the supporting insulator, the interrupting spring in the breaking head is



SL : Switch indicator lamp
CCX : Closing contactor
CY : Anti-pumping contactor
86A : Operation lock contactor
86B : Reclosing-lock contactor
86C : Closing-lock contactor
C70 : Changing contactor for thermostats
C60 : Electromagnetic starting switch for gas compressor
E4 : Reclosing-lock pressure switch (low pressure gas)
E31 : Operation-lock pressure switch (low pressure gas)
E2 : Pressure switch for gas compresor starting (low pressure gas)
E1 : Pressure switch for pressure-drop alarm
E5 : Pressure switch for operation-lock (high pressure gas)
E6 : Pressure switch for reclosing-lock (high pressure gas)
E7 : Pressure switch for reclosing-lock (high pressure gas)
E10 : Pressure switch for closing-lock (compressed air)
F : Fuse
CS_L : Switch for on-off indicating lamp
CS_H : Switch for heater source
PL : Pilot lamp for heater source
A : Current meter for detecting heater disconnection
PG_S : Pressure gauge (for high pressure and low pressure gas)
PG_Q : Pressure gauge (for compressed air)
B1 : Autobreaker for gas compressor motor
B2 : Autobreaker for gas heater
L : Temrinals
R_H : Space heater
W_1, W_2 : SF_6 gas inlet and outlet apparatus
$V_1 \sim V_9$: Stop valve (for gas)
V_0 : Safety valve (for gas)
V_{CS} : Non-return valve (for gas)
O_S : Oil separator (for gas)
M : Gas compressor
Fil : Filter (for gas)
COS : Changing switch for detecting heater disconnection
CSR : Switch for detecting heater disconnection
TANK : Auxiliary air tank for manual operation
MV_T : Manual operating valve (tripping)
MV_C : Manual operating valve (closing)
V_{CA} : Non-return valve (for compressed air)
$V_{20} \sim V_{22}$: Stop valves (for compressed air)
A_1 : High pressure pipe
A_2 : Low pressure pipe

Fig. 6 Control box of F-Schalter

released, the cam mechanism operates, the blast valve is opened and the high pressure gas enters into the breaking unit. The surface of the high pressure gas seal is precision finished and since the majority of the high pressure gas part is surrounded by low pressure gas, there are no gas leaks to the exterior.

In addition to the high pressure gas reservoir, the breaker base contains an pneumatic operating mechanism, auxiliary switches, oil dush-pot and magnetic contactors. Since there is single phase reclosing in HF912 type, a pneumatic operating mechanism is located in each phase. The gas compressor, gar pressure control devices, gas filters for high and low pressure, magnetic switches, air pressure control devices, manual control equipment at the site and terminals are all compactly assembled in single control boxes which are convenient for maintenance and inspection. *Fig. 6* shows the arrangement of equipment in these control boxes. All cotrol operations are performed by this control box. The features of the F-Schalter are as follows.

1) Interrupting capability is excellent

There is no parallel resistance and breaking under the short line fault conditions specified in JEC and IEC standards presents no problem.

2) Contact damage is minimum

The contacts have a long service life and need not be changed for up to 50 short circuit current interruptions.

3) Construction is simple

The operating system is all connected by link mechanisms and is easy to understand. Maintenance of rotating parts within the SF_6 gas is not necessary since metal bushings finished with teflon are employed.

4) Construction is compact

The control system is compactly assembled in a single control box and inspections are possible even when the lines are live.

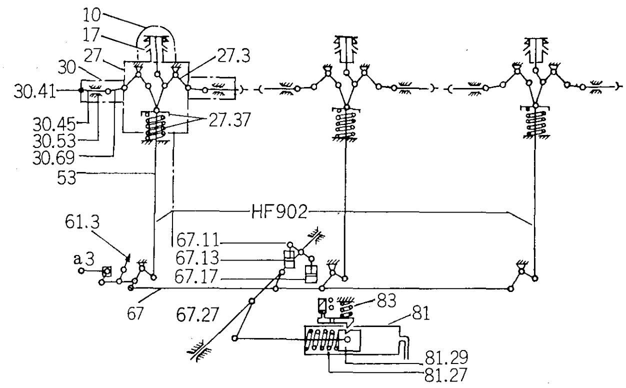
5) The noise level is low

The noise during operation is greater during closing than during interrupting but since the operating devices are all sealed within the breaker base, the noise, is much lower than that of other breakers such as the ABB. Hardly no noise can be detected at a distance of 20 m.

IV. CONSTRUCTION AND OPERATION OF F-SHALTER

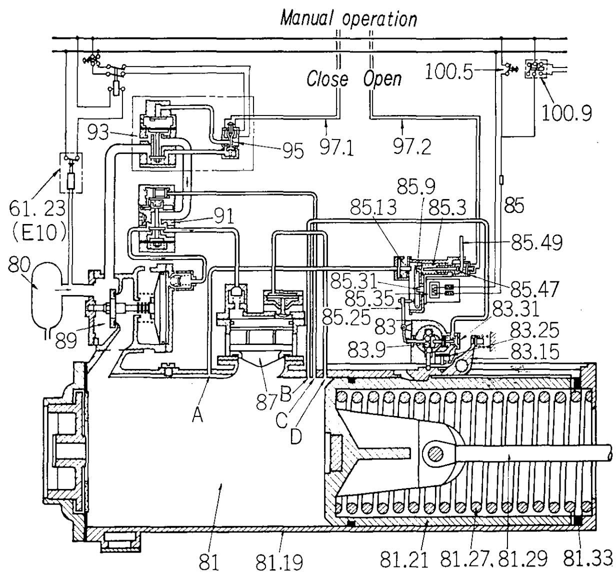
Figs. 7, 8 and *9* show the operating principle, a sectional view of the pneumatic operating mechanism, and the SF_6 gas flow respectively. The principles are the same as in HF904 type and 902 type and in this respect they are interchangeable. Since HF912 type employs separate operating devices in each phase, the same units as in HF904 type are used. These are more compact than those of HF902 type.

The liquefaction properties of SF_6 gas as shown



a 3	Auxiliary switch	61.3	ON-OFF indicator
10	High pressure bonnet	67	Connection rod
17	Blast valve	67.11	Intermediate shaft
27	Intermediate link mechanism	67.13	Oil dash-pot (trip)
27.3	Crank	67.17	Oil dash-pot (close)
27.37	Main spring	67.27	Connecting rod
30	Breaking unit	81	Pneumatic operating mechanism
30.41	Fixed contact	81.27	Auxiliary spring
30.45	Moving contact	81.29	Piston
30.53	Cross head	83	Ratch mechanism
30.59	Connecting rod		
53	Insulated operation rod		

Fig. 7 **Principle of link mechanism**



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

Fig. 8 **Sectional view of pneumatic operating mechanism**

in the liquefaction curve in *Fig. 1* are related closely to the pressure and temperature, and liquefaction becomes easier when the high pressure gas is reduced to low temperatures. Therefore, during automatic

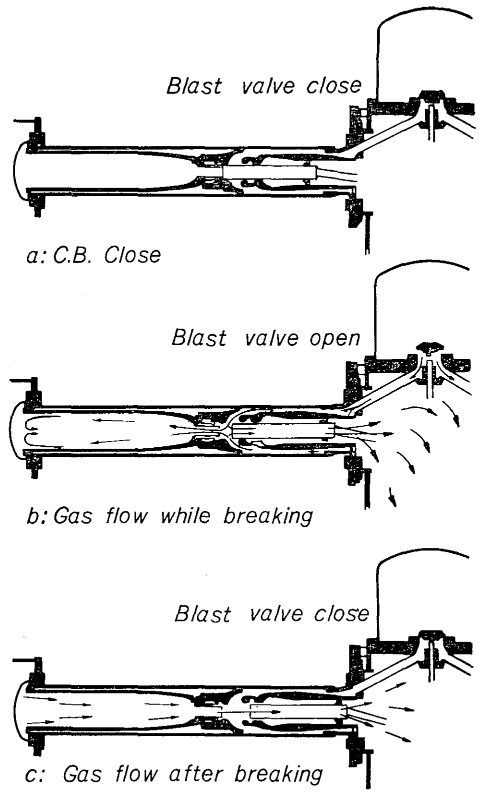


Fig. 9 **SF_6 gas flow**

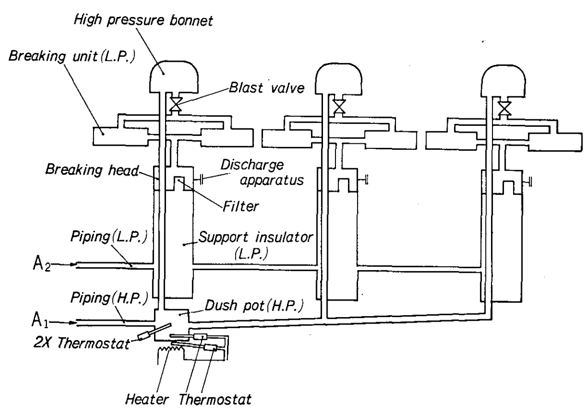


Fig. 10 **Explanatory diagram of SF_6 gas system**

reclosing for example, the heater is switched on if temperature of the gas drops to 15°C. As was mentioned previously, the heater is located in the bottom of the high pressure gas reservoir and is controlled by a temperature switch. In order to investigate gas control of temperature characteristics, drop in gas pressure when the auxiliary power source is shut off, etc., site tests were carried out in the cold region of Nayoro city in Hokkaido from the winter of 1969 to the spring of 1970. The details of these test will be given in a separate article.

V. TEST RESULTS

In HF912 type, the 90kV unit voltage of the previously completed HF902 and 904 types has been increased to 140 kV. The units, however, are all interchangeable and the operating characteristics are all the same so that when considering the unit voltage, exactly the same breaking characteristics are obtained for all of these types of breakers. The only structural difference is that the side of the breaking unit insulator has been increased because of withstand voltage and salt contamination density considerations. A part of the test results for HF912 type is has given below.

1) Operating characteristics

The operating characteristics are shown in *Table 4*. For the high speed reclosing characteristics, a reclosing time of 0.25 sec. is guaranteed.

2) Insulation withstand tests

Power frequency and impulse withstand voltage tests were performed at pressure-drop alarm pressure of 1.5 kg/cm^2 · g. For all the day and wet conditions specified in JEC standards, there was no insualation problem at voltages of AC 460 kV and impulse 1,050 kV.

3) Interruption tests

All items concerning the results of interrupting tests at the 300 kV, 20 GVA ratings are given in *Table 5*. Under interrupting conditions of out-of-phase, SLF, terminal short circuits and charging currents, an operation-lock pressure of 15.8 kg/cm^2 · g can be guaranteed.

VI. CONCLUSION

Fuji Electric has completed its 300/240 kV 20/15 GVA HF912 type with two breaking units. This series has already undergone the type tests of major power campanies. Since 1969, Fuji Electric has introduced technology from Siemens and adapted it to Japanese conditions in a concerted effort to develop new circuit breakers. In the field of SF_6 circuit breakers, special emphasis has been placed on such structural revisions as SF_6 gas leakproofing in addition to the excellent arc quenching properties of the SF_6 gas, and it is no exaggeration to say that superior breakers have been achieved.

In this respect, every effort has been made to supply products of maximum reliability and highest quality to meet all users' needs through such measures as careful quality-control, dust-proof assembly areas in our factory, highly sensitive leak tests, material defect checks using ultrasonic probes, special processing tools for packing surfaces, surface treatment protective devices and special protective measures for transport, The authors hope to hear from users concerning these breakers.

Table 4 **Characteristics of operation**

Closing characteristics			Tripping characteristics	
Operating pressure (kg/cm^2·g)	Control voltage (V)	Closing time (ms)	Tripping voltage (V)	Opening time (ms)
12.7	75	97	60	40
15	100	91	100	34
16.5	125	86	125	34
16.5	75	93		

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(4) Nagasawa: Earthquake resistance of 300 kV gas circuit breaker (HF904) and enclosed switching equipment (VMH), Fuji Journal 43 No. 5 (1970)

Type HF917M/250/$\frac{2000D}{4000D}$

Table 5 **Summarized data of interrupting tests**

Control voltage 100%

Test		Duty cycle	Test method	No. of break unit	Gas pressure (kg/cm^2·g)	Test voltage (kV)	Recovery voltage (%)	Breaking current AC component (kA)		Arc time (~)	Reactive voltage: Peak voltage (kV)		Frequency (kHz)		RRRV (kV/μs)		Times tested	Ramarks
								Objective value	Practical value		Objective value	Practical value	Objective value	Practical value	Objective value	Practical value		
Short circuit		10% 0-0.21^S-CO-1^M-CO	Single phase direct	1	18.0	120	100~103	4.0	3.0	0.50~0.83	238	267	1.9	4.0	0.905	2.14	1	Our max. testing ability
		30% 0-1^M-0-3^M-0	Weil's synthetic test	1	15.8	120	102~104	12.0	12.1	0.46~0.50	238	242	1.9	2.5	0.905	1.21	1	Our max. testing ability
		60% 0-1^M-0-3^M-0	Weil's synthetic test	1	15.8	120	102~109	24.0	24.7	0.50~0.56	238	259	1.9	2.3	0.905	1.19	1	
		110% 0-0.23^S-CO-1^M-CO		1	18.0	11.5	8.45	42.0	42.5~44.0	0.60~0.62	238	21.0	1.9	7.25	0.905	0.304	1	
		110% "0"	Weil's synthetic test	1	15.8	120	101	42.0	42.5	0.55~0.65	238	241	1.9	2.6	0.905	1.25	3	
Phase opposite		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Out of phase		25% 0-3^M-0	Weil's synthetic test	1	15.8	195	21.1E	10	10.8	0.50~0.52	325	347	0.48	2.22	0.312	1.54	1	
Short line fault		60% 0-3^M-0	Weil's synthetic test	1	15.8	92	100	24	24.4	0.50~0.55	83 (104)	(130)	10.2	11.1	1.70 (2.11)	(2.93)	1	
		75% 0-3^M-0	Weil's synthetic test	1	15.8	92	100	30	30.5	0.43~0.60	52.0 (62.5)	(75.6)	20.5	21.4	2.13 (2.54)	(3.54)	1	
		90% 0-3^M-0	Weil's synthetic test	1	15.8	92	100	36	36.5	0.45~0.46	20.8 (24.1)	(26.0)	61.7	55.1	2.56 (2.97)	(3.96)	1	
Small current	Breaking of inductive current	0	Single phase direct	1	21.0	92	100	20	21.9	0.25~0.45	—	—	—	—	—	—	12	Overvoltage multiple less than 2
	Breaking of charging current	0	S & S method	1	15.0	92	100	200	20.4	0.23~0.50	—	—	—	—	—	—	12	No reignition and on restrike

Note) Recovery voltage values of short line faults in parentheses are those of per one breaking unit (line side+power source side).