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SF_6 GAS CIRCUIT BREAKERS WITH HYDRAULIC OPERATING MECHANISM

Kohichi Iwata
Makoto Hirata
Toshihiko Nakamura
Yosuke Sasaki

1 INTRODUCTION

Fuji Electric developed a hydraulic operating mechanism for gas circuit breakers in 1973, and has applied it to all the gas circuit breakers of 72.5 kV or larger capacities. Since then, the gas circuit breakers with hydraulic operating mechanism have been delivered to and welcome by the electric power utilities and demand holders in the worlds as circuit breakers which meet with the various requirements charged to the circuit breakers. On the other hand, the recent economical environment is becoming more and more sever, and further energy-saving, compact and maintenance-saving machines and equipment are required in the electric power industries.

In order to cope with the needs, Fuji Electric has systemized series of the circuit breakers. This paper introduces the series and features of the Fuji Electric's presently manufactured circuit breakers.

2 FEATURES

Fuji Electric's hydraulic operating mechanism type gas circuit breakers have the following features:

- High reliability
- Small in dimensions and light in weight
- High performance
- Low noise
- Installation ease
- Maintenance ease

The Fuji's hydraulically operated circuit breakers with the above listed features have been developed by the following methods.

2.1 Reducing dimensions of arc-quenching chamber

An arc-quenching chamber of high current breaking performance is itself very compact and also capable of reducing the dimensions of the associated operating mechanism. To look for an arc-quenching chamber of this idea, Fuji Electric researches the essence of the puffer type arc-quenching chamber by fully using the most advanced technologies such as arc observations, calculation of electric field, measurement of puffer pressure during current breaking, and on-load operation analyzating programs.

2.2 Reducing dimensions of hydraulic operating mechanism

The hydraulic operating mechanism operated by 320 kgf/cm^2 hydraulic pressure is small in dimensions. Further, to improve reliability, number of the parts used in the hydraulic system is minimized, and an idea of "Block structure and piping less" has fully employed in Fuji's hydraulic operating mechanisms.

2.3 Aiming at the scale merit by using the parts for all series commonly

Based on such an idea as that to enhance reliability of gas circuit breakers and to reduce production cost, same parts should be used for all Fuji's gas circuit breakers, series of the arc-quenching chambers and hydraulic operating mechanisms have been simplified and parts have been used commonly among the various gas circuit breakers.

Table 1 and 2 indicate series of the arc-quenching chambers and hydraulic operating mechanisms.

2.4 Minimum maintenance

In addition to the reliability improvement of the arc-quenching chamber parts, maintenance free features of the gas sealed parts are further advanced by executing rust-proof countermeasures on the gas tight flange. Also for the hydraulic operating mechanisms, the minimum mainte-

Table 1 Series of arc-quenching chamber

Breaking current / Voltage	25	31.5	40	50
72.5	G1	G2		
123				
145				
170				
245				G3
300				

nance is further advanced by using valve assembly.

3 RATINGS AND SPECIFICATIONS

Fuji Electric's gas circuit breakers consist of two series; namely dead tank type BAK series and porcelain type BAP series. Because of the user's idea, the dead tank type is more demanded domestically, and porcelain type is more demanded in the overseas. Reduction of space and economically improving effect due to the incorporation of bushing current transformer can also be expected on the dead tank type of higher voltage classes such as 245 kV, andmany of these have been delivered to the overseas.

Table 3 shows the series of hydraulically operated gas circuit breakers, and *Tables 4* and *5* respectively show the ratings and specifications of BAP6 and BAP5/BAK5.

Figs. 1 and *2* respectively show the appearances of 145 kV 25 kA porcelain type BAP6 and 170 kV 40 kA dead tank type BAK5.

Moreover, the gas circuit breakers shown in *Table 5* are also applied as a circuit breaker of a gas insulated switchgear.

Table 2 Series of hydraulic operating mechanism

Rated voltage (kV)	Porcelain & tank type outdoor GCB	GCB for GIS
72.5	EA3–1	EA3–2
123		
145		
170		
245	EA3–3	
300		

Table 3 Series of gas circuit breakers with hydraulic operating mechanism

Rated voltage (kV)	Rated breaking current (kA)			
	25	31.5	40	50
72.5	BAP6			
123		BAP5 / BAK5		
145				
170				
245				
300				
362				

Table 4 Ratings and specifications of type BAP6 GCB

Model			BAP607	BAP612		BAP614
Rated voltage	[kV]	IEC, BS	72.5	–	123	145
		ANSI	72.5	–	121	145
		JEC	72	84	120	–
Power frequency withstand voltage	[kV]	IEC, BS	140	–	230	275
		ANSI	160	–	260	310
		JEC	140	160	230	–
Lightning impulse withstand voltage	[kV]	IEC, BS	325	–	550	650
		ANSI	350	–	550	650
		JEC	350	400	550	–
Rated normal current	[A]		400 ... 2000			
Rated short-circuit breaking current	[kA]		25			
Total break time	[cycles]		3			
Rated operating sequence		IEC, BS	O-3min-CO-3min-CO, CO-15sec-CO, O-0.3sec-CO-3min-CO**			
		ANSI	CO-15sec-CO, O-20cycles-CO**			
		JEC	O-1min-CO-3min-CO, CO-15sec-CO, O-0.3sec-CO-1min-CO**			
Rated short-circuit making current	[kA peak]		62.5			
Rated short-time current	[kA]		25			
Auxiliary power requirements of hydraulic operating mechanism			Three-phase AC 200/220V*0.75 kW			
Rated pressure of hydraulic operating mechanism [kgf/cm²]			320			

* Other value upon request ** In case of high speed auto-reclosing type

Fig. 1 145 kV 25 kA porcelain type gas circuit breakers BAP614

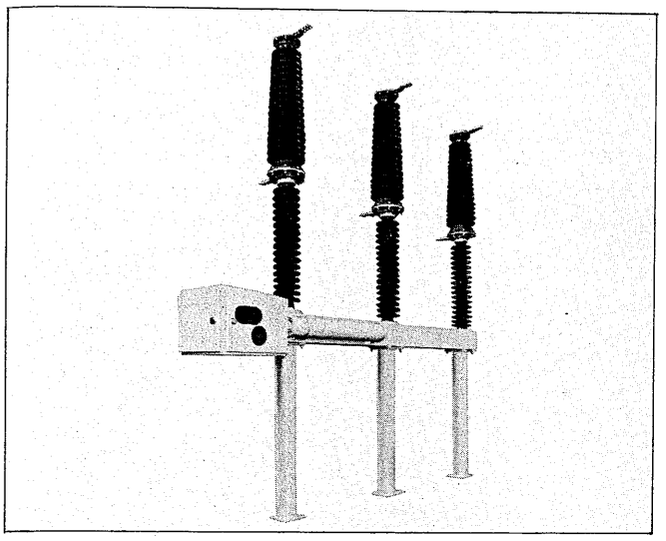
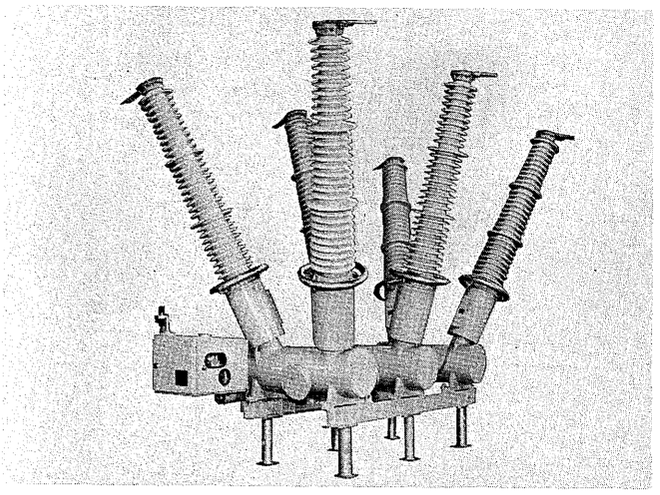


Fig. 2 170 kV 40 kA dead tank type gas circuit breaker BAK517



4 CONSTRUCTION AND DESIGN CONCEPT

4.1 Construction

Figs. 3 and 4 respectively show the constructions of model BAP5 porcelain type gas circuit breaker and type

Fig. 3 Cross-sectional view of model BAP5 porcelain type gas circuit breaker

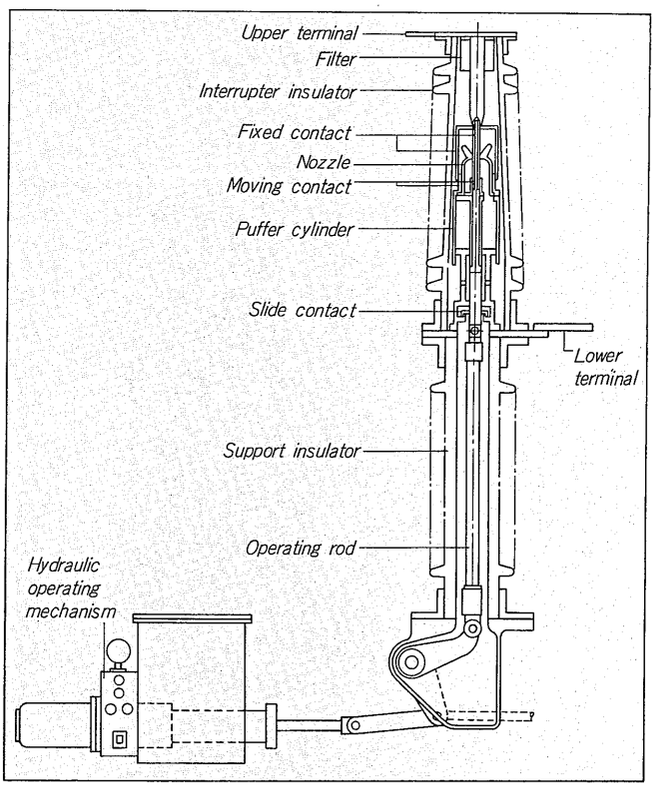


Table 5 Ratings and specifications of type BAP5/BAK5 GCB

Model (BAP: porcelain type / BAK: dead tank type)		BAP507 BAK507	BAP512 BAK512	BAP514 BAK514	BAP517 BAK517	BAP524 BAK524
Rated voltage [kV]	IEC, BS	72.5	123	145	170	245
	ANSI	72.5	121	145	169	242
	JEC	72	120	–	168 168	240
Power frequency withstand voltage [kV]	IEC, BS	140	230	275	325	395/460
	ANSI	160	260	310	365	425
	JEC	140	230	–	325	395
Lightning impulse withstand voltage [kV]	IEC, BS	325	550	650	750	950/1050
	ANSI	350	550	650	750	900
	JEC	350	550	–	750	900
Rated short-circuit making current [kA peak]		1200 3000			1200 4000	
Rated short-circuit breaking current [kA]		31.5	40			
Breaking-time [cycles]		3				
Rated operating sequence	IEC, BS	O-3min-CO-3min-CO, CO-15sec-CO, O-0.3sec-CO-3min-CO				
	ANSI	CO-15sec-CO, O-20 ~-CO				
	JEC	O-1min-CO-3min-CO, CO-15sec-CO, O-0.35sec-CO-1min-CO				
Rated short-circuit making current [kA peak]		80	100			
Rated short-time current [kA]		31.5	40			
Auxiliary power requirements of hydraulic operating mechanism		Three-phase AC 200/220V (other values upon request)				
Rated pressure of hydraulic operating mechanism [kgf/cm^2]		320				

Fig. 4 Cross-sectional view of interrupter and linkage mechanism

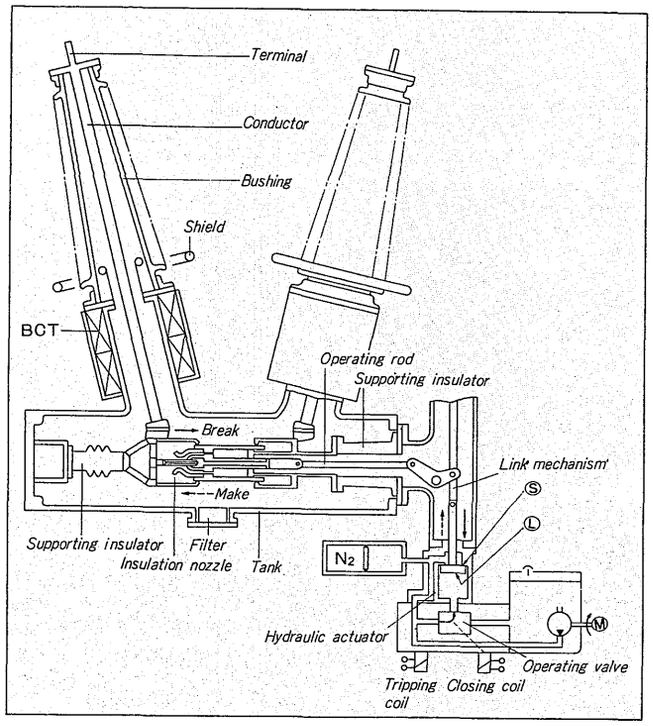
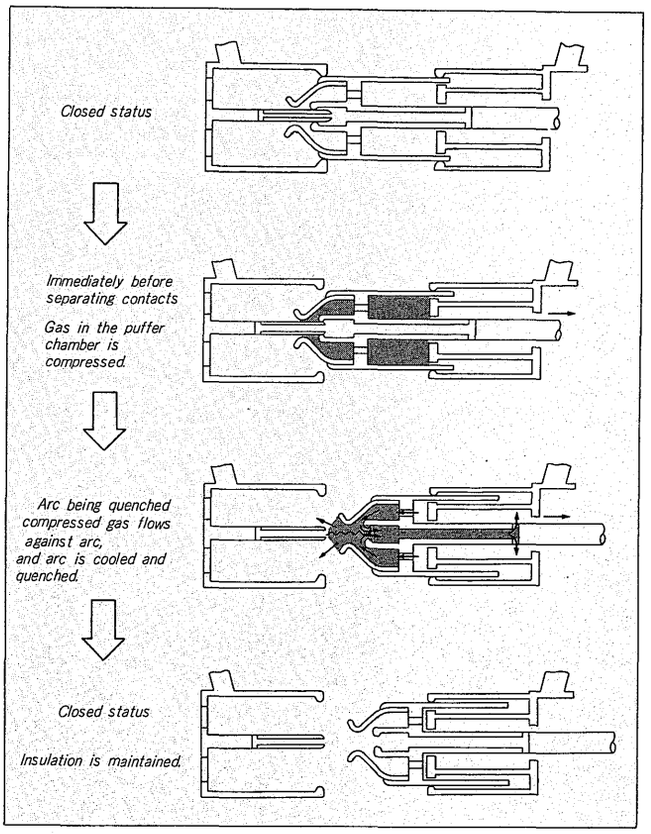


Fig. 5 Breaking system



BAK5 dead tank type circuit breaker. The basic construction of the BAP6 porcelain type circuit breaker is the same as type BAP5 except for the smaller arc-quenching chamber than that of the type BAP5.

For both closing and breaking, this gas circuit breaker is operated by 320 kgf/cm^2 hydraulic oil. In case of the three-phase encapsulated type, the link mechanism connected to the three-phase insulation operating rods is driven by one hydraulic actuator. Further, in case of a single-phase reclosing, the hydraulic actuator and hydraulic operating mechanism are directly connected to each phase.

4.2 Interrupter unit

Fig. 5 shows a circuit breaking system. The interrupter of this gas circuit breaker uses a double flow arc-quenching chamber, and all gas circuit breakers, the constructions are same. The arc-quenching chamber consists of an arcing contact in a double flow construction, insulation nozzle, current carrying main contact surrounding the arcing contact and insulation nozzle, etc.

4.3 Hydraulic operating mechanism

Table 6 shows the specifications of the hydraulic operating mechanism and *Fig. 6* shows the hydraulic system. Fuji Electric's hydraulic operating mechanism does not use oil piping at all including the hydraulic actuator, except for the only piping between the hydraulic operating mechanism and accumulator (due to the overall circuit breaker composition, the hydraulic operating mechanism must be separated from the accumulator).

Other main features of this hydraulic operating mechanism are:

Table 6 Specifications of hydraulic operating mechanism

Item		EA3-1	EA3-2	EA3-3
Oil pressure (kgf/cm^2)	Safety valve operating pressure (maximum pressure)	390		
	Pump stopping pressure	maximum 350		
	Pump operating pressure (rated pressure)	320		
	Reclosing lock pressure	295		
	Closing lock pressure	270		
	Tripping lock pressure	250		
	Accumulator N_2 gas sealing pressure	200		
Oil pump discharge capacity		0.75 *l*/min (at 1500rpm)		
Rated closing control voltage		DC 100 V		
Rated tripping control voltage		DC 100 V		
Rated motor output		3 ϕ, AC 200 V, 0.75 kW		

(1) For the entire range from 72 to 300 kV, the hydraulic operating mechanisms are arranged in a series without changing the fundamental design concept but changing the capacity and stroke only.
(2) Using steel ball valve, the valve changeover is separated from the opening function. As the result, large flow can be obtained with small volume of oil, allowing a high speed operation.
(3) Level of the parts management is enhanced by greatly reducing the dimensions and number of used parts, improving the reliability.

Next, the operating principle of the hydraulic operating mechanism is outlined. Compressed hydraulic oil discharged from the oil pump is stored in the accumulator always under a constant pressure, and when operating the mechanism, the oil is supplied to the hydraulic actuator. Further, the oil is always supplied to the rod site of the hydraulic actuator also. The hydraulic actuator is of a differential pressure type, and tripping and closing operations of the circuit breaker are hydraulically accomplished. To be more specific, the hydraulic actuator performs closing operation as the compressed oil is supplied to the head side, and as the oil is sent to the oil tank through the operating valve in the head side, the circuit breaker performs tripping operation. The valve operations are detailed as follows.

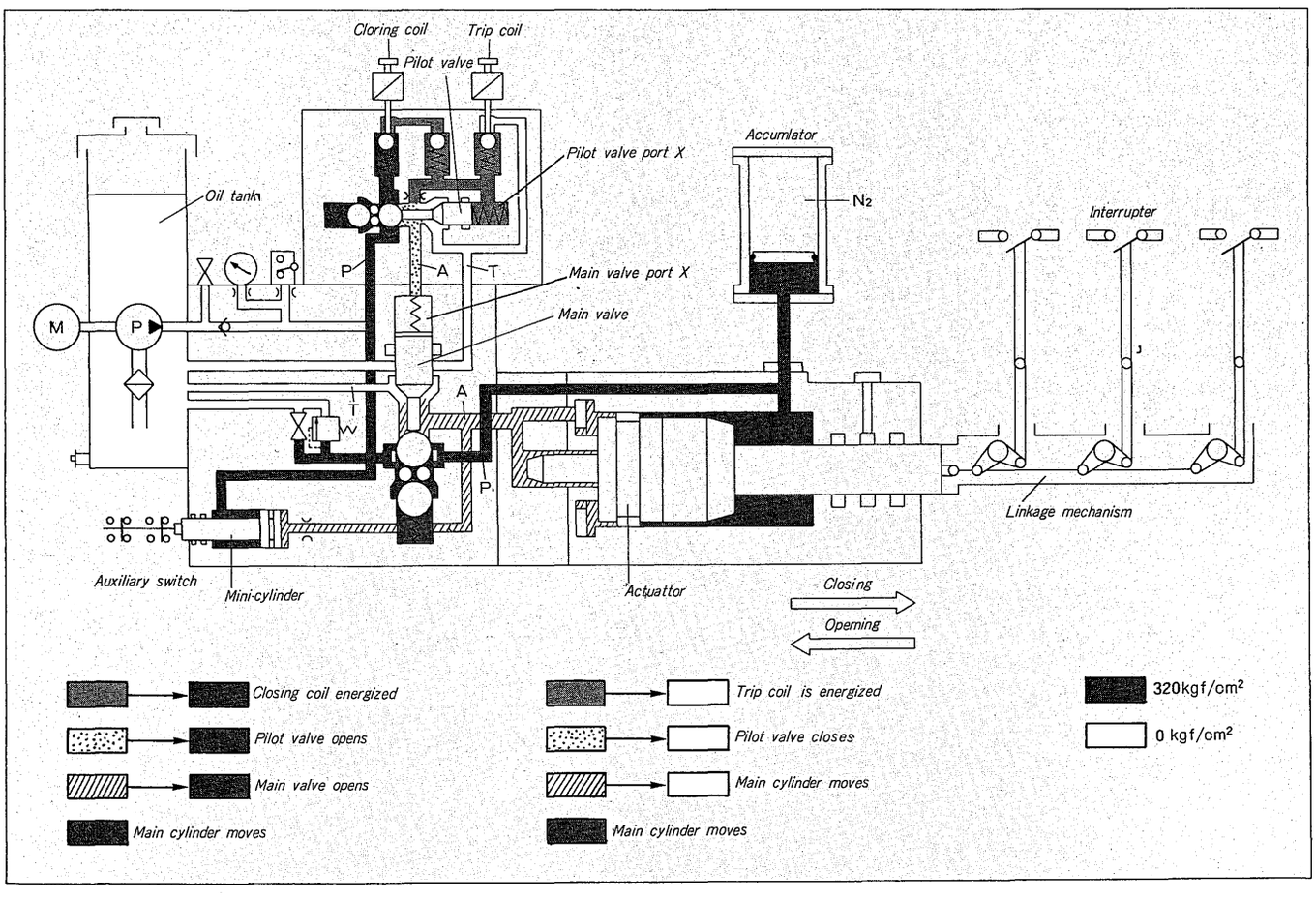
4.3.1 Closing operation

(1) When the closing coil is energized, the plunger is pushed downward, causing the steel ball seat to open. Then, high pressure oil is discharged, reaching the port X of the pilot valve through the check valve, and thus, the valve element of the pilot valve is moved to the left.
(2) The steel ball seat of the pilot valve opens, the high pressure oil goes to the port X of the main valve through the seat and port A, and the valve element of the main valve is pushed downward.
(3) The steel seat of the main valve opens, the high pressure oil goes to the head side of the actuator through the seat and port A, and actuator piston is pushed to the right.
(4) When the actuator piston moves to the right, the link mechanism connected to the piston moves to the circuit breaker closing directions, causing the main contact to close.
(5) Even if the closing coil is de-energized during the closing operation, the valve element of the pilot valve is self-held because the high pressure oil is discharged to port X from port A through the throttle.

4.3.2 Tripping operation

(1) When the tripping coil is energized, the plunger is pushed down, causing the steel ball seat to open, and high pressure oil is discharged from port X of the pilot valve to the oil tank.
(2) Then, the valve element of the pilot valve moves to the right, closing the stell ball seat, and high pressure oil is discharged from port X of the main valve to the oil tank through port A and port T of the pilot valve.
(3) The valve element of the main valve moves up, the steel ball seat closes, and when ports A and T of the main valve are joined, the high pressure oil in the head side of the cylinder is discharged to the oil tank.
(4) The actuator piston moves to the left, causing the main contact of the circuit breaker to be tripped.

Fig. 6 Hydraulic circuit diagram



5 TECHNOLOGIES TO REDUCE DIMENSIONS EMPLOYED IN FUJI GAS CIRCUIT BREAKERS

5.1 Reducing dimensions of arc-quenching chamber

As a method to reduce dimensions of the arc-quenching chamber and to improve current breaking performance further, the following technologies are used.

5.1.1 Separating main contact from arcing contact

To minimize metalic vapor generated between contacts during short-circuit current breaking, the arcing contacts made of arc-resisting metal (moving and stationary contacts) are separated from the main contact which surrounds the arcing contacts.

5.1.2 Use of double flow arc-quenching chamber

To rapidly exhaust the hot gas (ionized high temperature gas) generated during current breaking to the outside of the arc-quenching chamber at a proper timing, so called double flow arc-quenching chamber (which has exhaust holes in both the stationary and moving contacts) is used.

5.1.3 Actively employed self-arc-quenching effect

The self-arc-quenching effect can be accomplished by reducing puffer cylinder bore to the optimum diameter, optimizing cubic volume of the puffer chamber and by strengthening the blast gas pressure at the current zero point. Fuji Electric has developed a on-load operation calculation program, and decided the optimum puffer cylinder bore with this program. *Fig. 7* shows the analyzed puffer internal pressure rise occurred in a double flow arc-quenching chamber for 40 kA.

In this arc-quenching chamber, ratio of the pressure rise at current breaking is high, and this indicates that the arc energy produced during current breaking is led into the puffer chamber effectively, causing the internal pressure to rise.

5.2 Compact hydraulic operating mechanism

A large operating force can be obtained with 320 kgf/cm^2 operating oil pressure, and the operating mechanism is compact. (See *Fig. 8*.) Further, Fuji Electric's operating mechanism has the following featrues:

(1) The block coupling method developed by employing compound valves eliminates use of piping.
(2) For the valve elements of valves, steel balls are used, eliminating coaxial machining treatment on the case. Thus, compactness and reliability improvement can be accomplished.
(3) The cylinder and pump unit are connected to the operating valve.
(4) Number of parts is minimized.

Fig. 7 Comparison of pressure compositions between the conventional type and improved type arc-quenching chambers

	Arc-quenching method	Breaking current
Present standard arc-quenching chamber	Fouble flow	40kA
Conventional type arc-quenching chamber	Single flow	31.5kA
Model arc-quenching chamber	Double flow	40kA

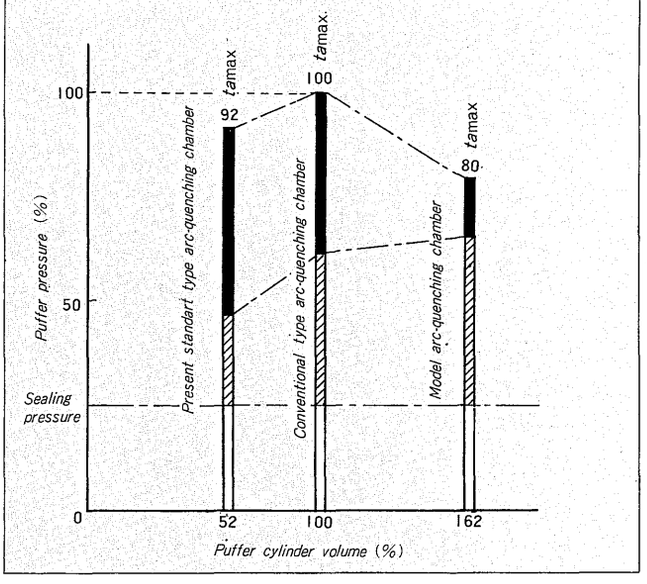
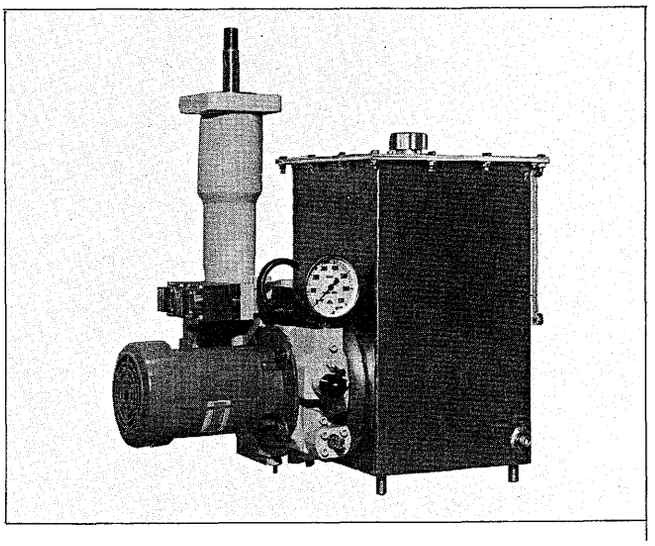


Fig. 8 Appearance of hydraulic operating mechanism



6 POST SCRIPT

Fuji Electric's hydraulic operating mechanism type gas circuit breakers were outlined, and the technologies employed in the series of GCBs were introduced. We will continue our efforts in improving the products with valuable advice and assistance provided by the users. We should like to ask the users for guidance.