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NEWLY DEVELOPED OIL-HYDRAULIC OPERATING UNIT FOR CIRCUIT-BREAKER

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I. INTRODUCTION

Fuji Electric has been producing the RF 951 and 952 series of single-pressure type SF_6 gas circuit-breakers which have shown excellent operating results in accordance with their stable performance and high reliability. The compressed air operating unit is used to drive these breakers but because of operating limitations, the double-pressure type SF_6 gas circuit-breaker is used as previously in the large capacity breaker field. In order to make possible the use of the single-pressure type breakers with their simple construction and many features in the large capacity field, it became necessary to develop a new, high performance operating unit.

There are two main types of breaker operating units: those employing compressed air and those employing oil-hydraulics. At present in Japan, compressed air operating units are widely used but the following features of the oil-hydraulic units have been confirmed:

(1) High driving force and good response
(2) Low operating noise
(3) Compact mechanism
(4) Low vibration because of small moving mass
(5) Less maintenance labor required
(6) Almost no effects from surrounding atmosphere
(7) Air compressor unnecessary

In Europe, the compressed air units are gradually being replaced by oil-hydraulic operating units. Already, the Siemens Co. of West Germany has completed this changeover. In Fuji Electric, the advantages of the oil-hydraulic units for the future have been noted and the plan is to use oil-hydraulics in new operating units.

As a result, the persons concerned have made considerable efforts and in a comparatively short time, a new oil-hydraulic operating unit has been developed for 3 cycle circuit-breakers. This unit will be introduced here. At present, these units have exhibited the features of high driving force and good response and an operating unit for 50 kA breakers is now under development but this will be described in a later article.

II. FEATURES OF THE NEW OIL-HYDRAULIC OPERATING UNIT

Compared with the previous oil-hydraulic operating units developed abroad, the new Fuji Electric unit has the following features:

(1) A trip free function has been provided oil hydraulically.
(2) For the source pressure, ultra high pressures of 300 kg/cm^2 or above are avoided and 210 kg/cm^2 which has been standardized and is widely used in Japan is employed so that safety is high and maintenance is easy.
(3) Since the block mount system is used for valve connections and external connection piping is unnecessary, the response is good and there is very little worry about oil leakage.
(4) The oil cylinder is connected directly to the bottom of the circuit-breaker and the piston rod is coupled directly with the insulated rod of the circuit-breaker so that no moving parts are on the outside, operation is safe and there are almost no gas leaks or mechanical losses during operation.
(5) Since oil-hydraulics are used not only for closing but also for opening, the driving force is high and response is good during opening.
(6) Operating noise was especially considered during design and it has been reduced considerably.
(7) An alarm circuit is provided to detect reduction in the amount of N_2 gas sealed in the accumulator, oil pump faults and oil leakage.

III. OIL-HYDRAULIC SYSTEM

1. Construction of System

The oil-hydraulic system consists of four main elements: the pump unit, the accumulator, the operating valve and the oil cylinder. These are all connected by high pressure piping. The movable arc contact of the breaker is directly coupled with the oil cylinder piston rod at ground potential on the bottom of the supporting insulator via the insulated rod, and no movable parts are exposed on

1. Oil tank
2. Oil gauge
3. Drain plug
4. Air breather
5. Oil pump
6. Motor
7. Filter
8. Check valve
9. Throttling valve
10. Safety valve
11. Stop plug
12. Dampener
13. Stop valve
14. Joint for standard pressure gauge
15. Pressure gauge
16. Pressure switch
17. Joint for portable pump (suction side)
18. Joint for portable pump (delivery side)
19. Joint for test pressure and vacuum gauge
20. Joint for test pressure and vacuum gauge
21. Operating valve
22. Solenoid valve for closing
23. Solenoid valve for opening
24. Accumulator
25. Oil piping
26. Oil cyiinder
27. Piston rod
28. Piston rod seal
29. Supporting insulator
30. Breaking chamber
31. Oil cylinder for auxiliary switch
32. Auxiliary switch
33. Auxiliary oil tank

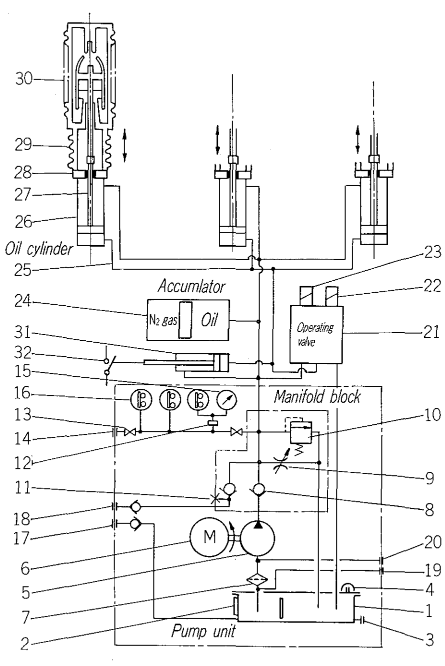


Fig. 1 **Oil-hydraulic circuit of F-Schalter (3-poles simultaneously operating type)**

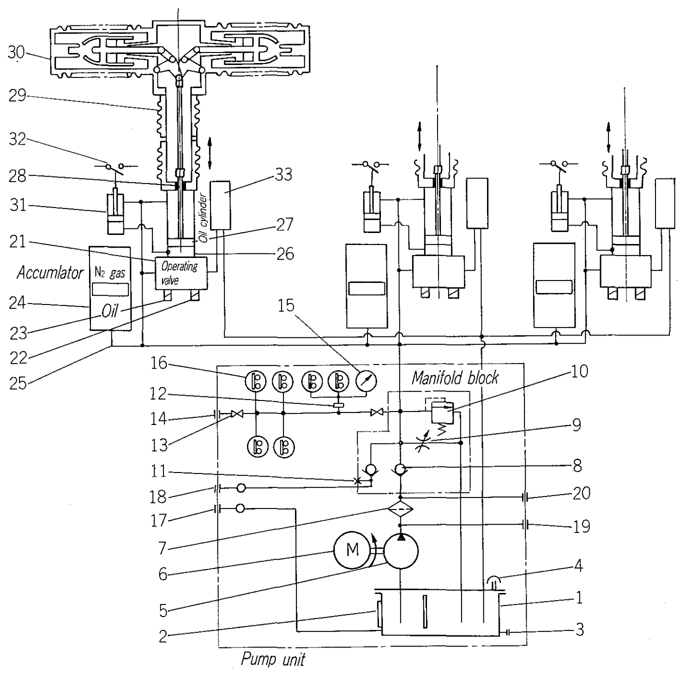


Fig. 2 **Oil-hydraulic circuit of F-Schalter (Each pole separately operating type)**

the exterior. Typical oil-hydraulic circuits are shown in *Figs. 1* and *2*. They are roughly classified into the 3-poles simultaneously operating type and the each pole separately operating type. In the former, the oil cylinders of 3-poles are driven simultaneously by the operating valve, and the pump unit and operating valve are contained in a control box as shown in *Fig. 3*. The accumulator is arranged under the control box frame. In the latter, operating valves are provided on the head side of the cylinder of each pole and it is of the single pole reclosing type in which each pole can be driven independently.

In this latter case, the accumulator is attached perpendicularly to the side surface of the base frame of each pole and even when the distance between the poles is great, oil can be supplied rapidly. The pump unit is located in the control box separated from the electrical compartment, that is convenient for handling. The cylinder for the auxiliary switch is located in the control box in the former or in the base frame in the latter and it can be aligned with the oil cylinder for the main contact. The operating valve, accumulator and cylinder for the auxiliary switch are the same for both cases and are all interchangeable.

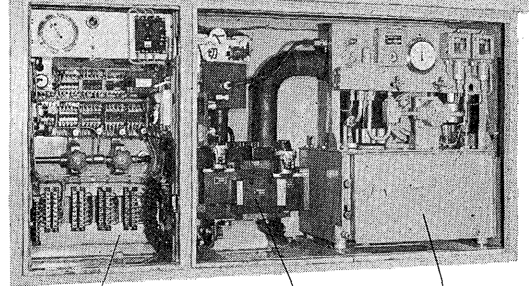


Fig. 3 **Control box**

2. Operating Principle

The oil injected from the pump unit is stored in the accumulator under a normal pressure within the 190～200 kg/cm² range. In this way, large amounts of oil can be supplied at the time of breaker operating. The oil from the pump unit is also normally supplied to the oil cylinder rod side. The oil cylinder is of the differential type and is operated by oil pressure both for closing and opening of the breaker. In other words, the cylinder performs closing operation by the charging of oil to the head side and opening operation by discharge of the head side oil. These operations are selected by changing over the operating valve. In the single pole reclosing system, the distance between the poles is great and the back pressure can not be disregarded. Therefore, after the oil discharged from the cylinder has once accumulated in the auxiliary tank, oil is then supplied to the main oil tank. Synchronization of the operation of each pole and the operating time of the auxiliary switch are adjusted by the throttles attached to each cylinder. When the power supply of the oil pump fails or a fault occurs, the portable pump can be connected to the quick coupler attached to the pump unit and oil can be supplied by simple operation.

IV. DETAILS OF EACH COMPONENT

1. Details of Oil-hydraulic Elements

Table 1 shows the names and the ratings of the main oil-hydraulic elements and also the numbers

Table 1 Ratings of the mechanical members for the oil-hydraulic operating unit

Name	Main specifications	No. for a curcuit breaker	
		3-pole simultaneously operating type	Each pole separately operating type
		1 break type 72～120 kV	2 break type 168～204 kV
Pump unit	As below	1	1
Filter	Paper element type 10 μ	1	1
Oil pump	Gear type 210 kg/cm² 2/2.4 ℓ/min	1	
	Gear type 210 kg/cm² 5/6 ℓ/min		1
Motor	AC 200/220 V 50/60 Hz 1.5 kW 4 p	1	
	AC 200/220 V 50/60 Hz 3.7 kW 4 p		1
Manifold block	1 safety valve, 1 throttling valve, 2 check valves included	1	1
Pressure gauge	500 kg/cm² 100 φ anti-vibration type with dampener	1	1
Oil pressure switch	For oil pump operation	1	1
	For operation locking at oil pressure drops	1	1
	For reclosing locking at oil pressure drops		1
	For over pressure alarm	1	1
Quick coupler	For portable pump connection	1	1
Oil tank	60 ℓ, with oil sight and air breezer	1	
	140 ℓ, with oil sight and air breezer		1
Auxiliary oil tank	10 ℓ		3
Accumulator	Piston type, 40 ℓ, N_2 gas injected, with gas valve	1	3
Operating valve	As below	1	3
Solenoid valve for opening	DC 100 V 5 A or 3.3 A	1	3
	DC 100 V 2×5 A or 2×3.3 A double coil type		or 3
Solenoid valve for closing	DC 100 V 5 A	1	
			3
	DC 33 V 5 A		
Locking valve		1	3
Servo-valve		1	3
Main valve		1	3
Oil pressure cylinder	A type, end cushion and throttle valve included	3	
〃	B type, end cushion and throttle valve included		3
Cylinder for auxiliary switch	C type, end cushion and throttle valve included	1	1
Operating oil	MIL H5606	60 kg	128 kg

of elements used in the 3-pole simultaneous and each pole separate systems.

In the system in which each pole is driven separately, there are twice the number of arc contacts and the load is larger than in the system in which the 3-poles are driven simultaneously. Therefore, the dimensions of the oil cylinder must be larger. Because of this, the pump capacity, motor output and oil tank are larger and the pump unit is comparatively big. The operating oil used must take into consideration the severe operating conditions required of circuit-breakers, operation in very cold regions, etc. and therefore, high quality operating oil (conforming to MIL standards) for aircraft which shows less viscosity changes with temperature is used and there is little deterioration over the years. Severe tests such as the leak test, pressure-withstand test, operating test and durability test are performed on the parts of each component and after assembly, a test is performed to check the overall characteristics. Their sufficient reliability is also assured in terms of quality control during manufacture.

2. Operating Valve

A more simple circuit to satisfy hydraulically trip free conditions has been used and the solenoid valve for opening, the solenoid valve for closing, the locking valve, the servo-valve and the main valve are all brought together in a block structure. Each valve is of the "poppet" type structure to reduce leaks and they are also of the form which is not influenced by viscosity change due to temperature.

For high speed and response, the solenoid valve for opening is extremely compact and the main valve is a bistable type valve of special structure. *Fig. 4* shows the construction of the operating valve.

3. Oil Cylinder and Accumulator

1) Oil cylinder

The cylinder flange part is directly coupled under the cover of the supporting insulator and the piston rod drives the insulated rod in the SF_6 gas via the piston rod seal part. In this way, no movable parts are exposed to the exterior so that operating safety is increased and the unit becomes more compact. Oil cylinders for circuit-breakers, unlike ordinary oil cylinders require rapid movement start because of the operating characteristics of the circuit-breaker and control equipment is also necessary to momentarily dampen the mechanical impact force at the end of the stroke because of the higher piston speed. Therefore, various model tests were performed on hydraulic cushions, quick starting devices, internal oil sealing devices, SF_6 gas seal mechanisms, etc., and a mechanically simplified oil cylinder for circuit-breakers was developed which shows sufficient operating capacity and mechanical durability. This oil cylinder is operated at a higher speed than that of any conventional oil cylinder and a pressure can be generated which is several times the pressure increase by means of the compressed air operating unit at the puffer cylinder inside the breaker. The breaking performance is also greatly improved.

The synchronization and speed regulation of each pole cylinder can be performed by adjustment of the throttle valve provided in the cylinders.

2) Accumulator

The accumulator is of the piston type with the N_2 gas and oil separated by piston packing. The gas is injected via the gas valve. The structure is simplified and handling is very easy. Various types of special tests were performed concerning external and internal N_2 gas leaks, and it has been confirmed that the accumulator is sufficiently durable for circuit-breaker use. There is also equipment provided which gives an electrical alarm in case an unexpected gas leak should occur. *Fig. 5* shows an outer view of the oil cylinder and accumulator.

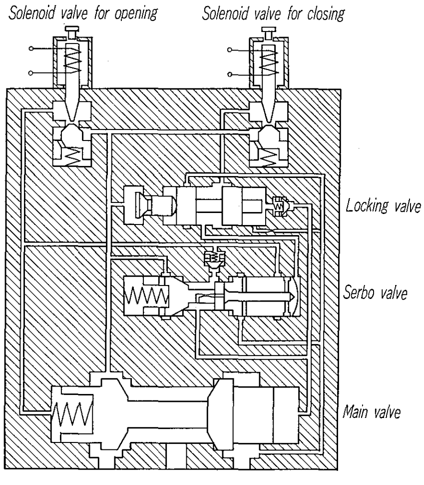


Fig. 4 Construction of operating valve

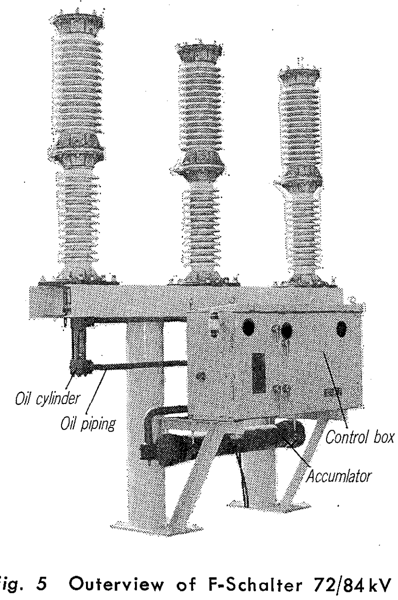


Fig. 5 Outerview of F-Schalter 72/84 kV

4. Pump Unit

The pump unit oil circuit diagram and specifications are shown in *Figs. 1* and *2* and *Table 1*. The various components are located on the top cover of the oil tank and they can be remove as an assembly. In order to prevent any oil leaks from the fittings, a safety valve, check valves and throttle valve are provided in the manifold block and except for parts removed as a component, all piping has been planned carefully to prevent oil leaks by the use of welded joints.

When there is an abnormal increase in oil pressure in the unit, the pressure is held to 250 kg/cm²•g or less by the safey valve, and damage to the unit is prevented.

Outside view of pump unit is shown in *Fig. 3*.

V. TEST RESULTS

1. Operation Test

Table 2 shows the operating characteristics for both the 3-pole simultaneously operating type and the each pole separately operating type. *Fig. 6* shows a typical operating oscillogram for the 3-poles simultaneously operating type.

2. Noise Test

The problem of noise hazard has arisen and there is a demand for low noise circuit-breakers. This will probably be one of the main sales points for the oil-hydraulic driven F-Schalters in the future.

Fig. 7 shows noise test results. From the results of frequency analysis, it is also evident that the

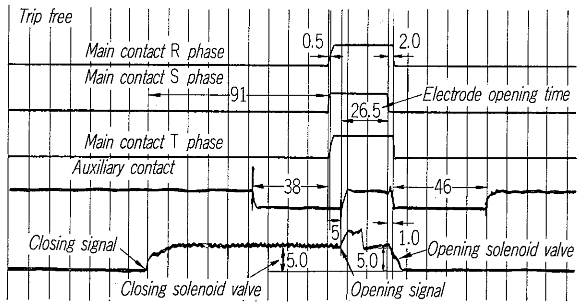
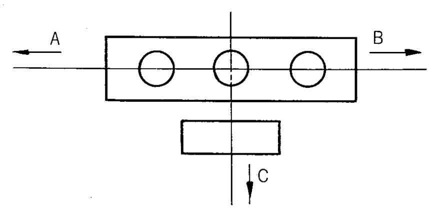


Fig. 6 Operating oscillogram

Tested unit:	F-Schalter with oil-hydraulic operating unit 72/8 kV 2,000 A 31.5 kA
Measurement dates:	28 and 29 March, 1973
Measurement location:	Fuji Electric Kawasaki Work, outdoors
Measurement device:	Indicating noise meter, A scale
Measurement results:	



Units: phone

Distance (m)	Closing			Opening		
	A	B	C	A	B	C
10	77	78	79	77	76	78
20	70	72	72	70	70	71
30	67	—	65	67	—	67

Fig. 7 Noise test results

***Table 2* Operating characteristics**

3-poles simultaneously operating type

Closing			Opening		
Operating oil pressure (kg/cm²•g)	Control voltage (%)	Closing time (sec)	Operating oil pressure (kg/cm²•g)	Control voltage (%)	Opening time (sec)
160	75	0.097	160	60	0.032
190	100	0.090	190	100	0.029
200	125	0.086	200	125	0.026
200	75	0.089	200	60	0.030

Each pole separately operating type

Closion			Opening		
Operating oil pressure (kg/cm²•g)	Control voltage (%)	Closing time (sec)	Operating oil pressure (kg/cm²•g)	Control voltage (%)	Opening time (sec)
160	75	0.117	160	60	0.030
190	100	0.109	190	100	0.027
200	125	0.106	200	125	0.026
200	75	0.107	200	60	0.028

***Table 3* Oil-pressure drop by operating (3-poles simultaneously operating type)**

(1) Closing and opening test

Closing			Opening		
Operating oil pressure (kg/cm²•g)	Control voltage (%)	Oil pressure drop (kg/cm²•g)	Operating oil pressure (kg/cm²•g)	Control voltage (%)	Oil pressure drop (kg/cm²•g)
160	75	5.0	160	60	8.0
190	100	7.0	190	100	10.0
200	125	8.0	200	125	11.0
200	75	8.0	200	60	11.0

(2) Opening free test (close-open)

Operating oil pressure (kg/cm²•g)	Control voltage (%)	Closing signal current (A)	Opening signal current (A)	Oil peessure drop (kg/cm²•g)
160	75	3.75	3.75	10.0
190	100	5.0	5.0	13.0
200	125	6.25	6.25	14.0
200	75	3.75	3.75	14.0

Table 4 **Oil-pressure drop by operating (Each pole separately operating type)**

(1) Closing and opening test

Closing			Opening		
Operating oil pressure (kg/cm²·g)	Control voltage (%)	Oil pressure drop (kg/cm²·g)	Operating oil pressure (kg/cm²·g)	Control voltage (%)	Oil pressure drop (kg/cm²·g)
160	75	5.0	160	60	6.0
190	100	7.0	160	100	9.0
200	125	10.0	200	125	13.0
200	75	10.0	200	60	13.0

(2) Opening free test (close-open)

Operating oil pressure (kg/cm²·g)	Control voltage (%)	Closing signal current (A)	Opening signal current (A)	Oil pressure drop (kg/cm²·g)
160	75	3.75	3.75	10.0
190	100	5.0	5.0	13.0
200	125	6.25	6.25	17.0
200	75	3.75	3.75	17.0

noise level has been reduced over the 1 kHz and when compared with the former unit F-Schalters with pneumatic operating unit, the unpleasant noise at high frequencies is less as was also confirmed from the opinions of related persons who heard the operating noise.

By such means as the use of simple sound-proof material, it is possible to reduce the number of phons by a further 5～10%.

3. Oil Pressure Drop during Operation

Table 3 and *4* shows the results of measurement of the oil pressure drop during breaker operation. The amount of the oil pressure drop is determined by the accumulator capacity. All results are good when compared with the pump-up time.

Table 5 **Oil leak test result**

(1) 3-poles simultaneously operating type

No. of operations (times)	Breaker condition (ON, OFF)	Internal leakage (kg/cm²·g)			Outer leakage
		Before standing	After standing	Oil pressure drop	
0	ON	189	181	8	None
	OFF	188	174	14	None
1,000	ON	186	178	8	None
	OFF	189	175	14	None
10,000	ON	190	181	9	None
	OFF	189	172	17	None

(2) Each pole separately operating type

No. of operations (times)	Breaker condition (ON, OFF)	Internal leakage (kg/cm²·g)			Outer leakage
		Before standing	After standing	Oil pressure drop	
0	ON	182	173	9	None
	OFF	192	178	14	None
1,000	ON	195	185	10	None
	OFF	188	175	13	None
10,000	ON	185	176	9	None
	OFF	187	171	16	None

Note: 1. Outer leakage observed visually
2. Internal leakage read from the pressure gauge after standing for 12 hours

4. Oil Leak Test

Sufficient contrivances are taken in structure to prevent oil leaks during actual operation, and all unit components are subjected to oil leak screening tests during the manufacturing process before assembly.

Table 5 shows the results of oil leaks tests for F-Schalter operating units of both the 3-poles simultaneously operating and each pole separately operating types.