UDC 621. 316. 57. 064. 25

INDOOR OIL CIRCUIT BREAKER OF NEW RO SERIES

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I. GENERAL DESCRIPTION

Fuji Electric has developed a new series of indoor type OCB for high voltage distribution system. They have been fully tested for breaking performance and short-circuit breaking efficiency with actual load applied. A 10,000 operation mechanical life test was also conducted on a unit extracted at random, confirming that the unit is fully durable under the most severe operating conditions, without requiring adjustments over long periods of use.

An epoxy resin bushing, a new simplified trip-free mechanism and a miniature oil injection preventive device are some of the most advanced improvements employed in the various portions of the unit. As many pressed parts as possible are employed for convenience in mass production, with modern methods of production control assuring units of stable quality. *Fig. 1* shows four types of indoor oil circuit breaker of the new RO series: from left to right, the model RO 56, model RO 106, model RO 156 and model RO 256. The ratings and specifications of each type are shown in *Table 1*.

II. CONSTRUCTION

1. Arc Extinction Chamber and Contact Unit

The energy generated in the arc during interrupting process is used for the thermal resolution of the insulating oil, producing a high gas pressure in the arc extinction chamber.

From the motion of the moving contacting, the gas injecting hole opens at the side of the arc extinction chamber and a mixture of gas and oil is blown laterally onto the contact-to-contact arc for extinction. Accordingly, this is termed a self-extinguishing arc, side blast type chamber. The oil circuit breaker may be permitted to shorten the arc time, if the internal pressure of the arc extinction chamber is increased upon breaking and the gas blowing force is increased, while the arc extinction chamber itself may increase in arc extinction efficiency. However, by doing this, the arc energy is increased and more gas is produced. This causes a greater shock to the tank and more gas is injected from the gas vent, thus causing deterioration to what is referred to as the secondary phenomenon. Consequently, it is desirable that the internal pressure of the arc extinction chamber be held to a proper value within a range which does not necessitate the extension of the arc time. In another words, the arc time is to be made as small as possible and the arc energy is to be the minimum sufficient for a self-extinguishing arc within this time.

To this end, it is necessary to optimize the interrelated values of the breaking speed (increasing the speed of the arc length), and the position and size of the injecting hole. In this respect, the arc extinction chamber of this new type of breaker has been shown to be extremely well balanced by the results of the short-circuiting breaking test under actual load. The arc extinction chamber is constructed with layers of pressed insulating plates tightened with four bolts to the bottom edge of the fixed contacting element, permitting easier disassembling and reassembling than the conventional type of repelit made arc extinction chamber. Complete interchangeability with the conventional type is provided.

2. Oil Injection Preventive Device

A mixture of gas and oil injected from the arc extinction chamber upon short-circuit breaking, rapidly moves into the air chamber inside the tank; the mixture, in the case of this breaker, passes through the pressure drop chamber and then through the clearance between the layers of thin metal plates and fed into the gas vent. In this case, the oil undergoes deceleration due to its own viscosity, so that only the gas component is discharged from the gas vent. The oil injection preventive device used for this new type of oil breaker is thus made small in size.

3. Bushings

Epoxy resin bushings are employed in all the types of the indoor oil circuit breaker of the new RO series, because of its superior mechanical and electrical performance characteristics. Epoxy resin bushings have high dimensional accuracy and are fully inter-

Table 1 **Summarized Data on New Type Indoor OCB**

Model (Code)	Ratings: Current (amp)	Ratings: Breaking Capacity At 3.6 kv (Mva)	Ratings: Breaking Capacity At 7.2 kv (Mva)	Ratings: Short Time Current (ka)	Ratings: Closing Current (ka)	Ratings: Breaking Time (~)	Ratings: Opening time (sec)	Arc Extinction System	Contact	Tank Shape	Oil Amount (*l*)	When Operating Voltage is 100 v dc: Tripping current (amp)	When Operating Voltage is 100 v dc: Operating current (amp)	Non-Loaded Closing Time (sec)	Aux. Contacting Element	Operating System	Type of Installation
RO 56-2	200	25	50	4	11.0	8	0.07	Plain break	Wedge contact	Rectangular type	25	1	—	—	3 A 3 B	HR HL	H
RO 106-4	400	50	100	8	21.8	8	0.07	Plain break	Wedge contact	Rectangular type	40	1	50	0.2	3 A 3 B	HR	H, B
RO 106-6	600	50	100	8	21.8	8	0.07	Plain break	Wedge contact	Rectangular type	40	1	50	0.2	6 A 6 B	H SH	P, M
RO 156-6	600	100	150	16	43.7	8	0.07	Side blast arc extinction chamber	Wedge contact with arc-proof metal provided	Rectangular type	57	1	50	0.2	6 A 6 B	H	P
RO 156-8	800	100	150	16	43.7	8	0.07	Side blast arc extinction chamber	Wedge contact with arc-proof metal provided	Rectangular type	57	1	50	0.2	6 A 6 B	SH	M
RO 256-6	600	150	250	24	65.5	8	0.07	Side blast arc extinction chamber	Wedge contact with arc-proof metal provided	Cylinder type	57	1	50	0.2	6 A 6 B	H	P
RO 256-8	800	150	250	24	65.5	8	0.07	Side blast arc extinction chamber	Wedge contact with arc-proof metal provided	Cylinder type	57	1	50	0.2	6 A 6 B	SH	M
RO 256-10	1000	150	250	24	65.5	8	0.07	Side blast arc extinction chamber	Wedge contact with arc-proof metal provided	Cylinder type	57	1	50	0.2	6 A 6 B	SH	M

(Note: The rated voltage for each model is 3.6 and 7.2 kv, while the insulation class is 6.)

• The code symbols are explained as follows:

R O 10 6 P—6 H

- H — Indicates the operating system
- 6 — Indicates the rated current in units of 100 amp
- P — Indicates the installation system
- 6 — Indicates the insulation class
- 10 — Indicates in units of 10,000 kva the breaking capacity at 7.2 kv
- O — Indicates OCB
- R — Term that covers general instrument

• Symbol for the installation system
- P: Portable type (either for independent installation or closed panel)
- B: Board type (for open self-supporting panel)
- H: Hanger type (either for closed panel or for box)
- M: Metal clad type

• Symbol for operation system
- H: Dc solenoid operation
- SH: Ac operation (Dc solenoid equiped with rectifier)
- HR: Round manual handle operation (for panel)
- HRS: Round manual handle operation (for independent installation)
- HL: Manual lever handle operation (for panel)
- G: Manual remote operation

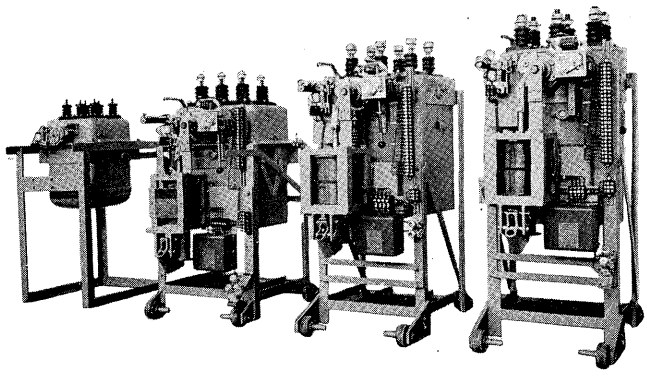


Fig. 1 Indoor oil circuit breaker of new RO series

changeable. It is possible to recess a conductor into a bushing; or else, a bushing can be combined with mounting flange into one unit. Thus the bushing is small and light.

The mechanical characteristics of the bushings are highly superior; a bending test has shown its strength to be three times that of porcelain bushings. It is also highly resistant to shock. It is excellent in resistivity to contamination. It also has excellent arc-resistance characteristics, superior to those of other bushings using organic materials or procelain.

Bushings for OCB use should be resistant to the severe operating conditions accompanying short-circuit breaking. That is, bushings ought to be able to withstand the short-circuit electromagnetic force, reaction force caused by gas injected from the arc extinction chamber and stress due to thermal expansion of the recessed conductor by the Joule effect. In this respect a careful study was made on the bushing alone through tests including short time current continuity, bending, and heat and cold tests.

Also, a number of short-circuit breaking tests were

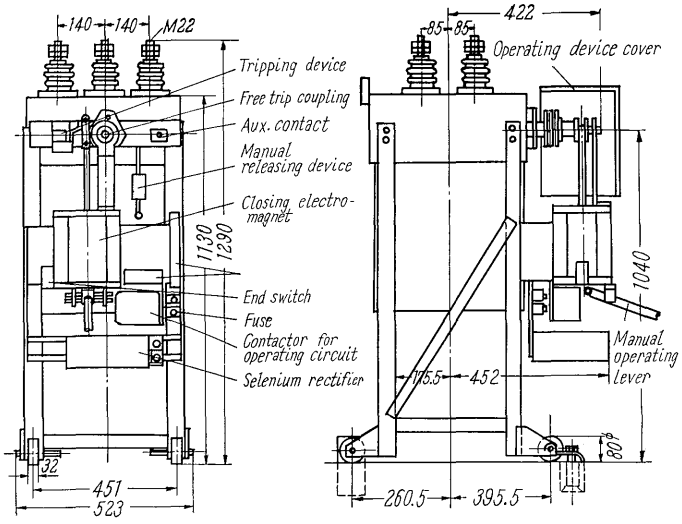
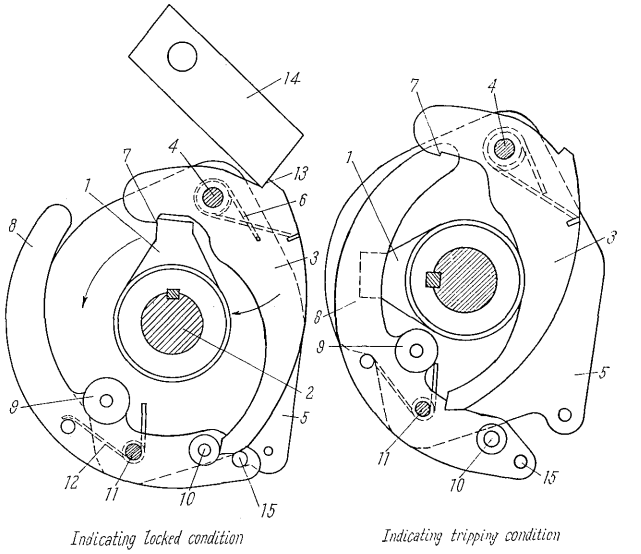


Fig. 2 Dimensions of oil circuit breaker, model RO 256



1. Cam
2. Control shaft
3. Ratchet lever
4. Ratchet lever rotating shaft
5. Mounting plate
6. Spring
7. Ratched portion
8. Release lever
9. Weight
10. Ratching roller
11. Release lever rotating shaft
12. Spring
13. Ratched portion
14. Stop pole
15. Stop pin

Fig. 3 Action of free-trip mechanism

repeatedly performed on the bushing installed on the OCB; all had satisfactory results.

4. Free-trip Mechanism

Dead center system or hook systems, as well as various other types, are included in the free-trip mechanisms. Generally, the mechanism consist of either a cam or crank installed on the breaker main unit control shaft which undergoes the breaking spring effect, and a number of levers that connect the above-mentioned cam to the releaser. Depending upon the number of the levers employed and upon the number of stages in a lever connection, the construction of the mechanism becomes complicated and the friction at ratched or hinged portions increases. In order to enable a small tripping force to perform the tripping, it is necessary to increase the precision of the ratched portion or else use anti-wear metal for this portion.

The free-trip mechanism of this circuit breaker has fewer levers, simplifying its construction. It is made compact so as to minimize the equal portions of each moving part centering upon the control shaft. Since the mechanism is arranged for easy observation from outside and yet is simplified, it can be easily inspected and maintained. The mechanism further features the employment of rollers at the ratched portions for minimizing friction, use of light alloy, and efficient assembly of the mechanism unit, thus minimizing the required tripping force so that the releaser may be small in size.

Because of the optimum arrangement of the centers of gravity of all components of the mechanism, the operation of the free-trip mechanism will not suffer because of inertia (Refer to *Fig. 3*).

5. Solenoid-operated Mechanism

The operating solenoid of the new series OCB may be used to control voltage of either 100 or 200 v dc by simply changing the connecting terminals. It can also be used for ac operation so that single phase ac power supply may be utilized. For the purpose of assuring accurate short-circuit closing performance, the attracting force of the plunger has been made sufficiently strong, with the operating current held below 50 amp, for all types of breaker. The closing time is less than 0.2 sec and it has been demonstrated that the mechnism can withstand open/close operations at a frequency of 600 times per hour.

For the standard attachment, the mechanism is provided with an end limit switch, so that even when the control switch is kept turned on, the solenoid is not damaged by heat. Furthermore, electrical and mechanical free-trip mechanism is obtained by a combination of the previously mentioned mechanical free-trip coupling and the anti-pumping relay.

The connection between the plunger and the free-trip coupling is made simple, thus increasing the practical reliability of the performance.

III. TRIPPING SYSTEM

The free-trip mechanism of the indoor oil circuit breaker of the new RO series, as mentioned in Art. 4 of Chapter II, requires only little power, so that the volt × ampere consumption of the tripping magnet (which is used to operate the mechnism), is extremely small (the constant exciting power is approximately 25 va in the under voltage tripping system). Thus, it is a typical small-power tripping mechanism. Consequently, a power supply of small capacity connected to the tripping magnet is sufficient, thus

permitting the potential transformer to be small in size and providing economic advantages as well. Up to the present, dc voltage tripping systems have mainly been used, only for the reason that it has the highest reliability. However, this system is costly since it requires a battery and charging device and their maintenance exclusively for the dc power supply unit. For this reason, the recent tendency is for general users not to employ dc power supplies, instead preferring the reliable and simple condenser tripping system and CT tripping system. To meet this growing demand of the present-day users, Fuji Electric has developed a condenser tripping system and CT tripping system with higher reliability and more features, making full use of the small power tripping mechanism.

IV. TESTS

At the test model stage for operation and mass production, the new series of breaker underwent the strict tests of all the items for test models stipulated in JEC 145. Given below are the results of the tests which are deemed important for maintenance of the breaking performance and the practical capability:

1. Open/Close Operation Characteristics and Mechanical Life

The closing time is as small as 0.2 sec, the breaking speed is 2 to 3 m/s, depending upon the type of breaker. Most of these OCB are used for a panel or box. Upon manufacture of the panel, there are frequent cases that the OCB is operated and the tripping test performed with oil not applied to the tank. Generally, in order to alleviate the mechanical shock produced upon opening the breaker, an in-oil operating type dashpot is provided inside the tank, using the insulation oil also as the dashpot oil, However, when, as mentioned above, the open/close operation is performed without filling the tank with oil, the dashpot will sometimes not function to alleviate the shock, thus resulting in damage to the moving parts of the OCB.

In the new series of breaker, however, the moving parts are mechanically strengthened to avoid the trouble of the above case. It has been shown that it can undergo open/close operation for more than 500 times without filling the tank with oil.

The mechanical life test was conducted up to 30,000 times at an open/close frequency of 600 times per hour, demonstrating that breaker can be used for further operation after a simple repair. However, the guaranteed life value is set at 10,000 times.

2. Short-Time Current Test

Values exceeding 100% of the rated short-time current were passed for periods of 2.0 sec through all types of the new series of breakers; no welding due to thermal damage of the contact and no excessive temperature rise in any part through which current passed was encountered. The standard stipulates only the electrical continuity effective value and the time, but does not give any information regarding the peak value at the initial stage of the short circuit current.

Welding of the contact and the electromagnetic force are affected by the initial peak value, so that in this test, the closing phase was controlled, setting the initial peak values of the short-circuit current at the value of the short-circuit closing current. No abnormality was encountered.

As an example, concrete figures are given below concerning the RO 256 type OCB: For 65.5 ka rated closing current value and 24.1 ka rated short-time current, current with peak value of 67.5 ka and effective value of 27.5 ka was allowed to flow for a period of 2.05 sec. No abnomality was encountered as a result. Following the peak value of 78 ka and effective value of 34 ka, an arc was produced at 0.36 cycle and arc production was continued for 1.9 cycle before stopping; thus no paractical difficulties were encountered.

3. Breaking Characteristics

The test was conducted on the basis of method stipulated in JEC-145. The result was that the breaker successfully breaked with respect to "0–1 min–CO–3 min–CO" and "CO–15 sec–CO" at 100% of the rated breaking capacity.

With respect to the short-circuit breaking of "0", ranging from 110% to a maximum of 130% of the rated value, successful breaking was performed without extension of the arc time and with almost no oil injection, and yet without producing shock, thus demonstrating the existence of a margin in the breaking performance. One of the outstanding factors in this successful performance is the improvement made in the oil separating device which operates to hold the oil injection to zero.

Fig. 4 shows the arc time characteristics of RO 256 type OCB, while *Fig. 5* illustrates typical oscillograms. With respect to the arc time characteristics, all types are within an arc time of two cycles, while the total breaking time is rated at eight cycles, but is actually

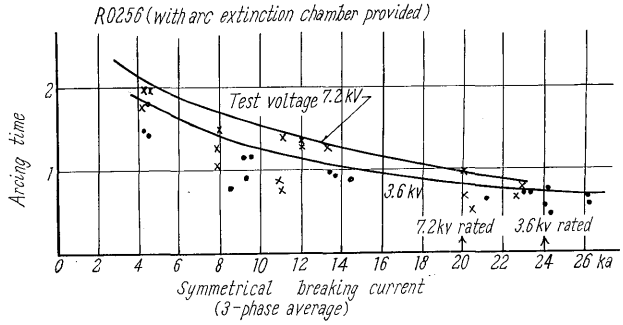


Fig. 4 Breaking current—Arc time characteristics of model RO 256

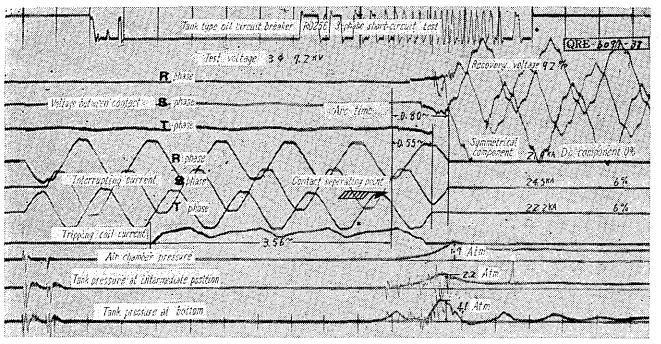


Fig. 5 Oscillograms of short-circuit test, model RO 256

close to five cycles.

The new series of OCB are designed with the tank size, oil amount, oil level and the arc extinction characteristics well balanced. As one of the effect of this balancing it is reported, as a result of an actual measurement of the pressure (produced upon breaking) at each portion of the tank, that the pressure was merely a few atmospheres, providing sufficient margin for the strength of the tank and cover.

V. CONCLUSIONS

The features of the new series of the OCB may be summarized as follows:

1) Accurate and dependable breaking capacity and short-circuit closing performance are guaranteed.
2) Small size and light weight for utmost convenience in installation, achieved by the rational arrangement of parts, smaller sized oil injection preventive device, and employment of epoxy bushings. Furthermore, the wheel-equipped angle frame mounting type provides much convenience in transportation.
3) The breaker can be used in combination with an unmatched condenser tripping system or with a CT tripping system. Both the operating and the control current are small and single phase ac control is available, so that a small scale facility for the control and operating power supply may be sufficient, thus reducing much of the expense of facility construction.
4) With the unique trip-free device, the mechanism has been simplified, so that mechanical reliability is high without adjustment required over long periods of use; inspection and maintenance are convenient and no special technical knowledge is necessary.
5) With the employment of epoxy bushings and pressed parts, the parts are interchangeable and the quality is kept stable.