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FUJI T-TYPE MINIMUM-OIL-VOLUME CIRCUIT BREAKER

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I. INTRODUCTION

In Japan, the present tendency in urban areas is to use 20 kv underground or overhead power distribution and even in less populated areas, increases to 20 kv are being made as a countermeasure against voltage drops and in respect to long term power requirements. In urban areas in Europe and the United States, primary distribution is almost always of the 10∼30 kv class when expansion takes place. Primary service is applied even to loads of comparatively small capacities and the trend is from 10 kv to 20∼30 kv. Because of the trends in Japan, highly reliable equipment for transformation of 20 kv incoming power is required in buildings, factories, etc. The T-type circuit breaker is especially appropriate for this purpose. For example, in recent skyscrapers with many stories both above and below the ground, 20 kv reception equipment is installed without exception. The breakers required in this equipment must be highly reliable and very compact. In West Germany, minimum-oil-volume circuit breakers, most of which are T-type circuit breakers, are used extensively in such cases. It is convinced that T-type minimum-oil-volume circuit breaker will meet all user's requirements.

Over 2000 T-type circuit breakers for 3.6 kv, 7.2 kv and 12 kv have been delivered to various industries, especially power companies and at present they are all operating satisfactorily. Their high performance and economy has been confirmed in all fields. In accordance with the trends described above, a 24 kv and 36 kv series are now being developed. The 24 kv 500 Mva model has been completed and is being mass produced.

An outdoor-type was developed at the same time. Since the insulator used in this equipment meets the requirements in Japanese Power Companies' Standard B-301 (Standard dimensions for salt resistant insulators), it can be used in coastal substations as well as in a wide range of other applications.

II. FEATURES

The merits of the T-type circuit breakers have been reported in detail before.[1][2] The features are briefly as follows.

1) Due to the use of a remarkable new arc quenching mechanism, "Formenausgleich" (volume equilibrium principle) and "Ringkanalduese" (ring nozzle blast system), arcing times of 1.2 cycles or less have been confirmed in short circuit, double phase ground fault and small current breaking tests.
2) With the spring type closing system, the closing rate is always constant even when there are variations in the operating voltage. Therefore, short circuit closing is highly reliable.
3) Transformer oil is used as the arc quenching agent but the oil volume is 1/30 (8.5 *l* per unit) of that used in former oil circuit breakers. Its volume is therefore the same or less than that of inflammable organic materials used in non-oil type circuit breakers so that it is suitable for buildings. Since there is no fear of sparks, it can also be used in atmospheres containing explosive gases.
4) The volume and weight are about 1/4 of that of former breakers and space needed on distribution panels is minimized.
5) The contacts, arc quenching chamber components and related parts are all simple in design and replacements can be made in as little as 30 minutes.

III. RATINGS AND SPECIFICATIONS

The ratings and specifications of these breakers are shown in *Table 1*.

IV. CONSTRUCTION AND OPERATION OF THE INDOOR-TYPE T-TYPE CIRCUIT BREAKER

1. Construction

Fig. 1 shows an external view of this breaker. As can be seen from *Fig. 2*, the operating mechanism is on the front and the breaking chamber (arc quenching chamber and current conducting parts) is on the rear. The three breaking chambers each

Table 1 **List of Ratings and Specifications**

Model	Indoor Type HF 515-20/600 1200-500/20 Msf	Outdoor Type OHF 515-20/600 1200-500/20 Msf
Rated Voltage	24 kv	
Insulation Level	Ac 50 kv Imp. 125 kv	
Rated Current	600/1200 amp	
Rated Frequency	50/60 Hz	
Rated Breaking Capacity	500 Mva	
Rated Breaking Current	12 ka	
Rated Making Current	32.8 ka	
Rated Short Time Current (2 sec)	12 ka	
Rated Opening Time	0.05 sec	
Rated Breaking Time	5 cycles	
Rated Making Time	0.1 sec	
Oil Volume	8.5 *l*	
Total Weight	280 kg	1100 kg

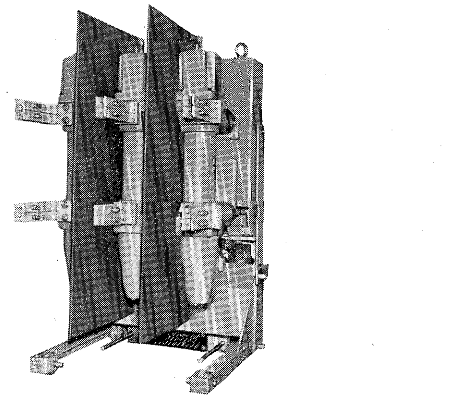
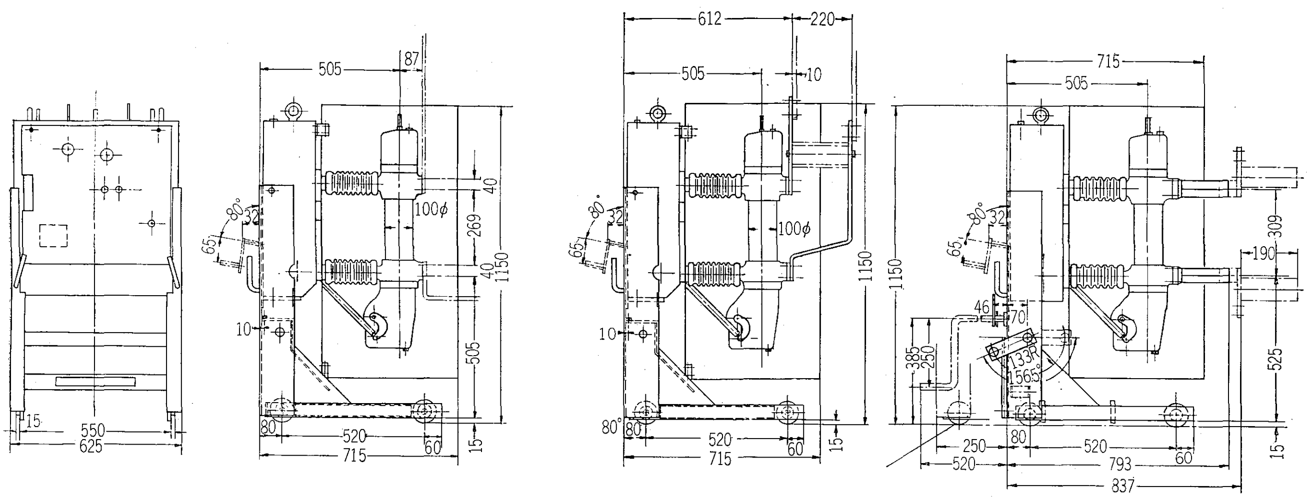


Fig. 1 Fuji T-type minimum-oil-volume circuit breaker, model HF 515-20 M/1200-500/20 Msf



(a) Front view (b) Portable type (P) (c) Portable type with connection conductor (PB) (d) Draw-out type

Fig. 2 Installation modes of T-type minimum-oil-volume circuit breaker

have two epoxy resin support insulators which attach them to the operating boxes.

The operating mechanism is almost the same as that used in the 3.6/7.2 kv 250/350 Mva breakers. The breaker pole consists of a high quality epoxy resin insulation cylinder (5.13) (in the construction diagram in *Fig. 3*) which contains the arc quenching chamber components making up the special arc quenching system. Above and below this cylinder are current conducting parts all of which have excellent conductivity. The upper and lower parts are enclosed by a top cover and crank case respectively.

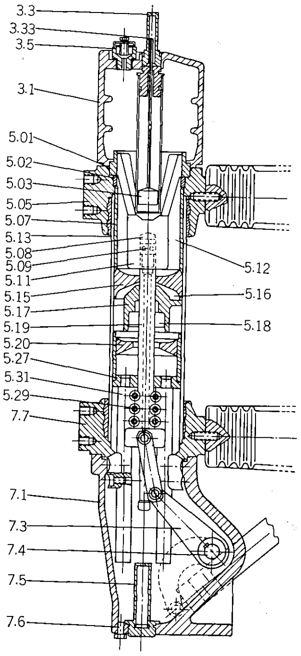
There are three installation modes; portable (P), portable with connection conductor (PB) and draw-out (M), as can be seen from *Fig. 2*. Any one of these can be used depending on requirements.

2. Arc Quenching Mechanism

Fig. 3 shows the section of the arc quenching chamber and *Fig. 4* illustrates the arc quenching principle.

During breaking operation, the moving contact rod (5.19) is pulled into the bottom part of the chamber which contains oil. At this time, a volume of oil from the lower part of the chamber equal to the volume which the moving contact occupied passes through the inner holes in immediate response to the contact movement. In this way oil is blown out on the arc. Non-restriking current breaking and exciting current breaking can also be performed with this system. This type of arc quenching system is known as the volume equilibrium principle.

When breaking large currents, arc quenching takes place between the upper arc chamber cover (5.15) and chamber insert (5.17). The arc which occurs during breaking is drawn from part A to part B as shown in *Fig. 4*. The gas formed in part A is exhausted upwards, but that formed in part B can not reach the upper exhaust area because of the insulation cap (5.08) and the arc itself. Therefore, a high gas pressure is maintained in part B. By means of the



3.1 Top cover
3.3 Oil level tube
3.33 Oil level indicating stick
3.5 Gas vent
5.01 Packing
5.02 Clamp ring
5.03 Float
5.05 Upper terminal
5.07 Distance cylinder
5.08 Insulation cap
5.09 Moving arc contact
5.11 Stationary contact
5.12 Upper breaking chamber
5.13 Insulation cylinder
5.15 Upper arc chamber cover
5.16 Ring nozzle
5.17 Arc chamber insert
5.18 Pressure chamber
5.19 Moving contact rod
5.20 Lower arc quenching chamber
5.27 Bulk plate
5.29 Contact roller
5.31 Guide rod
7.1 Crank case
7.3 Crank
7.4 Open/close shaft
7.5 Damper
7.6 Oil outlet plug
7.7 Lower terminal

Fig. 3 Design of T-type circuit breaker pole

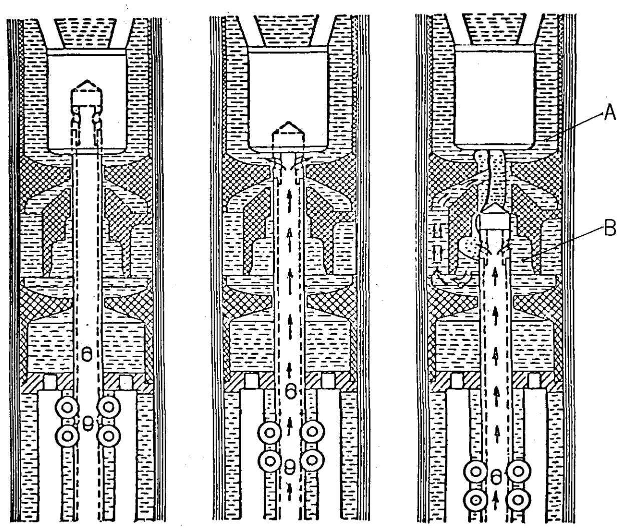
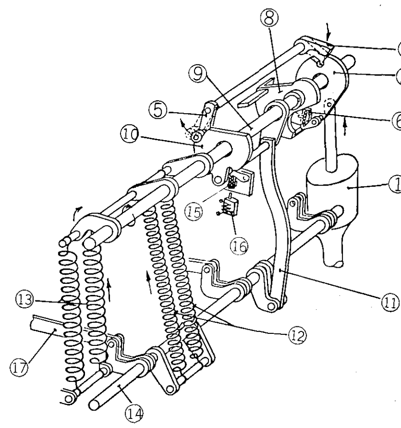


Fig. 4 Arc quenching mechanism

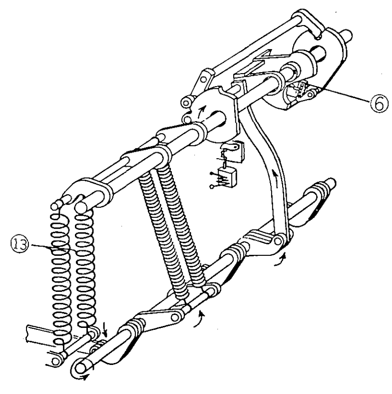
pressure difference between parts A and B, the oil from part B passes through the ring nozzle (5.16) and a strong spray extinguishes the arc (this oil spray is maintained until the pressure in the two parts are balanced). This is known as the ring nozzle blast system. The oil spray cools the arc quickly and breaking is thus achieved with a short arc time, minimum arc length and low arc voltage, i.e. low arc energy.

3. Operation

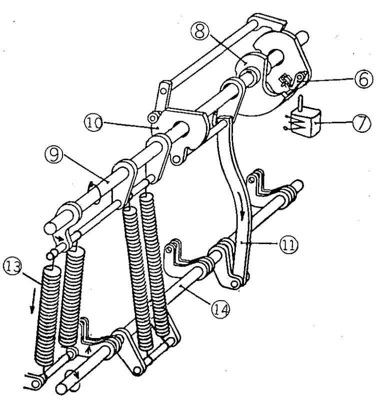
Fig. 5 shows the operating mechanism. In (a),



(a) Closing standby position



(b) Closed position



(c) Break position

① Motor drive
② Plate
④ Locking lever
⑤ Latch
⑥ Roller support
⑦ Tripping device
⑧ Drive plate
⑨ Shaft
⑩ Locking plate
⑪ Connection rod
⑫ Closing springs
⑬ Breaking springs
⑭ Open/close shaft
⑮ Roller support
⑯ Closing coil
⑰ Open/close rod

Fig. 5 Operating mechanism

when the motor drive (1) is moved in the arrow direction, closing spring (12) and breaking spring (13) are elongated at the same time. The elongation of the closing spring provides power to rotate the open/close shaft (14). However, this rotating power is transferred to connecting rod (11) and is stopped by interlock between locking plate (10) and latch (5) as well as between locking plate (10) and roller support (15). In this position, power is insufficient for closing. Once the position at which the required energy is accumulated in springs (12) and (13) is reached, latch (5) drops into the cut-out of locking plate (10), connection is disrupted and the closing interlock is released. This is the closing stand-by position. Closing energy is maintained only by the connection of locking plate (10) and roller support (15).

When the closing command is received, closing coil (16) pushes roller support (15) so as to release it from locking plate (10). Open/close shaft (14) provided with turning power by closing springs (12) rotates in the arrow direction as shown in *Fig. 5 (b)*. Open/close rod (17) and the moving contact which is connected to it are moved and closing is completed. In the closed position shown in (b), breaking springs (13) remain elongated and the breaking energy is maintained by roller support (6) for the free trip coupling.

When the breaking signal is received, tripping device (7) moves and connector (6) of the free trip coupling is disconnected. When shaft (9) and charging plate (8) are rotated because of springs (13), charging plate (8) pulls on locking plate (10), connecting rod (11) is moved downwards and open/close shaft (14) is rotated in the arrow direction until the position in (c) is achieved.

V. OUTDOOR TYPE T-TYPE CIRCUIT BREAKER

Figs. 6 and *7* show the construction and external view of the outdoor type respectively. As can be seen from this figure, the indoor type breaker is contained in a cubicle. The main circuit terminal which projects through the top of the cubicle is constructed to meet Japanese Power Companies' Standard B–301 (Standard dimensions for salt resistant insulators) and this can be used in the range of 0.1 mg/cm^2 or less degree of salt contamination.

This type can include a current transformer if required and is much more compact than previous breakers of this type.

VI. TEST RESULTS

Before marketing the breakers, a series of mechanical and electrical tests were conducted. These tests were performed in accordance with Japan Electrotechnical Committee Standard JEC–145 (1959) and Japanese Power Companies' Standard B–112. Satisfactory results were obtained in all cases as will be outlined below.

1. Open/Close Test

At the rated operating voltage, no load continuous open/close tests were conducted 20,000 times but no

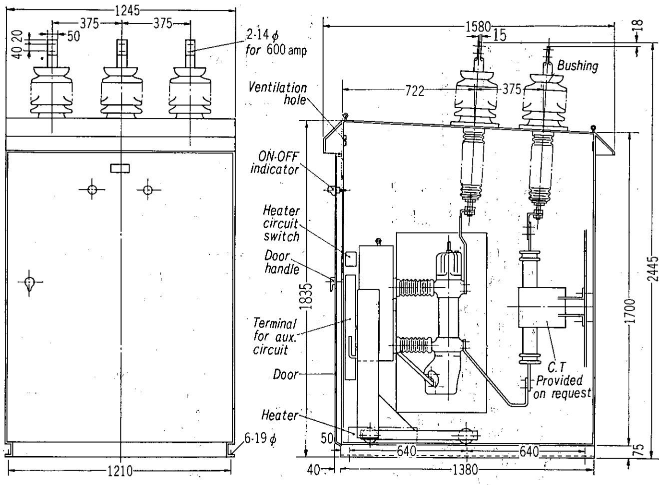


Fig. 6 Construction of outdoor type

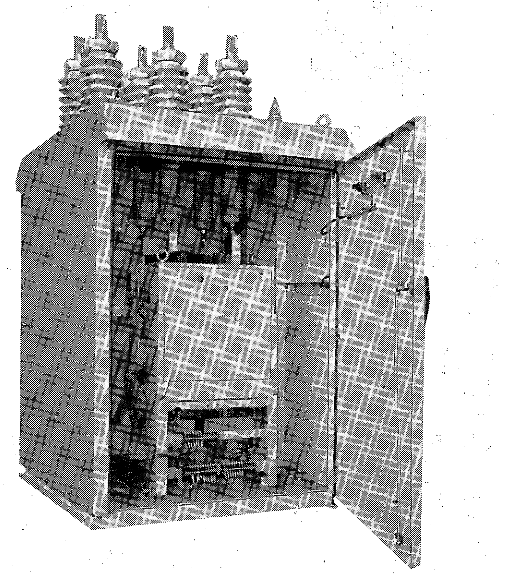


Fig. 7 View of outdoocr type

abnormalities were found in any of the parts. After the test, it was confirmed that the opening and closing characteristics had not altered.

2. Short-Time Current Test and Closing Test

A 3-phase short-circuit current breaking test was performed to confirm the mechanical strength and current capacity of the contacts during short-circuit currents. An actual value of 13.8 ka (Fundamental peak value: 37.1 ka) was applied for 2.07 seconds but no abnormalities such as contact fusing, partial overheating or large increases in contact resistance were observed.

A closing test was performed to confirm closing functions during short-circuit faults but no abnormalities were observed in the arc contacts for other parts and closing proved satisfactory. As was described previously, the closing speed can be kept constant even with changes in the operating voltage due to the spring type closing system.

Table 2 **Results of Short-Circuit Breaking Test**

Type	Operation Duty	Phase	Making Current	Breaking Current Sym. component	Breaking Current Dc component	Supply Voltage	Recovery Voltage	Inherent Restriking Voltage Frequency	Inherent Restriking Voltage Amplitude Factor	Arc Time	Opening Time	Total Break Time	Short-Circuit Power Factor	Operating Voltage
			ka	ka	%	%	%	kHz		~	~	~	%	%
Three-Phase Short-Circuit	"O"	R	—	13.5	21	24 kv 100	95	No. 1 phase 9	No. 1 phase 14	0.94	2.50	3.44	10 or less	100
		S	—	13.3	46					0.75				
		T	—	13.5	23					0.94				
	1 min "CO"	R	34.9	13.4	52	100		No. 2, 3 phase 20 or over	No. 2, 3 phase 1.5	1.00	2.30	3.30		
		S	37.7	13.3	66					1.00				
		T	23.9	13.5	15					0.65				
	3 min "CO"	R	32.0	13.5	39	100				1.10	2.30	3.40		
		S	39.1	13.2	70					0.95				
		T	28.5	13.4	31					1.10				
Double Phase to Ground Faults	"O" 3 min	S	—	10.0	20	24 kv 100	97	6.4	1.6	1.00	2.50	3.50	15 or less	
	"O"	S	—	10.0	23					0.70		2.50		

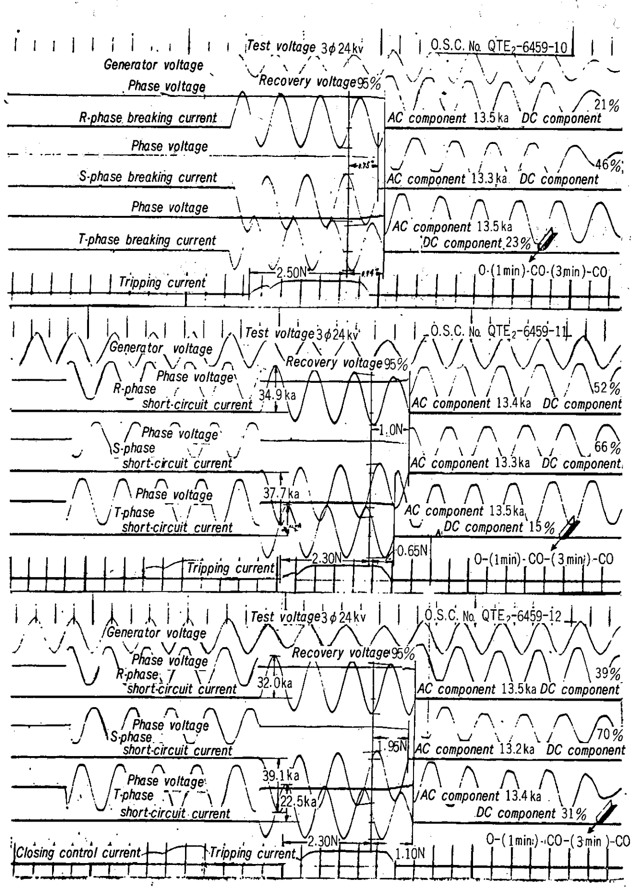


Fig. 8 **Oscillogram of three-phase short-circuit current breaking tests**

3. Short-Circuit Test

The test was carried out according to the JEC–145 stipulations (O—1 min—CO—3 min—CO) and excellent performance was confirmed.

Double phase ground fault test was carried out several times and proper breaking was confirmed.

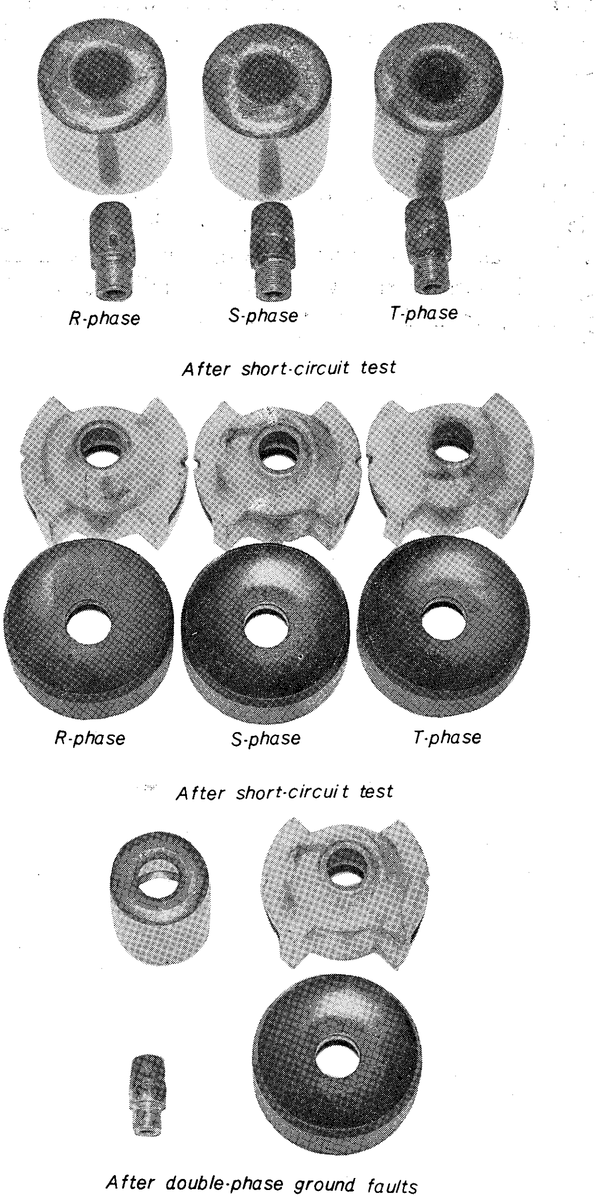


Fig. 9 **Contacts and parts of arc quenching device after short-circuit current breaking test**

Table 2 shows the test results. *Fig. 8* gives typical oscillograms and *Fig. 9* shows contact and arc quenching chamber parts after the short-circuit tests.

4. Small Current Breaking Test

1) Load current breaking

In previous oil-immersed breakers, one of the main defects was the very long arc times in the small current range. However, this equipment has excellent breaking characteristics even at small currents with arc times of 1.2 cycles or less. The test results are shown in *Table 3*.

2) Exciting current breaking

This test was carried out by controlling the contact parting time at single phase breaking currents of 10～30 amp. The results showed arc times of 0.4 cycles and below. Test results are listed in *Table 3*.

3) Line charging current breaking

When tests were carried out a single phase 10～50 amp, it was confirmed that there was no re-striking or re-ignition. These results are also listed in *Table 3*.

Table 3 **Results of Small Current Breaking Tests**

Type	Operating Duty	Supply Voltage	Breaking Current	Arc Time	Opening Time	Breaking Time	Operating Voltage	Re-ignition or Re-strike
		kv	a	～	～	～	%	
Exciting Current (Single-phase)	0	20.8	12.9	0.18	2.4	2.58	100	None
	0	20.8	12.9	0.35	2.35	2.7	100	〃
	0	20.8	12.9	0.3	2.5	2.8	100	〃
	0	20.8	22.5	0.3	2.45	2.75	100	〃
	0	20.8	22.5	0.1	2.4	2.5	100	〃
	0	20.8	22.5	0.3	2.35	2.65	100	〃
Line-Charging Current (Single-phase)	0	17.4	10.8	0.35	2.4	2.75	100	〃
	0	17.4	10.8	0.4	2.3	2.7	100	〃
	0	17.4	10.8	0.4	2.4	2.8	100	〃
	0	17.4	40.5	0.65	2.45	3.1	100	〃
	0	17.4	40.5	0.6	2.35	2.95	100	〃
	0	17.4	40.5	0.4	2.5	2.9	100	〃
Load Curernt (Single-phase)	0	20.8	600	0.9～1.2	25	—	100	—
	0	20.8	1,200	0.9～1.1	25	—	100	—

VII. CONCLUSION

The construction and test results of the newly developed 24 kv 500 Mva model of the T-type breaker series has been described here. In the manufacture, special consideration was paid to quality control. At present, around 50 of these breakers have been delivered and all are working satisfactorily.

Fuji Electric is now developing a T-type large capacity 36 kv breaker to complete this series.

References

(1) Fuji Electric Review Vol. 13, No. 6 (1967)
(2) Fuji Electric Review Vol. 14, No. 1 (1968)