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14.4 KV OUTDOOR TYPE LARGE CAPACITY AIR-BLAST CIRCUIT BREAKERS

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I. INTRODUCTION

Previous 14.4～34.5 kv outdoor type circuit breakers were almost exclusively of the oil immersed type. Fuji Electric, however, considering economy and easy maintenance, has developed the RF 702 and RF 703 types outdoor air-blast circuit breakers for 14.4 to 34.5 kv. The 14.4 kv, 4000～5000 amp RF 703 types are large current large capacity breakers with simple construction which makes them very lightweight. Maintenance is easy and they are much more economical than the oil immersed types. Tests based on ASA standards have been performed on these breakers and several units have already been shipped to Australia and Brazil. A considerable number of orders has been received for the RF 703 type from the United States and are being manufactured at present.

This article will describe the construction, operation and test results of the 14.4 kv, 15,000 Mva, 4,000 amp type and the 23 kv, 1500 Mva, 4000 amp type breakers. Table 1 shows the ratings and specifications of the RF 703 and RF 702 breakers based on ASA standards.

II. CONSTRUCTION

1. RF 702 (4000 amp) Type

In the RF 702 (4000 amp) type, the casing is one size larger than that of the 2000 amp type and a radiator plate has been added. Special consideration has been given to the contact points and as can be seen from *Fig. 6* the previous butt type current carrying contacts have been replaced by semi-slide types. With these contacts, it was not necessary to employ the bypass system which has always been used in breakers with this level of current

Table 1 **Ratings and Specifications of Breakers**

Type	Ratings								No load making time (sec)	Operating duty	Air reservoir capacity *2 (l)	Air consumption (in atmospheric pressure) (l)		Control current at dc 100 v (amp)		Rated operating pressure (kg/cm²)	Weight (Body) (kg)	Permissible amount of salt at which contamination proofing guaranteed *1 (mg/cm²)
	Voltage (kv)	Current (amp)	Breaking capacity (Mva)	Impulse level (kv)	4-second current (ka)	Momentary current (ka)	Breaking time (cycle)	Contact opening time (sec)				Closing	Tripping	Closing	Tripping			
RF 703 j/12/ 4000 D	14.4	4000	1500	150	72	115	3	0.03	0.15	CO – 15 sec – CO	800	60	1400	5	5	15	1550	0.06
RF 703 j/12/ 5000 D	14.4	5000	1500	150	72	115	3	0.03	0.15	CO – 15 sec – CO	800	60	1400	5	5	15	1700	0.06
RF 702 h/20/ 2000 D	23	2000	1000	200	48	76	3	0.03	0.15	CO – 15 sec – CO	520	60	1100	5	5	15	1100	0.06
RF 702 j/20/ 4000 D	23	4000	1500	200	52.5	80	3	0.03	0.15	CO – 0.3 sec – CO	520	60	1100	5	5	15	1400	0.06
RF 702 j/30/ 2000 D	34.5	2000	1500	200	38	61	3	0.03	0.15	CO – 15 sec – CO	520	60	900	5	5	15	1100	0.03
RF 702 j/30/ 4000 D	34.5	4000	1500	200	38	61	3	0.03	0.15	CO – 15 sec – OC	520	60	1100	5	5	15	1400	0.03

*1. Values given are applicable to one line-to-ground fault voltage. *2. CO 2 times possible

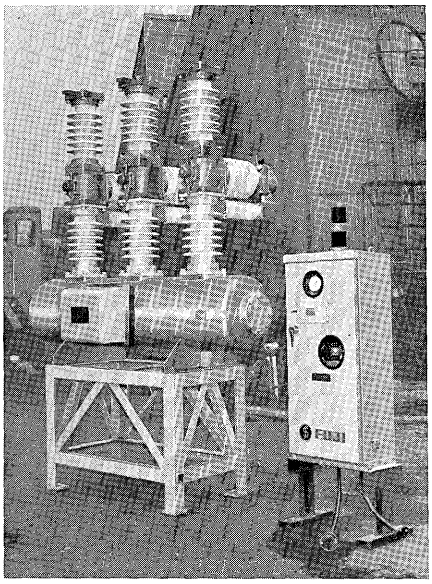


Fig. 1 RF 702 h/20/2000 D and RF 702 j/30/2000 D air-blast circuit breaker

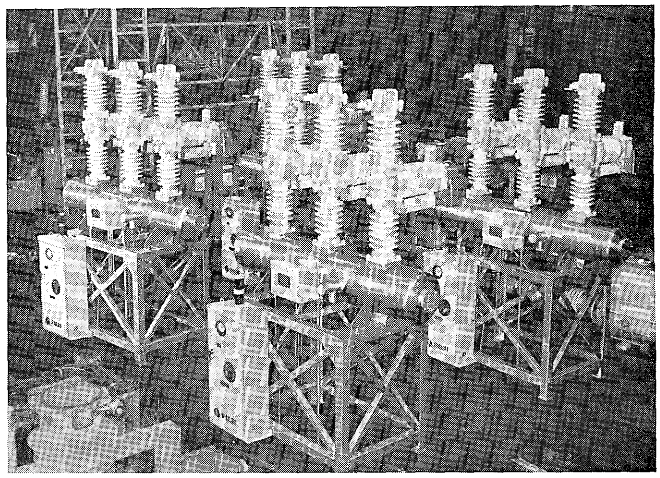


Fig. 2 RF 702 j/20/4000 D and RF 702 j/30/4000 D air-blast circuit breakers for Alcoa of Australia

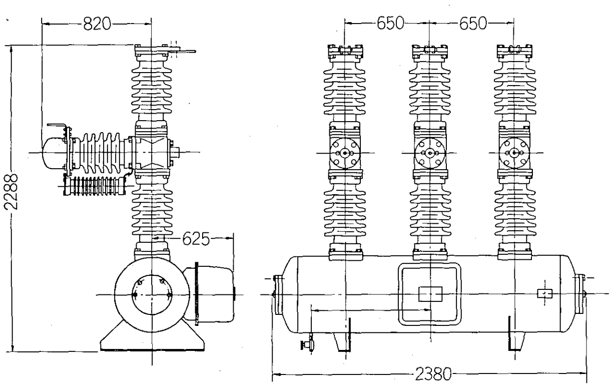


Fig. 3 Outline drawing of the RF 702 type (2000 amp)

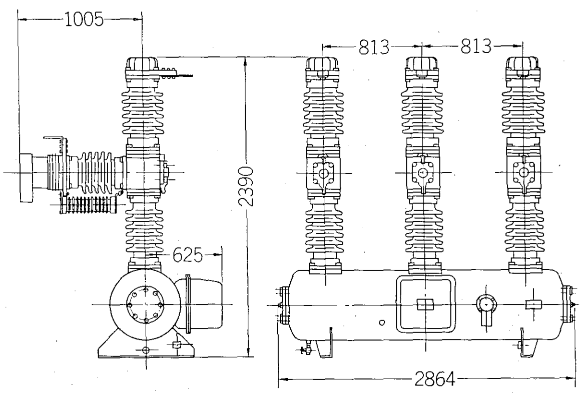


Fig. 4 Outline drawing of the RF 702 type (4000 amp)

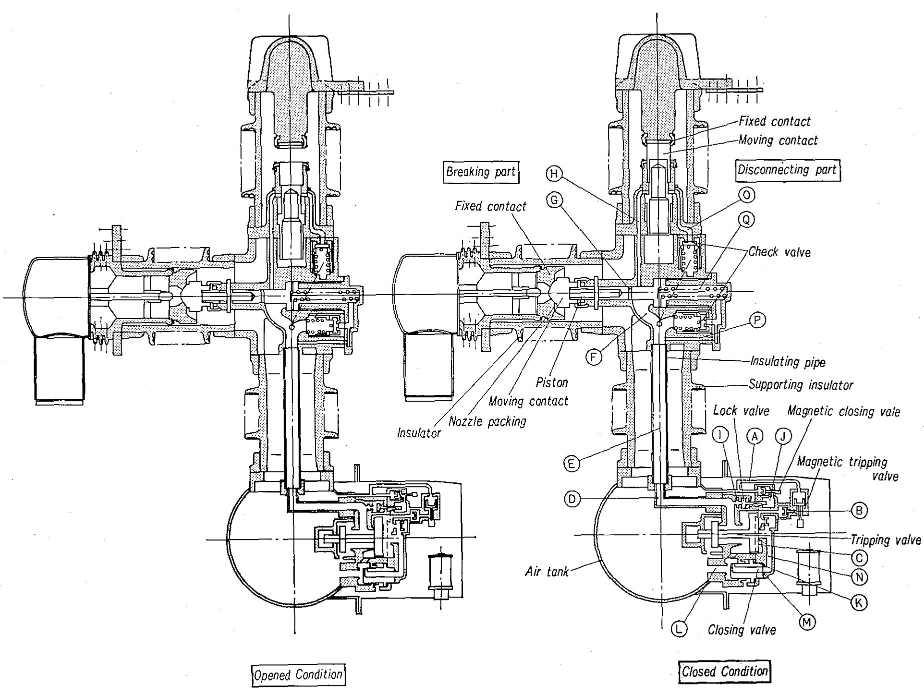


Fig. 5 Schematic diagram of the RF 702 type

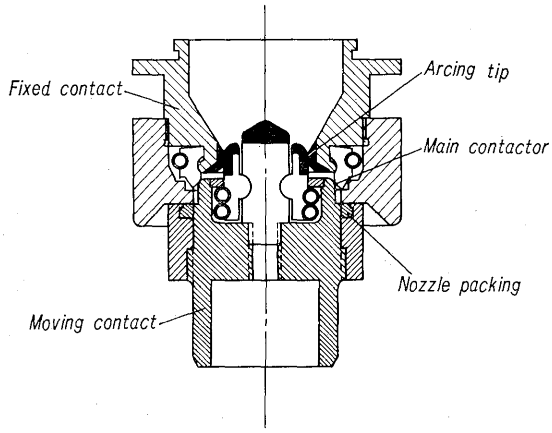


Fig. 6 Construction of contacts of the breaking part

capacity, and therefore, 3-cycle breaking became possible. Since the current carrying contacts are not near the current side above the nozzle, contact damage during short circuits has been reduced considerably. This also means that few metallic gasses are generated thereby improving breaking capacity. *Fig. 1* is an external view of the RF 702 (2000 amp) type and *Fig. 2* show sthe RF 702 (4000 amp) type. *Fig. 3* and *4* show the external dimensions of these two types respectively, while *Fig. 5* is a schematic diagram representing both the 2000 amp and 4000 amp types since they are analogous. *Fig. 6* indicates the construction of the breaking part contacts in the 4000 amp type. As mentioned above, the main construction elements of the 2000 amp and 4000 amp types are completely the same, however the 2000 amp types does not employ a low resistance for supression of restriking voltage. The following sections will describe the construction and application of the main components.

1) Air reservoir

Compressed air sufficient for two *CO* operations at the rated operating pressure of 15 kg/cm^2·g is stored in this reservoir.

2) Operating mechanism

The operating mechanism consists of a tripping valve through which the control air is sent during breaking, a lock valve for trip-free by air, a closing operations and a magnetic valve for both closing and tripping. The entire breaker is compact, lightweight, and it is easy to overhaul. A heater contained inside has strong packing to resist low temperatures during the winter and prevent water droplets from forming during humid weather.

3) Support insulator

This insulator provides insulation between the charged parts and ground.

4) Breaking part

In order to facilitate contact checking, this part is arranged horizontally. Inside there are nozzle packing type contacts which perform current breaking.

5) Resistor for supressing abnormal voltages

This resistor has non-linear characteristics and is employed for the supression of abnormal voltages during breaking of small inductive currents. It is positioned horizontally in parallel with the breaking part.

6) Disconnecting part

This part performs closing and maintains circuit insulation. Since disconnecting takes place in compressed air, the distance between the poles is small and contact wear due to advance discharges during closing is also a minimum.

Since the closing mechanim is operated by compressed air, there is no natural closing when the air is let off during tripping, as occurs with the spring mechanism, and the circuit can be protected as under normal conditions.

7) Separate control box

This control box is used for pressure suprervision, manual operation, electrical control, insertion of compressed air and feed in of external wiring. It is arranged separately from the main unit. If required, it is possible to fix it directly to the frame.

2. RF 703 (4000 amp) Type

The RF 703 (4000 amp) type is based on the RF 702 (4000 amp) type and includes a low value resistor for supression of restriking voltage and a gap for breaking resistive currents. Since the resistor gap part must be in series with the breaking parts, the breaking parts are arranged vertically. Except for these points and the fact that the length of the insulators are different due to the differences in insulation strength, all the construction including the contact parts is idential to the RF 702 (4000 amp) type. *Fig. 7* shows a photograph of the RF

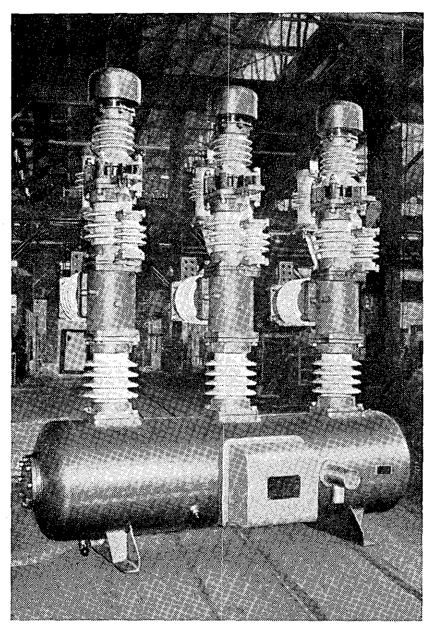


Fig. 7 RF 703 j/12/4000 D air-blast circuit breaker for Alcoa of Brazil

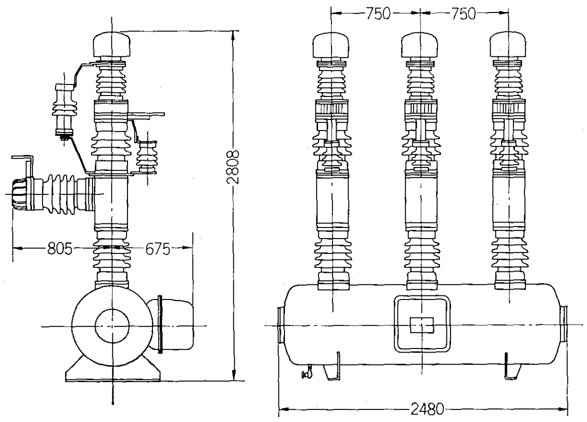


Fig. 8 Outline drawing of RF 703 type (4000 amp)

703 (4000 amp), while *Fig. 8* is an outline drawing and *Fig. 9 a* schematic diagram for the same type. The following sections will describe the construction and application of parts which differ from the RF 702 (4000 amp) type.

1) Low value resistor

This supresses restriking voltages during short circuits and facilitates breaking. It is connected in parallel with the vertical breaking parts.

2) Resistor gap

After short circuit currents are commutated by the previously mentioned resistor, resistive current is broken by utilizing the air blast of the breaking part. It is connected in series with the breaking parts.

3. RF 703 (5000 amp) Type

The RF 703 (5000 amp) type is basically of the same construction as the 4000 amp type. The material of the current carrying path has been partially altered and the area of the radiator plate has been increased.

III. OPERATION

Operation of the RF 702 and RF 703 types are idential. Refer to *Figs. 5* and *9*.

1) Breaking

(1) Tripping magnetic valve excited.

(2) Compressed air enters part Ⓒ via parts Ⓐ and Ⓑ. The tripping valve is moved to the left.

(3) The compressed air in the air reservoir enters part Ⓕ via parts Ⓓ and Ⓔ and the breaking parts piston is moved to the right (RF 702 type) or downwards (RF 703 type).

(4) The contacts open, the seal of the nozzle packing is broken and the arc is quenched by a blast of air between the contacts.

(5) The operation of the breaking piston causes compressed air paths Ⓕ and Ⓖ to be joined and the compressed air passes via Ⓗ and moves the disconnecting piston downwards (RF 702 type) or the right (RF 703 type). After the arc is quenched in the breaking part, disconnecting is performed by interrupting the nonlinear resistor current.

(6) The compressed air passes via Ⓕ and enters Ⓠ via the time limitter. When both of the pressures are equal, the contacts are closed again by spring force and compressed air is sealed again by the nozzle packing.

(7) Air also enters part Ⓘ, the lock valve is moved to the right and preparations are completed for closing.

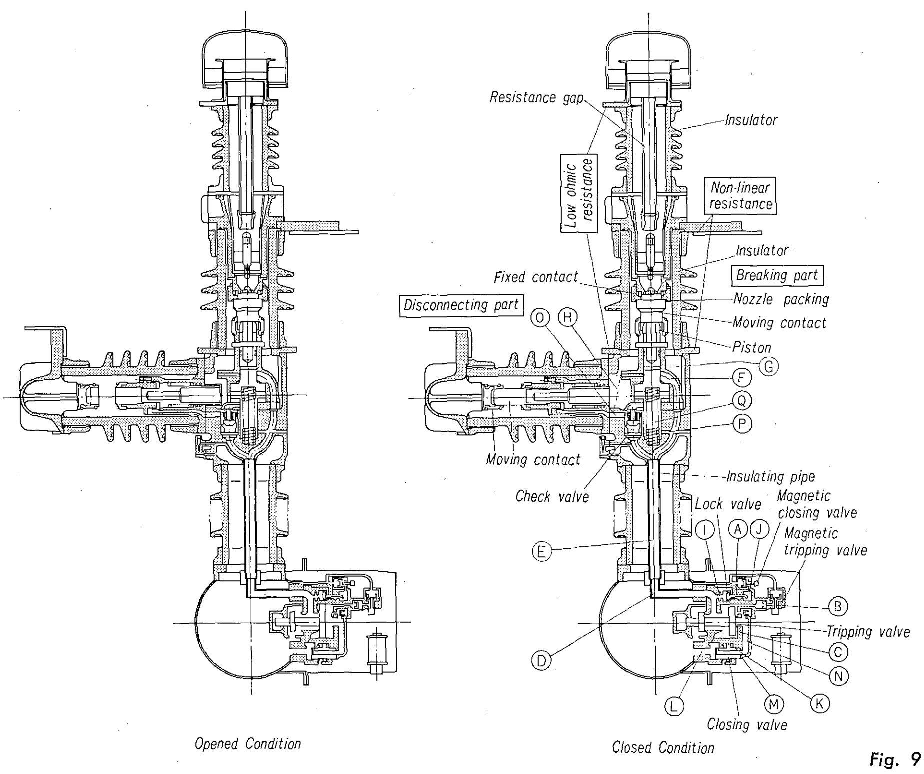


Fig. 9 Schematic diagram of the RF 703 type

2) Closing

(1) The closing magnetic valve is excited.

(2) Compressed air enters part Ⓚ and the closing valve is moved to the left.

(3) Compressed air in parts Ⓒ and Ⓝ is exhausted and the tripping valve piston returns to the right.

(4) Compressed air in parts Ⓞ and Ⓠ is exhausted via the check valve and that in part Ⓕ is exhausted directly. The disconnecting part piston is driven by compressed air from below (RF 702 type) or from the right (RF 703 type), and closing takes place. At this time the breaking piston does not move at all so that there is no air blast.

(5) The air is let out of part Ⓘ and the lock valve piston returns to the left.

(6) Compressed air in part Ⓚ is exhausted, the closing valve piston returns to the right, the compressed air of the air reservoir enters Ⓝ and preparations are complete for tripping.

3) Trip free

When a trip signal enters from the relay circuit while the closing signal is being given, breaking operation is performed once the breaker is completely closed (since contact "a" of the auxiliary switch is connected in series in the trip signal circuit), and the breaker stops in that position. After breaking, there is no closing while the closing signal is being given and closing occurs again only when the closing signal is stopped once and then resumed. This lock operation is performed pneumatically by the lock valve. In other words, while a continuous closing signal is given after breaking, the lock valve is pressed down by the compressed air on the Ⓘ and Ⓙ sides, but in this case, there is no movement when the valve is set to the left in relation to the area under pressure. Therefore the closing signal does not reach the Ⓚ side and closing is not carried out continuously. When closing is again performed, excitation of the magnetic closing valve stops once, Ⓙ attains atmospheric pressure and the lock valve piston is moved to the right. After Ⓙ and Ⓚ are connected, excitation is resumed and closing can take place.

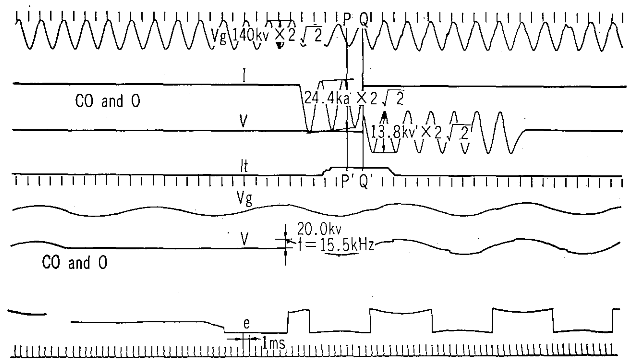


Fig. 10 Oscillograms of short-circuit interrupting tests of the RF 703 type (Test No. 9)

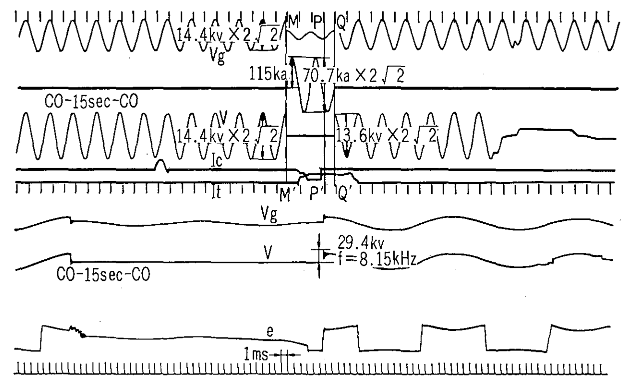


Fig. 11 Oscillograms of short-circuit interrupting test of the RF 703 type (Test No. 12-1)

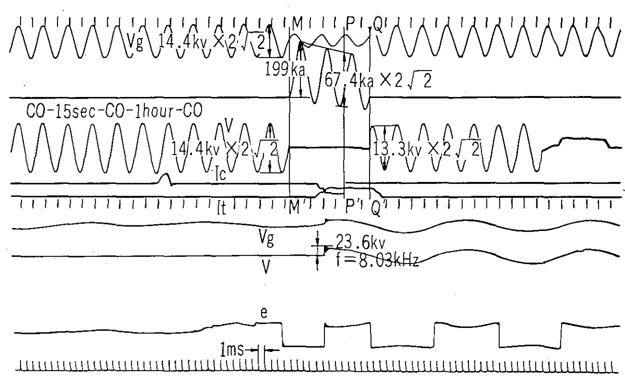


Fig. 12 Oscillograms of short-curcuit interrupting tests of the RF 703 type (Test No. 14-1)

IV. TEST RESULTS

These tests were performed in accordance with ASA C 37.09. An outline of the test results will be given in the following sections.

1. Short-Circuit Test

1) RF 703 type (14.4 kv, 1500 Mva)

This test was performed by means of a single phase actual load as per ASA C 37.09 *Table 2* at the Takeyama Ultra-High Voltage Power Laboratory. The test conditions were rated breaking current: 53 ka, asymmetrical factor: 1.2, voltage range factor: 1.3, and test voltage: 13.5 kv. Since the rate of rise of restriking voltage is not fixed in the ASA standards, the 12 kv class of the IEC standards was employed and the rrrv became 344 v/μs. The test results are given in *Table 2* and typical oscillograms are shown in *Figs. 10~12.* The condition of the contacts after the tests is shown in *Fig. 16* which shows a breaker undergoing a test.

2) RF 702 (4000 amp) type (23 kv 2000 Mva asy)

The test was performed on short circuit test equipment in the factory and a single phase actual load was used on the basis of ASA C 37.09, *Table 2.* The test conditions were rated breaking current:

Table 2 **Results of Short-Circuit Interrupting Tests (RF 703)**

Test No.	Oscillo No.	Operation Duty	Supply Voltage (kv) (%)	Test Frequency (Hz)	Recovery Voltage (%)	Closing Current (ka)	Breaking Current: Symmetrical Value (ka)	Breaking Current: Asymmetrical Value (ka)	Breaking Current: Dc Component (%)	Arc Time (~)	Contact Opening Time (~)	Breaking Time (~)	Short-Circuit Power Factor (%)	Restriking Voltage: Peak Value (kv)	Restriking Voltage: *1 rrrv (kv/μs)	Control Voltage (v (dc))	Operation Pressure (kg/cm²)
1	012689	O and CO	(13.7) 101.5	50.0	101.5	—	4.24	6.26	76.5	0.11	1.08	1.19	3 or Below	17.4	0.13	125	15
2	012690		(13.7) 101.5	50.0	105.5	10.9	4.21	5.85	78.0	0.27	1.15	1.42	3 or Below	19.6	0.35	125	15
4	012692	CO and O	(13.8) 102.0	49.0	100.5	30.8	15.5	17.0	31.5	0.76	1.16	1.92	3 or Below	23.6	0.71	125	15
5	012693		(13.7) 101.5	50.0	100.5	—	15.5	15.7	11.0	0.25	1.08	1.33	3 or Below	23.6	0.7	125	15
8	012696	CO and O	(14.1) 104.5	50.0	103.0	68.6	24.5	37.1	80.5	0.17	1.08	1.25	3 or Below	15.3	0.47	125	15
9	012697		(14.0) 103.5	50.0	102.0	—	24.4	34.8	72.0	0.70	1.07	1.77	3 or Below	20.0	0.62	125	15
12–1	012703	CO-15 sec-CO	(14.4) 137.0	49.3	129.5	115	70.7	71.0	6.0	0.37	1.17	1.54	5 or Below	29.4	0.48	125	*2 15
12–2	012704		(14.4) 137.0	48.8	128.5	124	70.9	72.0	12.5	0.65	1.18	1.83	5 or Below	28.4	0.46	125	*2 13.3
14–1	012711	CO-15 sec-CO-1 hour-CO	(14.4) 137.0	50.0	126.5	199	67.4	91.3	64.5	0.99	1.16	2.15	5 or below	23.6	0.368	125	15
14–2	012712		(14.5) 138.0	49.2	129.5	154	65.8	75.3	39.5	0.81	1.07	1.88	5 or Below	26.7	0.417	125	14
14–3	012713		(14.5) 138.0	50.0	127.5	123	65.2	67.2	17.5	0.53	1.12	1.65	5 or Below	28.5	0.485	125	15

*1. rrrv was calculated as $2\times f\times e_m$.
*2. Test No. 12 was performed with the compressed air supply cut off.

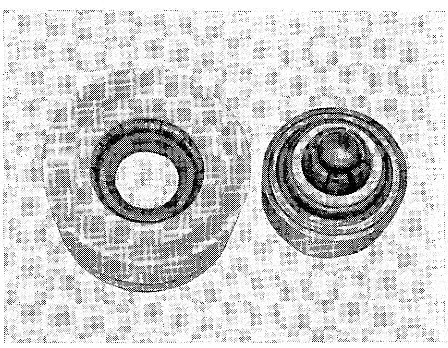


Fig. 13
Contacts of the breaking part after the short-circuit interrupting tests (After tests No. 1~9)

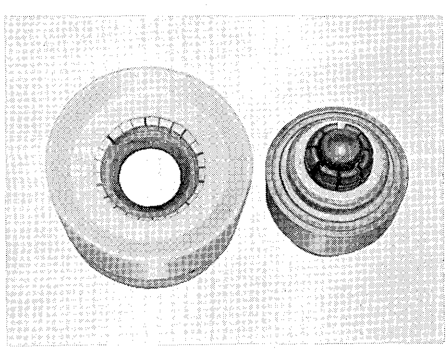


Fig. 14
Contacts of the braking part after the short-circuit interrupting tests (After test No. 12)

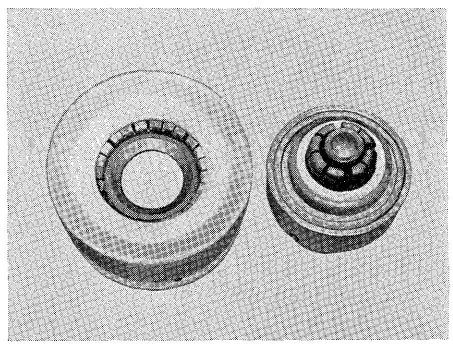


Fig. 15
Contacts of breaking part after the short-circuit interrupting tests (After test No. 14)

36.5 ka, asymmetrical factor: 1.23, voltage range factor: 1.17, test voltage: 22.4 kv, rate of rise of restriking voltage: 465 v/μs (as per IEC specifications), and interrupting capability factor for reclosing service: 93%. Typical results are shown in *Fig. 17*.

2. Short Time Current Tests

A 14.4 kv, 1500 Mva short time current test was performed on the RF 703 type. In the 4-second current test, the standard value after 1 sec from the time of initial flow was 72 ka eff, and in the momentary current test, the 1st wave effective value was 115 ka $_{\text{eff}}$, and the peak value of the same wave was 184 ka $_{\text{peak}}$ (115 ka × 1.6). These tests showed absolutely no trace of arcs or welding on the current carrying surfaces and no mechanical damage due to electromagnetic force. Since the con-

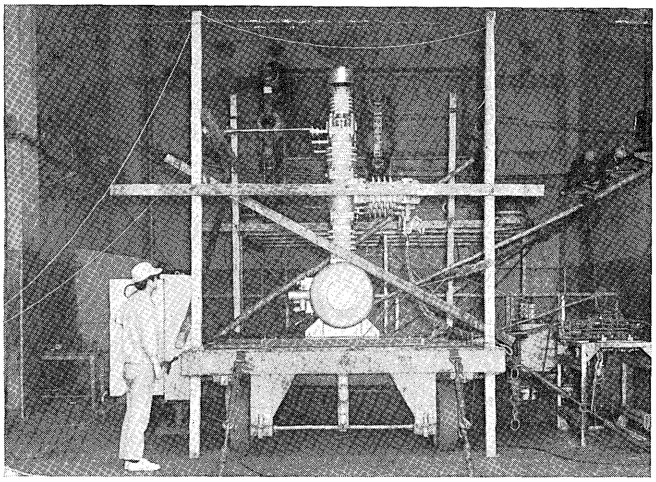


Fig. 16 Air-blast circuit breaker in short-circuit interrupting test (RF 703 type)

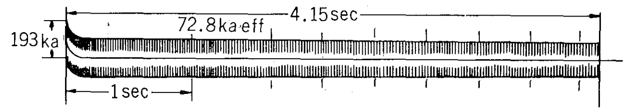
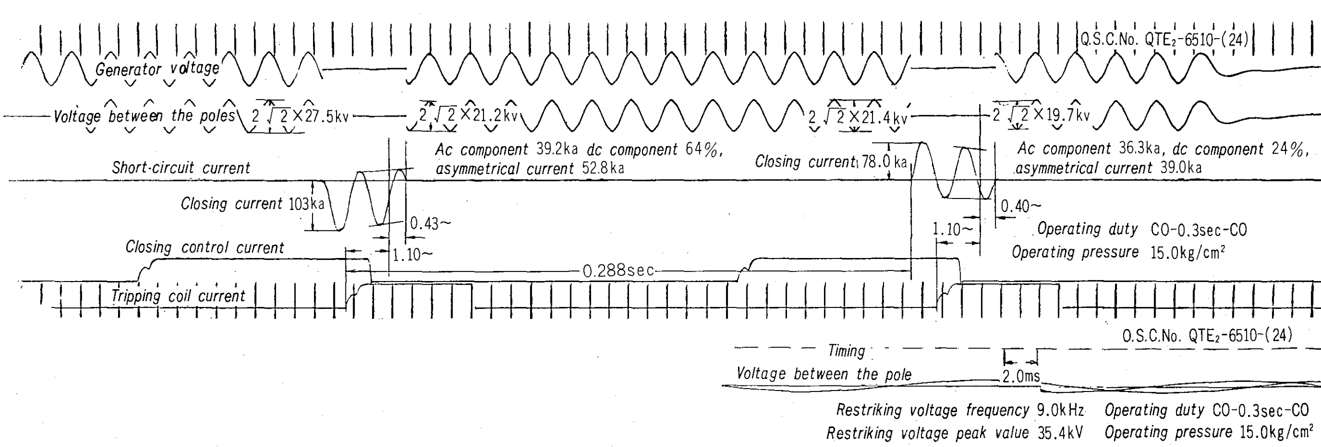


Fig. 18 Oscillogram of 4-second current test (RF 703 type)



Oscillo No.	Test Voltage (kv)	Closing Current (ka)	Breaking Current: Ac component (ka)	Breaking Current: Dc component (%)	Arc Time (~)	Contact Opening Time (~)	Total Breaking Time (~)	Restriking Voltage: Frequency (kHz)	Restriking Voltage: Peak Valve (kv)	Operating Duty
24	22.5	103	39.2	64	0.43	1.1	1.53	9	—	CO-0.3 sec-CO
	21.4	78	36.3	24	0.40	1.1	1.50	9	35.4	

Fig. 17 Oscillograms of short-circuit interrupting tests (RF 702 type)

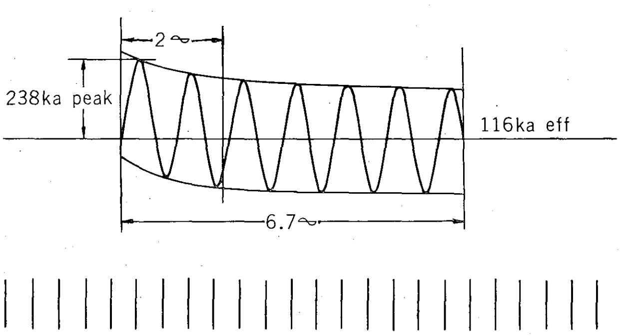


Fig. 19 Oscillogram of momentary current test (RF 703 type)

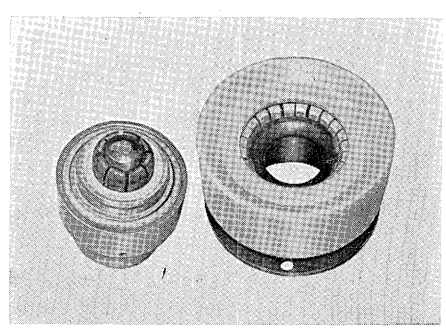


Fig. 20 Contacts of the breaking part after load current switching tests (RF 702 type)

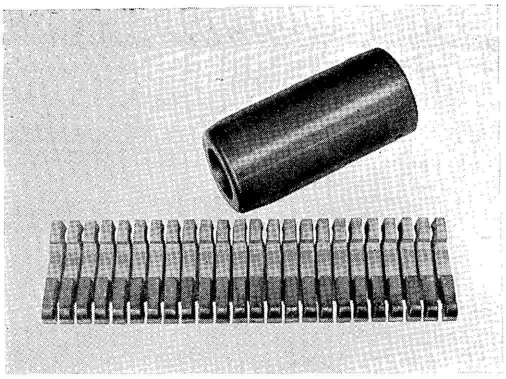


Fig. 21 Contacts of the disconnecting part after load current switching tests (RF 702 type)

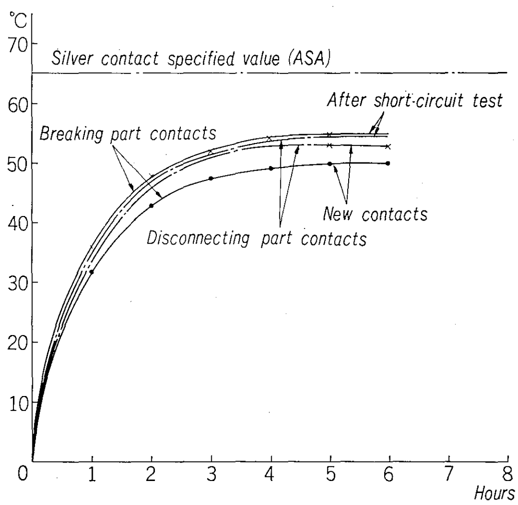


Fig. 22 Results of the current carrying test (RF 703 type)

tact construction etc. is the same, this data also applies to the RF 702 type. *Fig. 18* is an oscillogram of the 4-second current test and *Fig. 19* is an oscillogram of the momentary current test. The tests were performed at a 2-phase loop-connected.

3. Load Current Switching Tests

The RF 702 (4000 amp) type was subjected to 250 times load current switching tests at 4000 amp as per ASA standards and no problems were noted. This

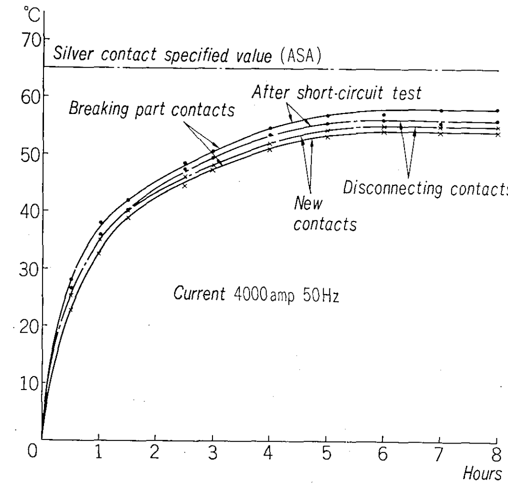


Fig. 23 Results of the current carrying tests (RF 702 type)

data can also be applied to the RF 703 type. The condition of the breaking part contacts after the test is shown in *Fig. 20* and it is evident that there is absolutely no damage to the contacts. The contacts of the disconnecting part shown in *Fig. 21.*

4. Current Carrying Test

Current carrying tests were performed on new contacts and on contacts which had undergone the short circuit tests. The temperature rise curve for the RF 703 type is shown in *Fig. 22* and for the RF 703 type in *Fig. 23.* There was highest temperature rise in the disconnecting and breaking contacts while they were carrying currents.

V. CONCLUSION

The RF 702 and 703 type air blast circuit breakers described here were developed as the result of Fuji Electric's long years of experience in the manufacture and operation of air blast circuit breakers. The excellent breaking performance and unsurpassed application performance assure that these breakers will fulfill all user's demands. Since economy is also very high, these breakers will soon replace the oil-immersed types as outdoor circuit breakers.