UDC 621. 316. 57. 064. 45

NEW SERIES OF INDOOR AIR BLAST CIRCUIT BREAKERS

Katsumi Chobara
Kawasaki Factory

I. FOREWORD

Since the market announcement in October 1954 of the RF701 indoor air blast circuit breaker constantly pressurized, disconnecting in compressed-air, nozzle packing system, Fuji Electric has already manufactured and delivered some four hundred units. All are performing to standards.

A new series retaining the excelling features and construction of the old series but offering even better performance has been developed. This new series is known as RFa 701. A silencing tank has been added at the interrupting chamber exhaust area for all models, greatly reducing generated noise and providing for cubicle construction. By equipping medium capacity types with the slide system contacts developed for high interrupting capacity types, the short-circuit interrupting resistor has been reduced. Modifications in the power interrupting section of high current capacity types (3,000 A, 4,000 A) have made elimination of the bypass unit (paralleled with the main circuit in older types) possible, decreasing the interrupting time from five cycles to three cycles and simplifying construction. In the following paragraphs, I wish to present an outline of construction of types in the new series and the results of tests.

II. RATINGS AND SPECIFICATIONS

Ratings and specifications of units in the new series are shown in *Table 1*. *Fig. 1* shows photographic views, while *Fig. 2* and *Table2* cover dimensions.

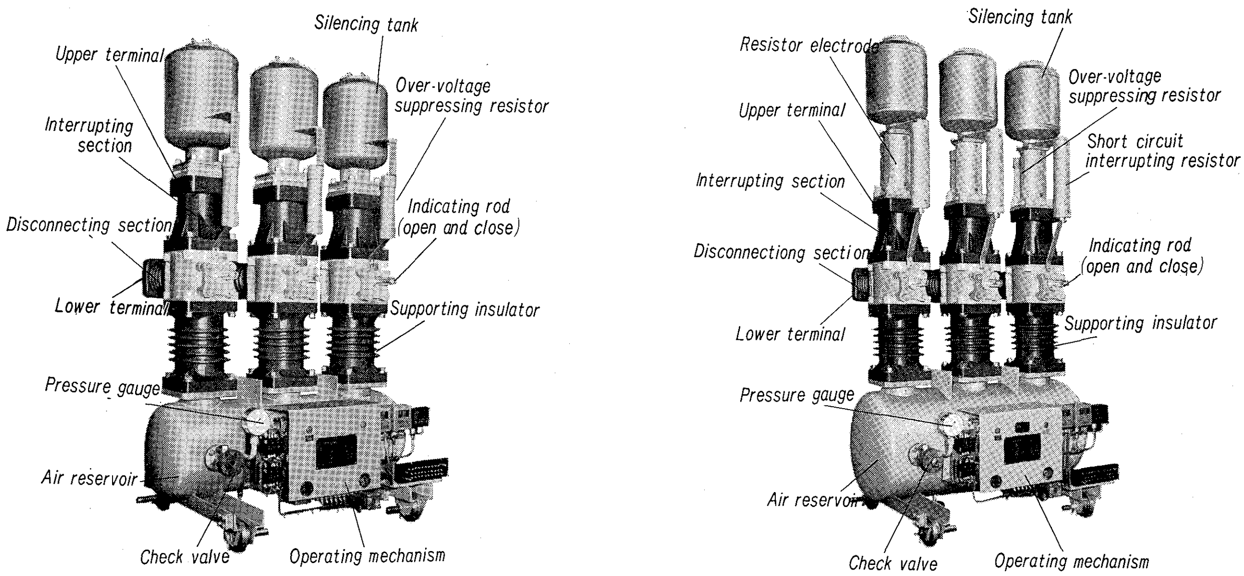
As the No. 2 requirement for the restriking volt-

Table 1 **Ratings and specifications**

Type (※)	Rating									No load closing time	Air reservoir capacity	Air consumption (reduced in atmosphere) (*l*)		Weight (※※)	Interrupting capacity at other than rated voltage	
	Voltage (kV)	Current (A)	Interrupting capacity (MVA)	Insulation class (JEC-145)	Restriking voltage (JEC-145) (kHz)	Short time (2 sec) current (kA)	Making current (kA)	Interrupting time (~)	Opening time (s)	(s)	(*l*)	Closing	Tripping	(kg)	Voltage (kV)	Interrupting capacity (MVA)
RFa 701 h/10/2000 D		2,000												680	7.2	500
RFa 701 h/10/3000 D	12	3,000		10 A	II 15	48.1	131.3				230	60	1,200	700	14.4	1,200
RFa 701 h/10/4000 D		4,000	1,000											740		
RFa 701 h/20/1200 D		1,200				24.1	65.5				135	60	600	620		
RFa 701 h/20/2000 D		2,000														
RFa 701 j/20/2000 D	24	2,000		20 B	II 9			3	0.03	0.08				690		
RFa 701 j/20/3000 D		3,000				36.1	98.5				230	60	1,200	710		
RFa 701 j/20/4000 D		4,000	1,500											750		
RFa 701 j/30/1200 D	36	1,200		30 B	I 1.4	24.1	65.5				195	60	800	680		
RFa 701 j/30/2000 D		2,000														

Ratings common to all units
Frequency: 50/60 Hz
Operating duty: O-1min-CO-3min-CO or CO-15 s-CO
Control power: 100, 110 V DC at 5 A (Closing and tripping)
Rated operating pressure: 15 kg/cm²·g
Air reservoir capacity: CO one time

(※): Designation "−d" is appended in the case of pull-out construction
Example: RFa 701 h/10/2000 D−d
(※※): In the case of pull-out construction, weight is 5~10% more than that indicated



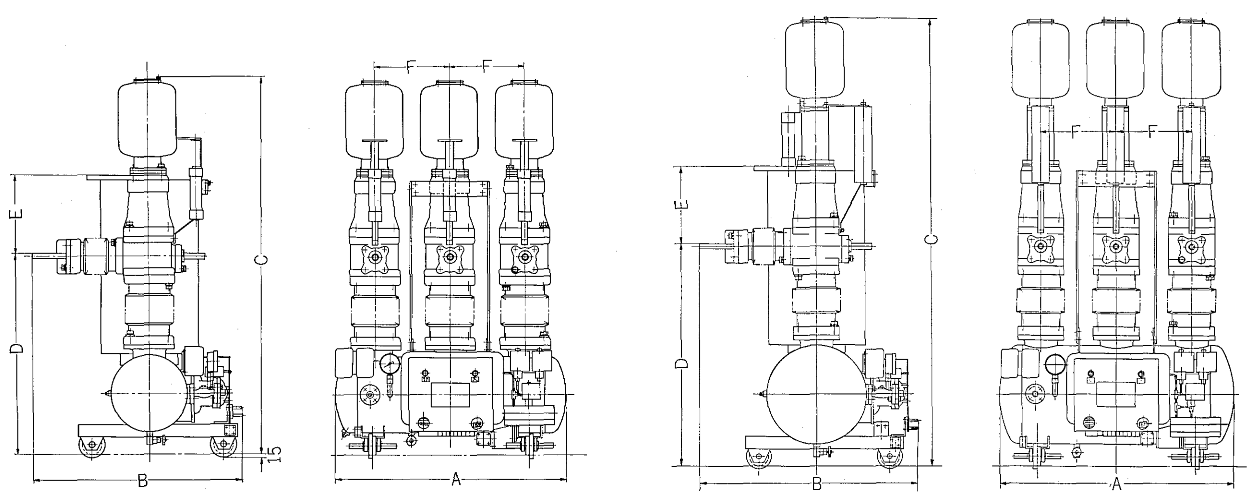
(a) 24 kV 1,000 MVA

(b) 12 kV 1,000 MVA

Fig. 1 Views of air blast circuit breakers

Table 2 **Outline dimensions**

Type	Fig. No.	A Width	B Depth	C Height	D Lower terminal	E Upper terminal	F Phase distance	Pull-out dimension for pull-out type
RFa 701 h/10/2000 D	2 (b)	1,220	1,132	2,321	1,155	407	390	250
RFa 701 h/10/3000 D	2 (b)	1,220	1,132	2,321	1,155	407	390	250
RFa 701 h/10/4000 D	2 (b)	1,220	1,172	2,321	1,155	407	390	250
RFa 701 h/20/1200 D	2 (a)	1,200	988	1,945	1,024	412	390	300
RFa 701 h/20/2000 D	2 (a)	1,200	1,072	1,945	1,029	407	390	300
RFa 701 j/20/2000 D	2 (b)	1,220	1,132	2,321	1,155	407	390	300
RFa 701 j/20/3000 D	2 (b)	1;220	1,132	2,321	1,155	407	390	300
RFa 701 j/20/4000 D	2 (b)	1,220	1,172	2,321	1,155	407	390	300
RFa 701 j/30/1200 D	2 (a)	1,360	1,118	2,055	1,134	412	470	400
RFa 701 j/30/2000 D	2 (a)	1,360	1,155	2,055	1,139	407	470	400



(a)

(b)

Fig. 2 Outline dimensions

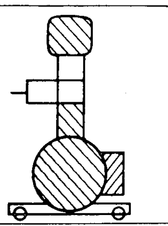
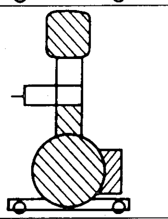
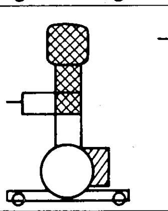
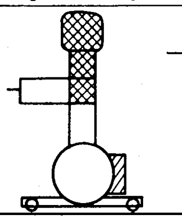
Basic construction (hatching shows common part)	Added condition		Circuit breaker rating
	Parallel resistor for 12kV		12kV 1,000MVA 2,000A
		3,000A terminal	12kV 1,000MVA 3,000A
	Parallel resistor for 24kV		24kV 1,500MVA 2,000A
		3,000A terminal	24kV 1,500MVA 3,000A
	Parallel resistor for 12kV		12kV 1,000MVA 4,000A
	Parallel resistor for 24kV		24kV 1,500MVA 4,000A
			24kV 1,000MVA 1,200A
	Terminal for 2,000A		24kV 1,000MVA 2,000A
	Operation at 7atg		Frequently operated circuit breaker for electric furnace 24kV 250MVA 1,200A
			36kV 1,500MVA 1,200A
	Terminal for 2,000A		36kV 1,500MVA 2,000A

Fig. 3 Circuit breaker construction

age frequency in the case of 36 kV, 1,500 MVA type is not stringent, No. 1 (JEC-145) has been used as the standard. If short-circuit interrupting resistor is not included, however, the No. 2 (JEC-145) requirement may be applied. In the new series, compatibility of components has been a key objective. Construction is shown in *Fig. 3*.

III. CONSTRUCTION, OPERATION, AND TEST RESULTS

1. Explanation of Operation

Fig. 4 shows cross-sectional views of the circuit breaker, and serves to illustrates the operating principles. *Fig. 5* is a cross-sectional view which illustrates the operating mechanism, construction of which is the same as that of the old series. Interchangeability has been retained.

Bypass unit are now unnecessary in high current (3,000 A, 4,000 A) types, and the operating system is common for all ratings.

In the closing operation, the magnetic valve is excited, allowing compressed air to enter the rear of the control valve. Due to the amplifying effect of the valve, the control valve operates at high speed, passing compressed air from the air reservoir to the rear of the piston in the disconnecting section. This action causes the lock valve to interrupt air from the magnetic valve. At the same time, the flow of air from the magnetic valve ceases of its own accord. Therefore, after closure, the trip command is given priority over the close command and pump-

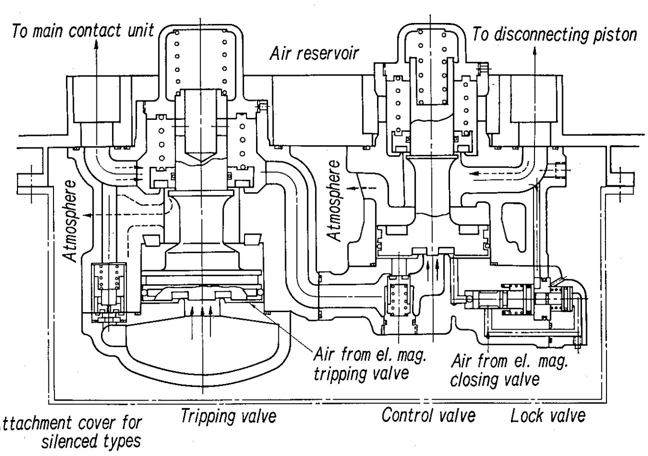
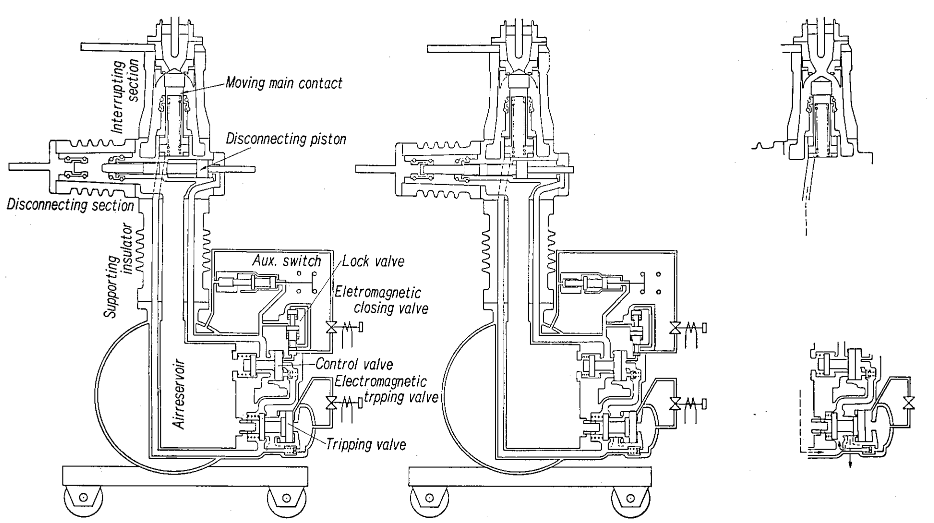


Fig. 5 Operating mechanism



(a) Tripped position (b) Closed position (c) During interruption

Fig. 4 Cross-sectional views and system

ing is completely blocked.

In the tripping operation, the magnetic valve is excited and compressed air passes to the rear of the tripping valve. Due to the amplifying effect of the valve, tripping takes place at a very fast rate. The supply of air from the air reservoir to the tripping valve is interrupted. Air at the rear of the moving main contact is vented to the atmosphere, forcing the moving main contact downward and thereby causing interruption. At the same time, air at the rear of the control valve is also vented to the atmosphere, allowing the control valve to return to home position after a certain time delay. Air at the rear of the piston is vented to the atmosphere, allowing the disconnecting portion to open fully.

When the tripping valve operates, air in the chamber is vented to the atmosphere, lowering the pressure. After a certain time delay, the trip valve returns to the home position, permitting air to flow again from the air tank to the rear of main contacts. The disconnecting section stops the air blast function.

Regardless of whether the circuit breaker is in the closed or tripped state, pressure at the breaking and disconnecting sections will remain the same when the nominal air pressure drops.

Fig. 6 depicts the standard sequence diagram. The minimum guaranteed breaking pressure is 12.7 kg/cm^2 · g. A tripping lock circuit is included: To eliminate danger when a pull-out circuit breaker is pulled out in the closed state, an automatic tripping circuit which functions when the pressure drops below 12.7 kg/cm^2 · g has been included. (When the pressure is above this level and the circuit breaker is closed, pull-out is blocked by the lock system.)

Refer to *Fig. 7*, in which the current paths are shown by hold lines. In the current breaking process:

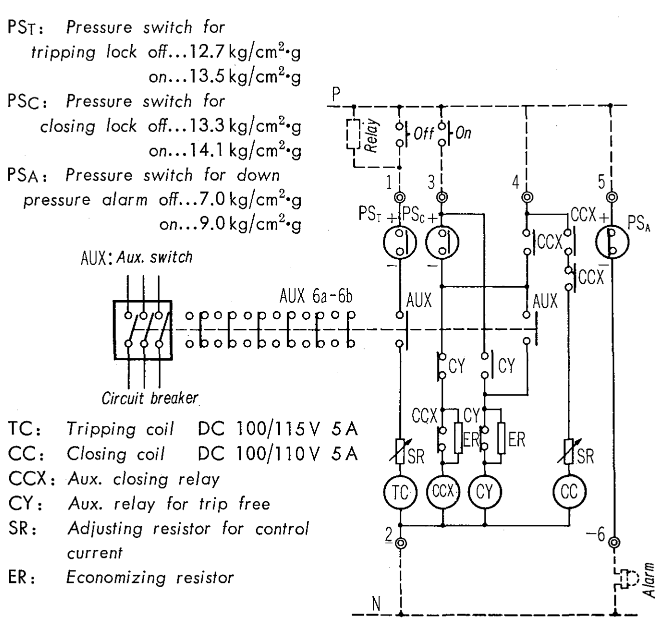


Fig. 6 Sequence diagram

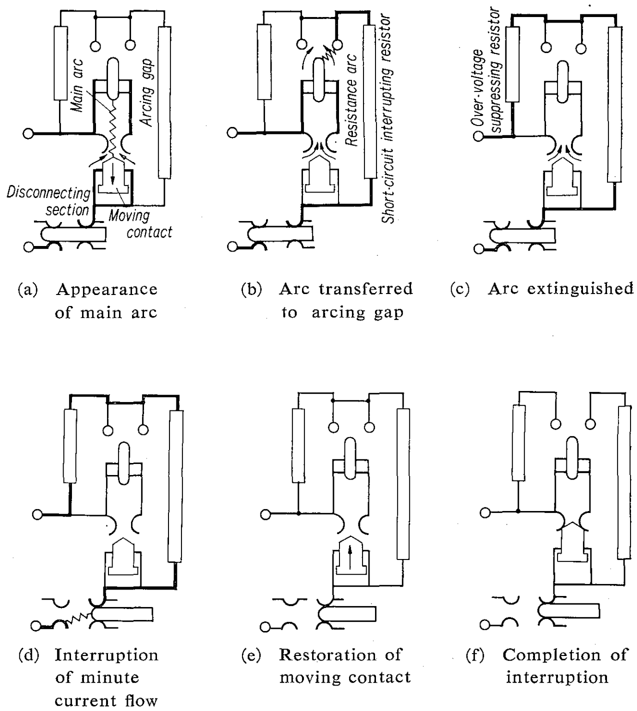


Fig. 7 Process of interruption

a) Operation of the tripping valve causes the main contacts to open, at which time arcing occurs.

b) Arcing at the main cantacts ceases after a zero current flow point has been reached, but is transferred to the arcing gap. Current is limited by the short-circuit interrupting resistor and the rate of rise of the restriking voltage is suppressed. When the short circuit current is low, arcing is not transferred to the arcing gap: Instead, direct interruption is used. In the case of 24 kV, 1,000 MVA and 36 kV, 1,500 MVA types, short-circuit interrupting resistor and a arcing gap are not equipped. Therefore, the process in which arcing is transferred to the arcing gap by means of the recovery voltage when arcing at the main contacts reaches a zero current point is eliminated. A minute level of current flows in the over-voltage suppressing resistor. In other words, the processes in *Fig. 7* (b) and (c) are eliminated.

c) Approximately one-quarter of a cycle later, arcing at the arcing gap is interrupted. At the same time, a minute level of current caused by the recovery voltage flows in the over-voltage suppressing resistor.

d) Operation of the control valve opens the disconnecting section and this small current is interrupted.

e) Recovery of the tripping valve restores the main contacts and stops the air blast.

2. Construction of Interrupting and Disconnecting Sections

Fig. 8 depicts construction of the interrupting and disconnecting sections in a 12 kV, 1,000 MVA, 4,000 A type. In the new series, bypass section have been eliminated by procedures which include reduction of

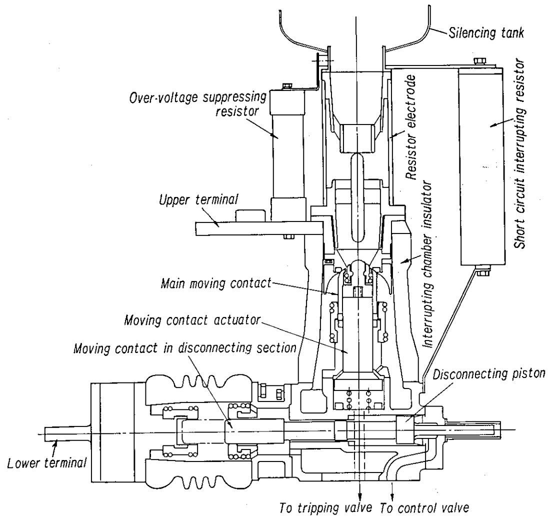


Fig. 8 **Construction of interrupting and disconnecting sections**

contact resistance, that is, without extensive changes in the former 2,000 A models. Construction is quite simple. In comparison to the old 2,000 A types, dimensions of interrupting section and disconnecting sections of the new 4,000 A units have been made somewhat larger. In the case of 3,000 A, only the external terminals have been changed. That is, 2,000 A types have been upgraded to 3,000 A. This means that field modifications to already delivered 2,000 A type may be made to upgrade the rating to 3,000 A.

With the earlier approach (use of bypass unit), it was necessary to open the bypass section ahead of the interrupting section, requiring some five cycles for interruption. Without the bypass unit, interruption can take place in three cycles.

The results of temperature rise tests on units with bypass unit are shown in *Fig. 9* and *Fig. 10*. There is very little difference in comparison to units with bypass one but ample margin in respect to standard values.

Fig. 11 depicts construction of interrupting and disconnecting sections in a 24 kV, 1,000 MVA type.

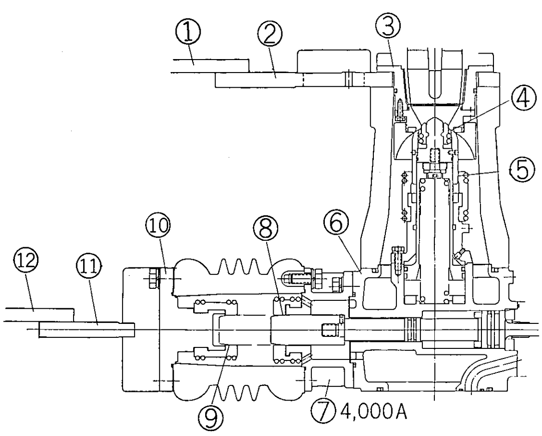
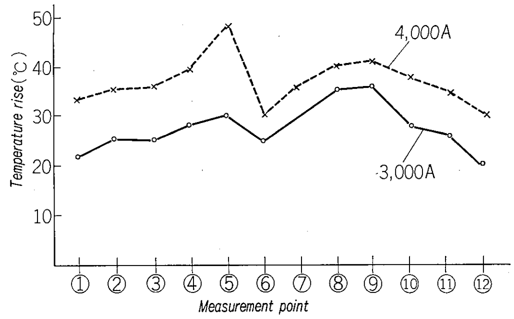


Fig. 9 **Temperature rise measurement points**



Note 1: Measurement conditions...Air pressure of 12.7 kg/cm^2•g Frequency 60 Hz

Note 2: Thermocouple used at points (5), (8), and (9). Alcohol thermometer used at other points

Fig. 10 **Temperature rise test**

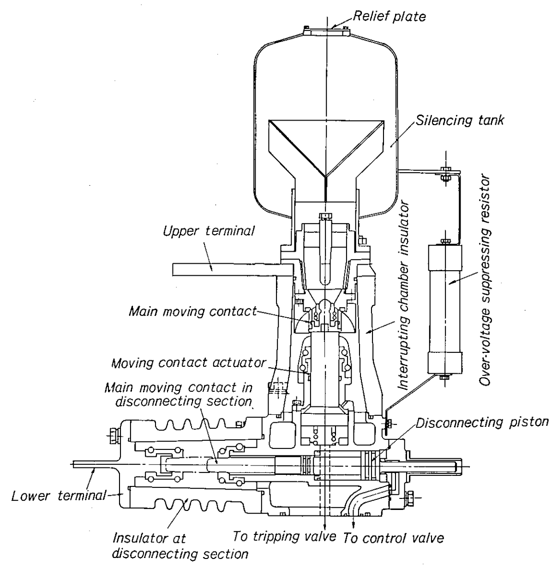


Fig. 11 **Construction of interrupting and disconnecting sections**

Bat contacts are used for current carrying surfaces. By using slide system contacts constructed from arc resistance metal in place of bat contacts for medium capacity types (current interrupting capacity of 25 kA), it was shown that interruption was possible at a rating of 24 kV, 1,000 MVA under restriking voltage frequency No. 2 (9 kHz) without suppressing the restriking voltage. Therefore, in 24 kV, 1,000 MVA types, the arcing gap and short-circuit interrupting resistor have been eliminated. For types rated at 36 kV, 1,500 MVA, the same contacts were not able to effect interruption under No. 2 (7 kHz) conditions. Demands for No. 2 in types of this category are not frequent, enabling the application of No. 1. Limit tests in respect to the restriking voltage frequency were not conducted, but the feasibility of interruption at 4.5 kHz was demonstrated. Naturally, if a short-circuit interrupting resistor is added to a No. 1 (1.4 kHz) type, No. 2 interruption will be possible.

By changing the bat contacts to slide system contacts, contact service life has been extended considerably. The operating pressure in 24 kV,

Table 3 **Test results of short-circuit current interruption**

Objective interrupting capacity	State	Operating duty	Tetsing voltage	Interrupting current		Frequency of restriking voltage	Arcing time	Interrupting time	Recovery voltage	Remarks
				Symmetrical	DC component					
			(kV)	(kA)	(%)	(kHz)	(∾)	(∾)	(kV)	
24 kV 1,000 MVA	110% Short circuit	—1 min.— | —3 min.—	21.5	26.5	10	9.2	0.58	2.08	20.0	
			21.5	26.6	18	9.2	0.55	2.05	20.0	
			21.5	27.8	76	9.2	0.50	2.00	20.0	
36 kV 1,500 MVA	110% Short circuit	—1 min.— | —3 min.—	18.8	25.6	27	4.5	0.55	1.78	44	Synthetic test by "Weill" method
			18.8	24.8	20	4.5	0.53	1.80	44	
			19.8	25.8	52	4.5	0.53	1.79	44	
12 kV 1,000 MVA	110% Short circuit	—1 min.— | —3 min.—	10.9	51.3	26	15.2	0.37	1.69	11.0	
			10.9	51.3	51	15.2	0.50	1.68	11.0	
			10.9	51.3	47	15.2	0.45	1.72	11.0	
24 kV 1,500 MVA	110% Short circuit	—1 min.— | —3 min.—	20.6	37.7	53	10.4	0.42	1.67	20.0	
			20.6	36.4	20	10.4	0.52	1.79	20.0	
			20.6	39.7	44	10.4	0.40	1.62	20.0	

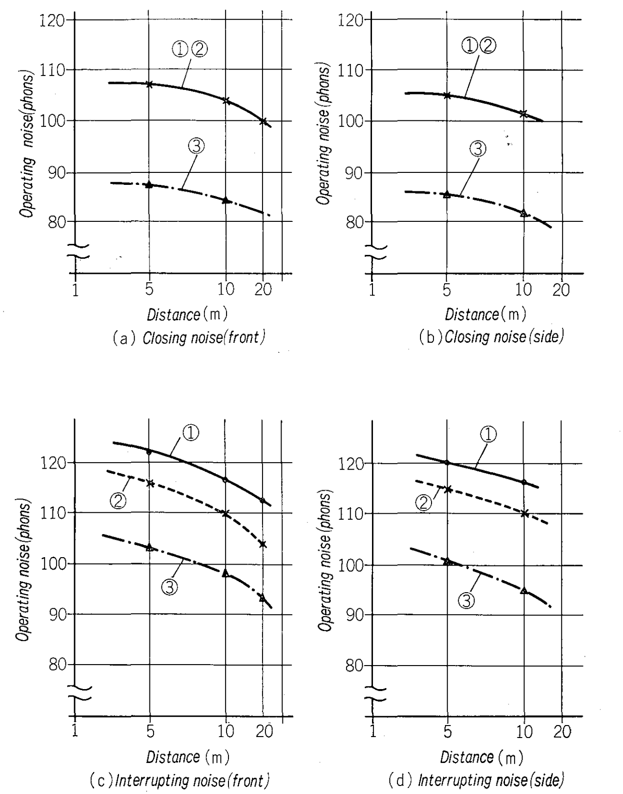
Note: Test condition......Single phase, operating pressure of 12.7 kg/cm²·g

1,000 MVA types has been dropped to 7 kg/cm²·g. That contacts in a circuit breaker for electric furnace operation (some one hundred operations daily) exhibit no sign of damage after 10,000 closing-opening operations at 1,200 A is proof of the service life.

3. Silencing Construction

The silencing tank located at the exhaust section stores the discharge during interruption. Later, the discharge is vented slowly through a small hole. The air blast in the interrupting section is of a duration and volume which satisfy requirements. During short-circuit interruption, of course, arcing will cause the temperature and pressure of the exhaust gas to rise. Ample margin was confirmed by measuring the silencing tank pressure during short-circuit interruption. Even though a silencing tank has been installed, there is no deterioration in interruption performance. Results of interrupting tests have been tabulated in *Table 3.* Air stored in the silencing tank escapes through a five millimeter hole during the course of fifteen seconds. This arrangement does not disturb operating duty of the circuit breaker. A pressure relief plate is located on top of the silencing tank. In the event that interruption is not possible for some reason, the pressure in the silencing would rise to an excessive value. To prevent rupture of the tank, the relief plate serves as a safety valve which limits pressure rise.

With the silencing tank installed, the operating noise is some ten phons less than that of ordinary air blast circuit breakers. Including the effect of a cover attached to the operating mechanism, the operating noise is some twenty phons less. Results of noise measurement are shown in *Fig. 12.* With



Note 1: In these graph ① Old RF 701
② Standard RFa 701
③ Low noise RFa 701

Note 2: Conditions of measurement
Single installation, operating pressure of 15 kg/cm²·g, height above ground of 1.6 meters, dark noise level of 80 phons (measuring range C of phonometer used)

Note 3: In the case of cubicle installation, noise level will drop by 5~10 phons

Fig. 12 Noise level measurement

the silencing tank equipped, the phase-to-phase insulating distance becomes less. Therefore, the insulation must offer an ample breakdown margin. Results of phase-to-phase flash over tests are:

(1) Types rated at 12 kV, 24 kV (same phase-to-phase dimensions)
 Low-frequency (50 Hz) flash over test
  93 kV (position of flash over...side of silencing tank) > No. 20, 50 kV
 Impulse flash over test (1×40 μsec, 50% short)
  Positive polarity 143 kV (position of flash over... side of silencing tank) > No. 20 B, 125 kV
  Negative polarity 151 kV (position of flash over...side of silencing tank) > No. 20 B, 125 kV

(2) Types rated at 36 kV
 Low-frequency (50 Hz) flash over test
  110 kV (position of flash over...side of silencing tank) > No. 30, 70 kV
 Impulse flash over test (1×40 μsec, 50% short)
  Positive polarity 220 kV (position of flash over...intermediate case) > No. 30 B, 170 kV
  Negative polarity 250 kV (position of flash over...intermediate case) > No. 30 B, 170 kV

IV. CONCLUSION

Retaining merits of the RF701, a silencing tank has been added to limit ambient noise. The shock of air discharge has no effect on the cubicle or structure in which the circuit breaker is housed. The short-circuit interrupting resistor has in part been eliminated, simplifying construction. Bypass units have been eliminated in types handling high (3000 A, 4,000 A) currents, further simplifying construction. Contact service life has been extended and troublesome inspection and maintenance eliminated. That this new series offers a number of advantages is quite evident.

References

(1) Nishino, Noguchi: 12~36 kV Indoor Air blast Circuit Breakers Fuji Electric Journal 39 No. 12 (1966)

(2) Noguchi, Yamaguchi: High-capacity Indoor Air blast Circuit Breakers Fuji Electric Journal 41 No. 9 (1968)