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AIR BLAST CIRCUIT BREAKER

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I. FOREWORD

In accordance with the increased demand for electric power in recent years, circuit breaking capacities required in power supply systems have also increased. It is a well-known fact that, to comply with these tendencies, air blast circuit breakers which can be easily maintained and inspected, and with which a high voltage large capacity circuit breaking system can be constructed economically, have been spread over electric power supply systems.

These circuit breakers began with the so-called pulsive-blast type in which, at the time of breaking, compressed air is sent to the nozzle contact from a valve provided on the lower ground potential portion. However, it has been recognized that the constantly pressurized type (in which compressed air constantly fills the breaking chamber and in which highly compressed air up to nearly the rated value can be effectively utilized for arc-extinction at the time of breaking) is far better than the pulsive-blast type.

As a matter of fact, manufacturers in America and Europe have, for several years, been directing their testing and research works strictly toward the constantly pressurized type.

Based not only on the increased breaking-capacities in electric power supply systems, but also on practical efficiency, air blast ciucuit breakers with fewer breaking units (air blast circuit breakers constructed with large capacity breaking units) are expected to appear.

In this situation, based on circuit breaker manufacturing experience of many years, Fuji Electric has for several years given priority to development and testing of constantly pressurized type air blast circuit breakers. As a result, an air blast circuit breaker has been developed in which a 72/84 kv (3500 Mva) high capacity breaking chamber is applied as the breaking unit. This is the first application of such a high capacity breaking chamber to a circuit breaker product developed strictly on Japanese engineering. Various models of all outdoor type, air blast circuit breakers are constructed using this breaking unit.

In addition, the constantly pressurized system has also been applied to a series of indoor type air blast circuit breakers with a capacity of less than 36 kv rated voltage; this series is also introduced in this edition.

For the ratings, refer to *Table 1*.

II. OUTDOOR TYPE AIR BLAST CIRCUIT BREAKER

In development, one unit was manufactured for trial which has the same size as the actual product. Utilizing this, direct and synthetic tests, by using 1500 Mva short-circuit testing instruments available at Fuji, were performed over a long period of time. Through these tests, confirmation of the maximum capacity of 84 kv 3500 Mva, with 4 kc restriking frequency (JEC-145) was made with 85% of the rated pressure (12.7 kg/cm^2 g). After performing noise tests and revising each portion, final design was concluded.

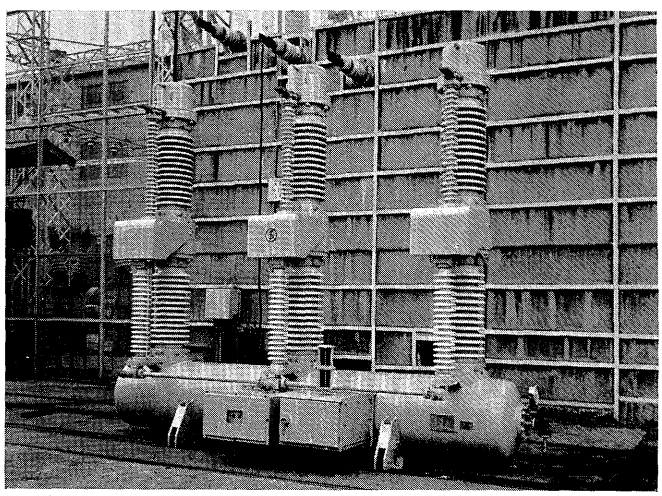


Fig. 1 72/84 kv 3500 Mva 2000 amp air blast circuit breaker

1. Characteristics

In addition to the advantages provided with former constantly pressurized air blast circuit breakers, this model has the following characteristics:

1) Two nozzles are opposed on the contacts, and these nozzles are fitted closely through a gasket

Table 1 **List of ratings and specifications**

Type / Ratings	Outdoor Use			Indoor Use			
	RF720JⅢ/ 140/2000D	RF720GⅢ/ 100/2000D	RF720CⅢ/ 70/2000D	RF701jⅢ/ 30/1200D	RF701hⅢ/ 20/1200D	RF701gⅢ/ 10/1200D	RF701CⅢ/ 6/1200D
Rated Voltage (kv)	168	120	72/84	36	24	12	3.6/7.2
Insulrtion Level (kv)	Ac 325 Imp. 750	Ac 230 Imp. 550	Ac 140/160 Imp. 350/400	Ac 70 Imp. 170	Ac 50 Imp. 125	Ac 28 Imp. 75	Ac 22 Imp. 60
Rated Current (amp)	2000	2000	2000	1200	1200	1200	1200
Rated Freqency (cps)	50/60	50/60	50/60	50/60	50/60	50/60	50/60
Rated Breaking Capacity (Mva)	7500	5000	35000	1500	1000	750	200/350
Rated Opening Time (sec)	0.04	0.04	0.04	0.03	0.025	0.025	0.02
Rated Breaking Time (cycles)	3	3	3	3	3	3	3
Operating Pressure (kg/cm^2)	15	15	15	15	15	15	15
Control Voltage (v)	Dc 100	Dc 100	Dc 100	Dc 100	Dc 100	Dc 100	Dc 100
Rated Restriking Frequency (kc)	2.5	3	4.5/4	7	9	15	20
Closing Time (sec)	0.15	0.15	0.15	0.1	0.08	0.08	0.06
Standard Operating Duty	O-(1 min)-CO-(3 min)-CO			O-(1 min)-CO-(3 min)-CO and CO-(15 sec)-CO			
Rule	J E C - 1 4 5 (1 9 5 9)						

when the circuit breaker is in a closed condition. Hence, spaces in and outside of the nozzles are blocked. In the closed condition, the difference of these pressures is 15 kg/cm²g. The 15 kg/cm² g of pressure can be utilized as is for the pressure gradient of the nozzle portion at the time of breaking and at the beginning of contact separation. Due to these facts, effectiveness of blasting at the beginning is large and superior breaking capacity against a high frequency of restriking-voltage, even in a large current area, is obtained. At the same time, contact erosion is minimized.

2) Air blasting begins a little before separation of contacts due to utilization of the above described gasket. As the stoppage of blasting is performed by closing the exhaust valve provided on the exhaust side, stoppage is accomplished without any relation to motion of the contacts. As a result, the amount of expended air is limited to a minimum.

3) Under the condition where the circuit breaker is closed and current is flowing, the insides of both the upper and lower nozzles are opened to air. Therefore, Joule's heat, generated in the inside of the current path, is released through this path which has a chimney shape. As the result, the inside temperature rise is limited to a very small value which is advantageous for electric current carrying capacity.

4) As the main contact is tulip shaped, the contacts never vibrate (even at the time of closing).

5) A cooler and glass-wool silencer are provided in the interest of quiet operation.

6) As the unit is 84 kv, inside inspection is easier in comparison with the 42 kv unit.

7) Inspection and replacement of the contacts can be performed easily by removing the six bolts which hold the head portion of the mechanism and by lifting the head portion up as is.

8) The external dimensions are smaller in comparison with a general type circuit-breaker of the same capacity.

9) This device is classified into three different types by individual purpose as follows:

(1) RF 720 type
For general purpose in which exciting current is not excessively large. This type has no parallel resistance.

(2) RF 721 type
This type is to be used for reactor switching or for application of a large exciting current. This type is provided with non-linear resistance to prevent surge voltage generated by breaking electric current.

(3) RF 722 type
This type is to be applied to important lines in the electric power suuply system with which low resistance is arranged in parallel to stand for short line fault (SLF).

Modification of these type can be accomplished by removing and adding the parallel resistance parts.

2. Structure

1) Operating unit

Interruption and closing are performed by actuating the trip valve and closing valve installed on the side surface of the tank located on the ground through the magnetic valve. For the trip valve, a

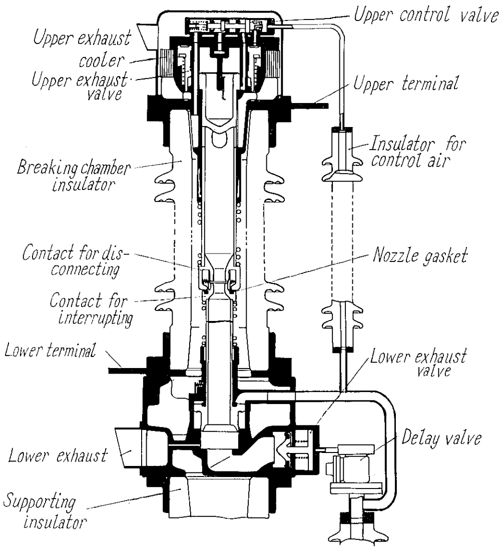


Fig. 2 Cross-sectional view of breaking chamber (84 kv unit)

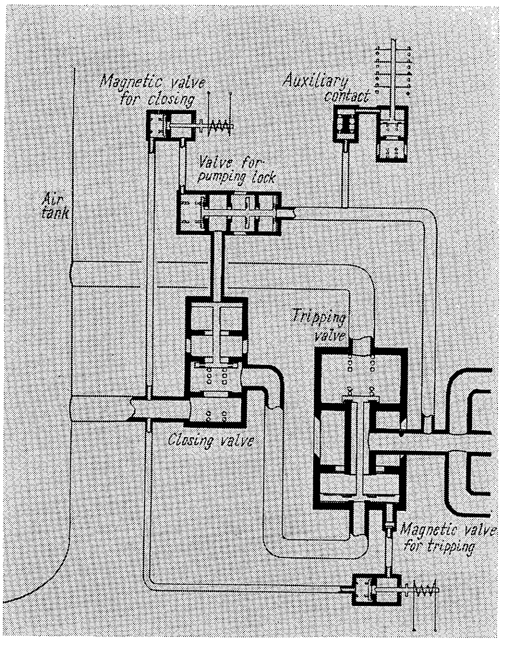
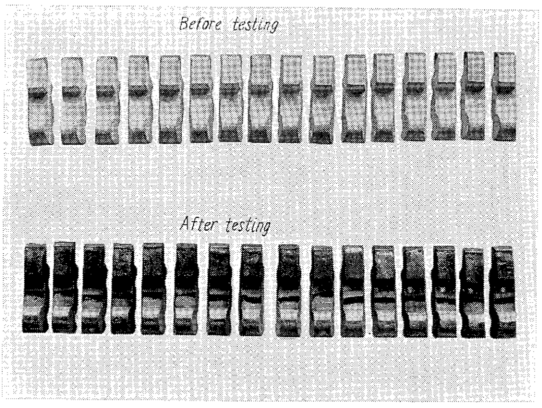


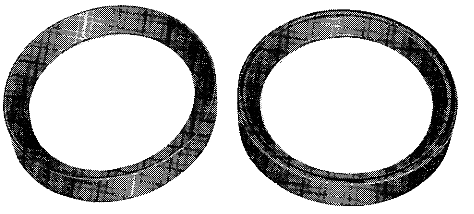
Fig. 3 Main valve system

characteristic, self-amplifying type, rapid operating system which was developed by Fuji Electric has been applied ; hence, motoin of the valve is very fast.

Operating air is fed at the time of breaking and exhausted at the time of closing. The tube line is passed through the operating air insulating tube located adjacent to the supporting insulator and reaches to the delay valve and other necessary portions. A small amount of dry air is always fed into the inside operating air tube having no pressure at the time of closing, hence preventing freezing of the water content. Prevention of pumping at the time of free tripping is performed pneumatically by the lock valve provided on the operating unit.



(a) Sliding contacts



Before testing After testing

(b) Nozzle gaskets

Fig. 4 Contact parts around nozzles before and after tests breaking a total of 1,960,000 amp

Manual operation is accomplished by pushing the bottons provided on the side surface of the tank for tripping and closing, after supplying compressed air.

2) Breaking unit

The breaking unit consists of two nozzle-shaped contacts which oppose each other. The lower contact moves backward over an adequate distance for breaking and stays in this position from the beginning of breaking through the time of complete breaking. The upper contact motion is delayed from that of the lower contact and moves backward over a distance required for breaking.

As stated in the previous paragraph, a heat-proof gasket is provided on the contact portion of these upper and lower contacts. This gasket holds the difference of pressures between in and outside of the nozzles at the rated value (15 kg/cm^2 g) during closing time. Because of this, blasting effectivenss at the beginning of contact opening is remarkably high and the breaking efficiency is extremely satisfactory. The life of the heat-proof gasket is such that wear at the edge of the gasket after usage for 50 or 60 times of opening and closing under the rated breaking current (accumulated 2,000,000 amp.) is only 0.5 through 0.7 mm and is still serviceable for further usage. This means that the gasket has a longer life than that of the contact portions of the nozzles.

3. Results of Testing

1) Temperature rise test

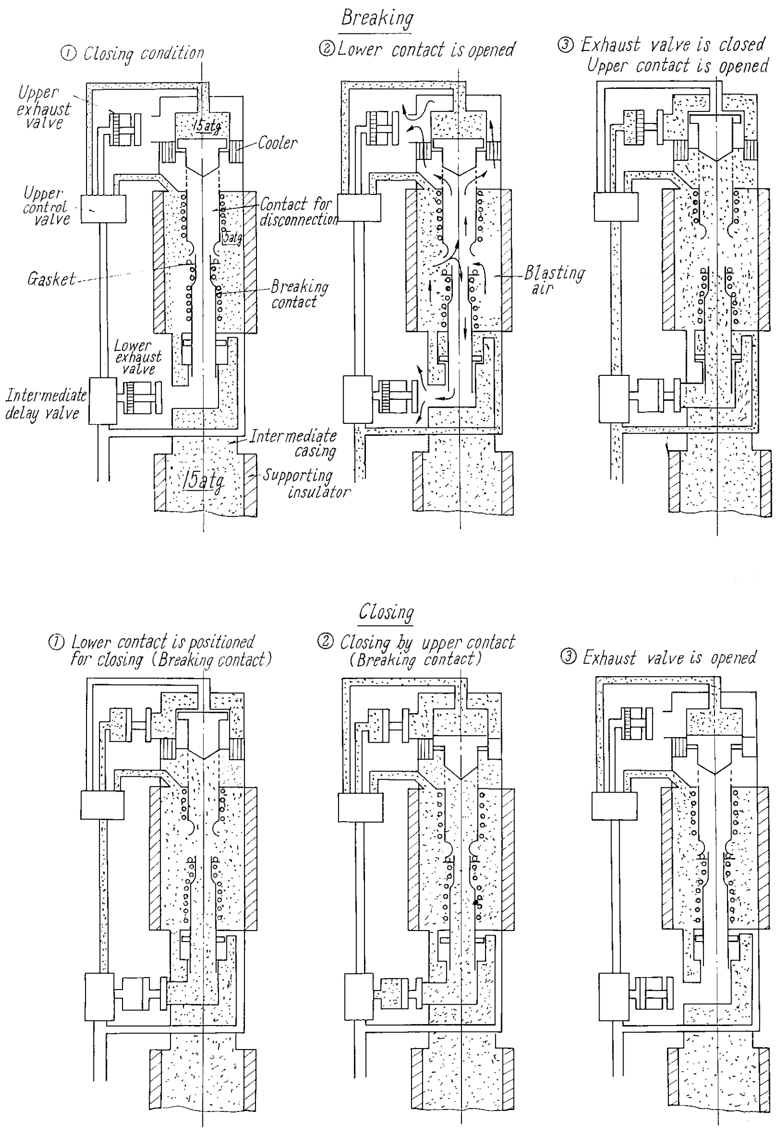


Fig. 5 **Explanatory diagrams concerning opening and closing**

When 2000 amp of current (60 cps) flows, the temperature rise of all portions is under 30°C and there is still sufficient margin left.

2) Insulation test

Passed from the following No. 70 tests which are stipulated in JEC–145 : in contacts opening.

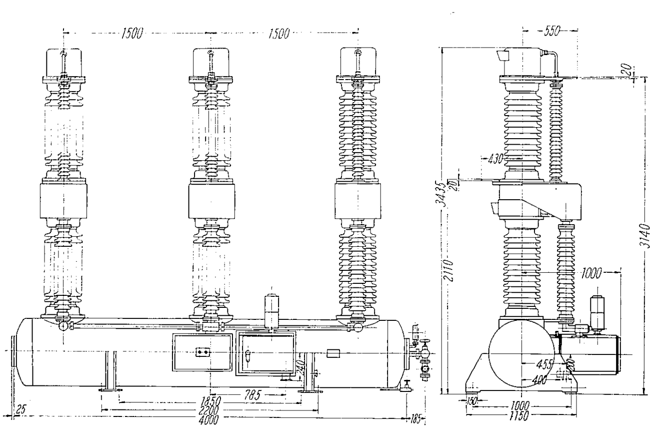


Fig. 6 **Outline dimensions of 72/84 kv air blast circuit breaker**

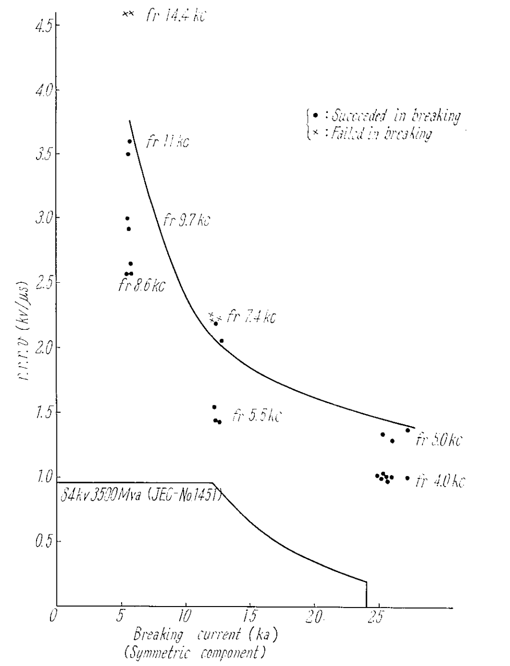


Fig. 7 **Characteristics curves in short-circuit breaking**

Insulation test for ac :

160 kv 50 cps 1 min

Insulation test for impulse :

400 kv (1×40 μs)

3) Breaking test

Short-circuit breaking under operating pressure 15 kg/cm^{2}g and exciting current breaking under 16.5 kg/cm^{2}g were performed. Reactor current breaking was accomplished under 16.5 kg/cm^{2}g for the RF 721 type after attaching additional non-linear resistance.

(1) Short-circuit testing

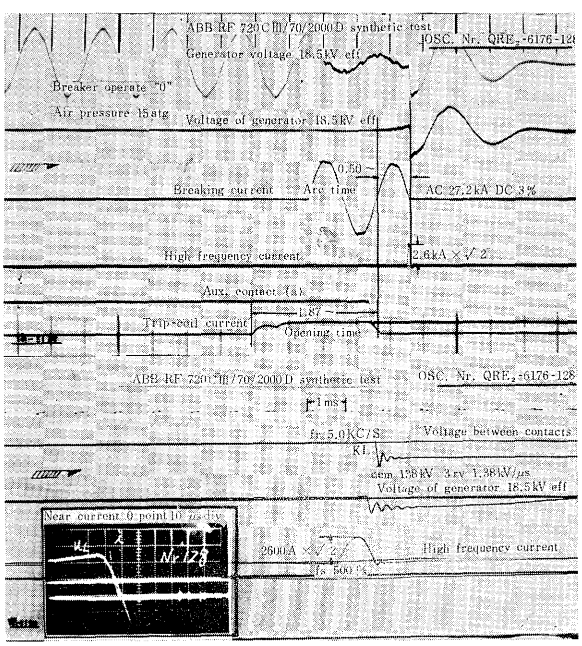
Direct testing of 25% breaking capacity was performed, and equivalent testing by applying a Weil circuit was accomplished up to 110%. Hence, it was confirmed that the capability is better than that described in JEC–145 No. II even under the condition of 72/84 kv (3500 Mva). (Refer to *Fig. 7* and Table 2 above.) During testing, many breakings were obtained without replacing the contact points and wear was insignificant (Refer to *Fig. 2*).

(2) Different phase grounding and phase opposite tests

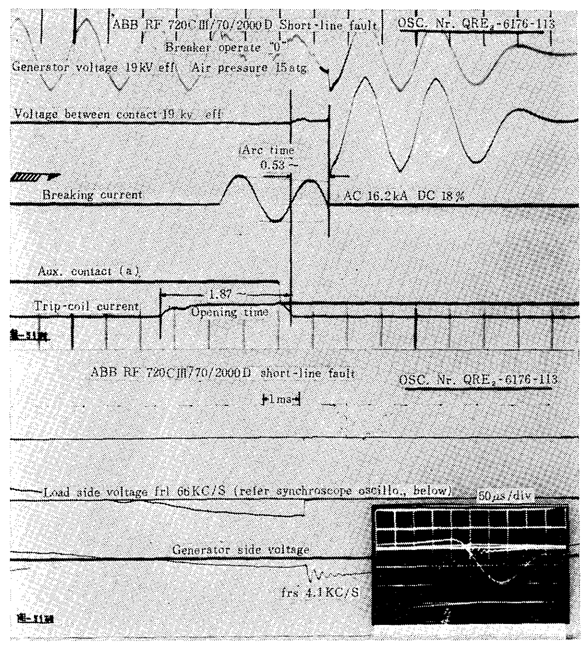
These tests were made with the modified Skeats equivalant test method. For the different phase grounding, breaking was obtained under the recovery voltage which corresponds to the line voltage, up to 87% of the rated breaking current. As the result, the breaking of up to 4.5 kc of restriking frequency was accomplished. Phase opposite breaking was obtained under 130%

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

Type of Tests	Supplied Voltage (kv)	Breaking Current (ka)	Arcing Time (~)	Restriking Frequency (kc/s)	Restriking Voltage (kv)	r. r. r. v. (kv/μS)	Number of Successes / Number of Tests	Remerks
	5.7	5.5	0.1~0.42	4.5	82	0.74	4/4	Direct test
Breaking of Short-current	73	5.7	0.44~0.49	8.6	154	2.65	3/3	Weil circuit
	73	5.7	0.44~0.52	9.7	154	2.99	2/2	
	73	5.7	0.48~0.51	11.0	163	3.60	2/2	
	73	5.7	0.45~0.53	14.4	160	4.60	0/2	
	73	12.3	0.39~0.52	5.5	140	1.54	3/3	
	73	12.3	0.32~0.51	7.4	150	2.22	2/5	
	73	25.8	0.32~0.52	4.0	127	1.01	7/7	
	73	27.2	0.44~0.05	5.0	135	1.35	3/3	
Different Phase Grounding	87	13.5	0.60	4.2	190	1.60	1/1	Modified Skeats circuit
	82	21.8	0.48~0.50	4.5	155	1.39	2/2	
Phase Opposite	108	12.3	0.42~0.50	3.4	252	1.53	3/3	
Short Line-fault					Max. rate of 1st wave			Lumped LC circuit
	19	16.2	4.41~0.53	66/4.1	14.6	1.93	8/8	
	19	20.8	0.40~0.48	100/4.5	7.0	1.40	4/4	



(a) Synthetic test by Weil method



(b) Short line-fault test

Fig. 8 Oscillograms of breaking test

of the recovery voltage and 50% of the rated breaking current. As the result, breaking up to 3.4 kc of the restriking frequency was obtained. Hence, it was proven that the unit withstands even a high recovery voltage.

(3) Breaking test with high R. R. R. V. (rate of rise of restriking voltage)

Modifying the test which corresponds to the so-called "short-line fault" with a lumped constant circuit, testing was accomplished under 21 ka and 16 ka breaking currents which correspond to 1 and 2 km. Both breakings were successful. One oscillograph example is depicted in *Fig. 8* (b).

(4) Exciting current breaking test

This test was performed under 16.5 kg/cm^{2}g maximum operating pressure in which current chopping readily occurs. Changing the making phase, it was found that breaking up to 7.5 amp was possible and that overvoltage was less than 120% of the testing voltage.

(5) Charging current breaking test

When checking charging current breaking of non-grounded systems, restriking phenomena can be checked under 125% of the phase voltage. However, supposing that a voltage rise occurs on a long distance transmission line, the contact opening phase control was made under a condition where the phase voltage was 150% of the normal rating and operating pressure was a minimum of 12.7 kg/cm^2 g. Hence, an attempt was made to find the point where load side voltage becomes maximum. As the result, it was found that there was neither reignition nor restriking in breaking up to 14 amp, and insulation was superior.

(6) Reactor switching test

The explanations in paragraph (1) through (5) above are concerned with tests for the RF 720 which has no parallel resistance. In addition to these tests, reactor switching tests were made by using the RF 721 type with parallel resistance, under 150 amp～7.5 amp. The operating pressure was 16.5 kg/cm^{2}g. As a result, the overvoltage factor generated at the time of 50 amp breaking became maximum ; however, it was still less than 180% of the test voltage.

(7) Charging current breaking test with RF 721 type

It is severe to impress a value of more than two times the maximum rate of fundamental wave on non-linear resistance. Hence, the charging current breaking test for the RF 721 type was made. As a result, it was confirmed that breaking up to 12.7 kg/cm^{2}g, 73 kv, 14 amp of current under the most severe phase without restriking or reignition was possible and that the resistance remained in a normal condition.

In the above, test results with the air blast circuit breaker, as indicated in *Fig. 1*, were described. In addition to these tests, planning has been made to extend to short line-fault breaking test by distributed LC circuit in the future. This insures the capacity.

III. INDOOR TYPE AIR BLAST CIRCUIT BREAKER

1. Characteristics

1) Employment of a constantly pressurized system is the best for arc extinction among all air blast circuit breakers and hence has been employed in this model. This is the first system in the world in its class, indoor type air blast circuit breaker under 36 kv.

As with the outdoor types, gaskets are provided on the nozzle portion. Hence, the output side of air flow is open to the atmosphere. Due to this structure, characteristics of the constantly pressurized system can be fully utilized, providing that arc blast air flow pressurized quickly and the initial blast efficiency is very high.

Life of the gasket is very high. Even after an accumulated total of approximately 1,200,000 amp of breaking the gasket remains undamaged.

2) Ability of reducing total break-time

The nominal break-times established in the I.E.E.J. specification for ac circuit breakers JEC–145 (1959) are 5 and 8 cycles. Occasionally, however, a very short break-time is required for circuit breakers in a bus tie line system.

For 36 and 24 kv circuit breakers, the break-time can be further reduced from the nominal times by applying a superhigh-speed valve using a electromagnetic repulsion force developed by Fuji engineering.

3) Employment of compressed air disconnect system

Generally, for indoor type air blast circuit breakers under 36 kv, the air disconnect system is employed.

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

Type of Tests	Operating Pressure (kg/cm^{2}g)	Supplied Voltage (kv)	Current (amp)	Arcing Time (～)	Rate of Overvoltage	Number of Reignition	Number of Tests	Parallel Resistance
Exciting Current	16.5	73	1.6	0.04～0.06	Less than 1.1	—	4	Without, RF 720
	16.5	73	7.5	0.04～0.12	Less than 1.2	—	7	
Charging Current	12.7	73	7.2	0.05～0.18	Not generated	0	5	
	12.7	73	14.4	0.05～0.06	Not generated	0	3	
Reactor Current	16.5	73	12	0.07～0.17	Less than 1.4	—	11	With, RF 721
	16.5	73	30	0.10～0.42	Less than 1.8	—	6	
	16.5	73	47	0.20～0.48	Less than 1.8	—	12	
	16.5	73	110	0.34～0.37	Less than 1.6	—	9	
	16.5	73	160	0.38～0.40	Less than 1.5	—	3	
Exciting Current	16.5	73	7.5	0.04～0.07	Not generated	—	6	
Charging Current	12.7	73	7.2	0.01～0.05	Not generated	0	3	
	12.7	73	14.4	0.03～0.08		0	5	

However, this model uses the compressed air disconnect system in accordance with recent trends for the outdoor type, air blast circuit breakers. Due to employment of this system, closing is made in compressed air and hence contact damage from pre-arc is very slight.

4) Use of epoxy resin insulator

Utilizing epoxy resin insulators which were developed by the Fuji Electric for the interrupting chamber and other necessary portions, high mechanical strength characteristics were fully utilized.

2. Structure

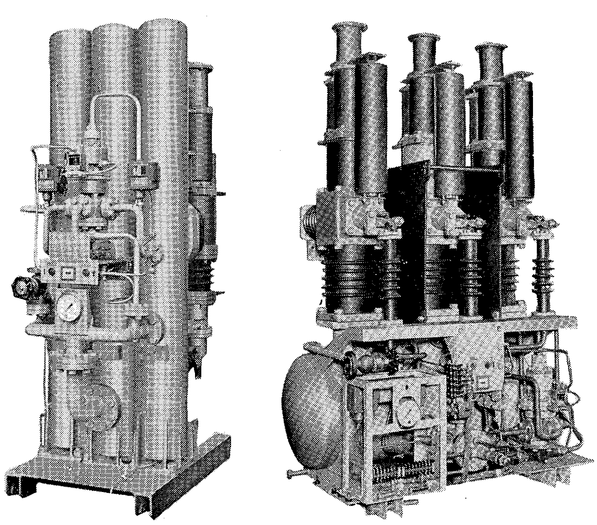
The photograph in *Fig. 9* shows the appearance and *Fig. 10* indicates an example of sectional view. Explanations in the following paragraphs concern the 24 kv type for convenience; however, there is not much difference when compared to other types of breakers.

The breaking and disconnecting units for 3-phase are installed on the upper portion of the air reservoir which functions also as the base of the breaker. The disconnecting unit is arranged horizontally on the supporting insulators and, in the front, insulators for the operating air of the disconnecting unit are supplied. All of these insulators are made of epoxy resin. Other units are assembled above the disconnecting unit in the sequence of breaking chamber, resistance electrode, and cooler and muffler. Resistances for short-circuit breaking and for overvoltage suppression are placed on the front and rear sides of the resistance electrode.

Parts required in controlling of the breaker are all concentrated on the front panel of the air tank.

1) Breaking chamber

The breaking chamber is made of epoxy resin and the main contacts contained in this chamber are a butt type. Around the surface where electric current flows, heat resistant packing is provided. As



(a) 3.6/7.2 kv (b) 24 kv

Fig. 9 External view of ABB

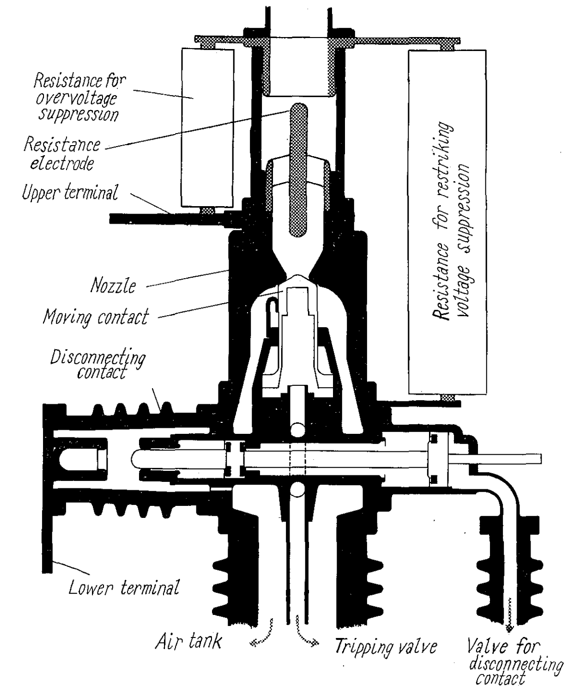


Fig. 10 Cross-sectional view of ABB

was explained in the paragraph on characteristics, life of the packing is extensive. On the surface inside the breaking chamber, special arc-resistant material is applied. Outdoor circuit breakers are a double-flow type; but for these types, a single-flow system was employed.

2) Disconnecting unit

Constantly pressurized air always exists inside the epoxy resin breaking insulator tube; opening and closing operations are made in compressed air. For fixed and sliding contact, tulip types are employed.

3) Resistor for short-circuit breaking

The resistor, on the spool of which metallic resistance wire is wound, is contained in the cylindrical insulator for protection. This reduces the rate of restriking voltage rise which is generated between the contacts during the arc extinguishing time.

4) Trip valve

This valve was designed as based Fuji engineering. The construction is such that the volume of control air passing from the electromagnetic pilot valve is amplified in the valve itself.

3. Examples of Test Result

1) 3.6/7.2 kv type

The *Table 4* shows an example of the breaking test series based on JEC–145 (1959).

Items 7 through 14 in the table prove the rated breaking capacity of the breaker. Taking, for an example, 1.3 cycle appearing in Item 10 of the table and assuming the opening time as a 60-cycle base, the total break time is only 2.3 cycles. Large currents are commuted to the resistor for short-circuit breaking; hence, the restriking voltage suppresing effectiveness is sufficiently displayed.

Table 4 **Results of 3.6/7.2 kv ABB Breaking Tests**

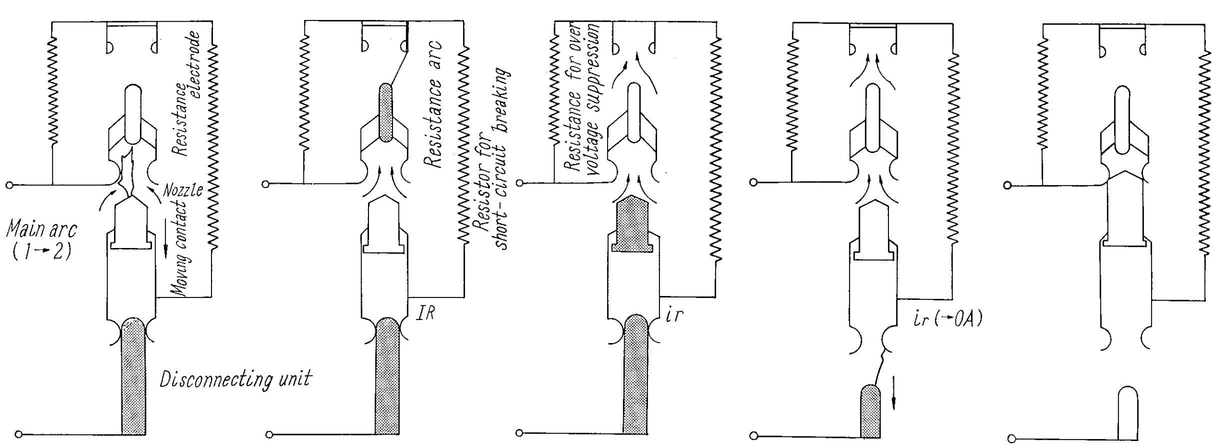
Type of Tests	Item No.	Operating Pressure (kg/cm²g)	Operating Duty	Voltage (kv)	Current (amp)	Arcing Time (~)	Making Current (ka)	Restriking Frequency (kc/s)	Number of Test Times		Breaking Capacity (3-phase) (Mva)
Capacitive Current	1	12.5	O	18*	23.6	0.1~0.3	—	—	12	Neither reignition nor restriking of arc	
	2	12.5	O	18*	50.0	0.1~0.3	—	—	12		
Inductive Current	3	16.5	O	20.5*	14.4	0.1~0.4	—	—	12	Overvoltage multiple is less than two	
	4	16.5	O	20.5*	29.5	0.1~0.4	—	—	12		
	5	16.5	O	20.5*	58.0	0.1~0.4	—	—	12		
Short-circuit Current	6	15.0	O	20.5*	1900	0.43~0.57	—	10	3		80
	7	15.0	O	20.5*	5400	0.3~0.6	—	10	3		220
	8	15.0	O	20.5*	7750	0.33~0.7	—	10	3		320
	9	15.0	O	20.5*	12,200	0.25~0.6	—	10	3		500
	10	15.0	O	20.5*	17,500	0.68~0.75	—	10	3		730
	11	15.0	O	20.5*	26,300	0.5~0.75	—	11	3	O-1 min-O-3 min-O	1100
	12	12.5	O	20.5*	26,300	0.5~0.75	—	11	3	O-1 min-O-3 min-O	1100
	13	12.5	O, CO, CO	24.0**	29,000	0.35~0.56	50~75	11	1	O-1 min-CO-3 min-CO	1200

Note) Test Frequency: 49.5 cps   Opening time: 24 ms (1.22~)   Percentage of contained dc for item 13: 45%
*: 1ϕ **: 3ϕ

Table 5 **Results of 24 kv ABB Breaking Tests**

Type of Tests	Item No.	Operating Pressure (kg/cm²g)	Operating Duty	Voltage (kv)	Current (amp)	Arcing Time (~)	Making Current (ka)	Restriking Frequency (kc/s)	Number of Test Times		Breaking Capacity (3-phase) (Mva)
Capacitive Current	1	12.5	O	6.6	15	0.1~0.3	—		12	Neither reignition nor restriking of arc	
	2	12.5	O	6.6	25	0.1~0.3	—		12		
	3	12.5	O	6.6	51	0.1~0.3	—		12		
Inductive Current	4	16.5	O	6.6	13	0.2~0.3	—		12	Overvoltage multiple is less than two	
	5	16.5	O	6.6	21.5	0.1~0.36	—		12		
	6	16.5	O	6.6	38	0.1~0.42	—		12		
Short-circuit Current	7	15.0	O	6.3*	1500	0.15~0.5	—	—	3		20
	8	15.0	O	6.3*	6500	0.37~0.45	—	—	3		80
	9	15.0	O	6.3*	11,800	0.25~0.9	—	—	3		150
	10	15.0	O	6.3*	16,700	0.3~1.3	—	—	3		200
	11	15.0	O	6.3*	21,300	0.5~1.0	—	20	7		260
	12	15.0	O, CO, CO	7.2**	29,000	0.4~1.1	88	22	7	O-1 min-CO-3 min-CO	360
	13	12.5	O, CO, CO	7.2**	29,000	0.4~1.0	88	22	1	O-1 min-CO-3 min-CO	360
	14	12.5	O, CO, CO	3.6**	33,000	0.7~1.2	122	20	1	O-1 min-CO-3 min-CO	210
	15	12.5	O	3.6**	44,000	1.2	—	20	1		270

Note) Test Frequency: 49.5 cps   Opening time: 17 ms (0.85~)   Percentage of contained dc for item 12 and 13: 52%
*: 1ϕ **: 3ϕ



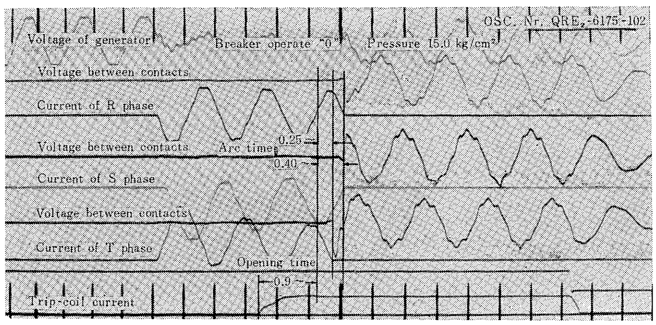
(a) Generation of main arc   (b) Moved to resistance arcing   (c) Suppression of over voltage   (d) Breaking of minor current   (e) Completion of breaking

Fig. 11 Explanatory diagrams for actuation

It was recognized that some margin remains in the breaking capacity; up-rate testing is still being perfromed continuously. Item 15 is an example of this.

As depicted in *Table 4*, there is no unusual occurrence in capacitive or inductive current breaking.

An example of oscillograms produced during breaking tests is shown in *Fig. 12* (a).

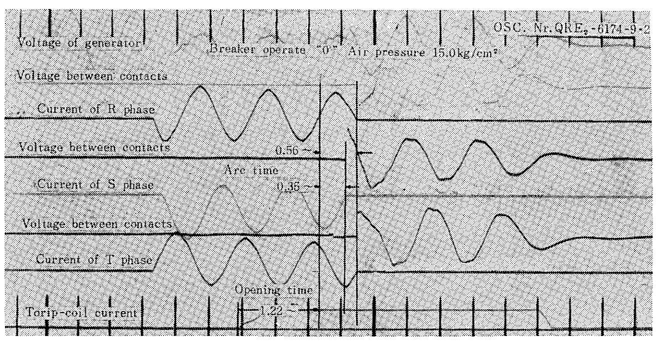


Breaking current of R phase ac 29.0 ka dc 45%

Breaking current of S phase ac 39.0 ka dc 58.2%

Breaking current of T phase ac 28.7 ka dc 52.3%

(a) Testing voltage of 3.6/7.2 type: 7.2 kv



Breaking current of R phase ac 29.0 ka dc 18.2%

Breaking current of S phase ac 28.6 ka dc 45.0%

Breaking current of T phase ac 26.6 ka dc 30%

(b) Testing voltage of 24 kv type: 24 kv

Fig. 12 Oscillograms of short-circuit current breaking

2) 24 kv type

As with the 24 kv type, test results are depicted in *Table 5* and the oscillogram in *Fig. 12* (b).

The rated breaking current is 24.1 ka and the maximum breaking current is 26.2 ka. However, testing was made under low pressure up to 29 ka and in all cases, breaking was accomplished in one cycle of arcing time. This type can hence be called a practical 2 cycle circuit breaker.

IV. CONCLUSION

From the results of testing and research accomplished during the past several years, a series of air-blast circuit breakers equipped with large capacity and high voltage breaking units using a constantly pressurized system was successfully developed as explained in the preceding paragraphs. Concentration of energy with a view toward future development of higher capacity circuit breakers will continue.

Correction

Table numbers and titles have been erroneously interchanged for Tables 4 and 5 shown on page 111.