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NEW EXPANSION CIRCUIT BREAKER, TYPE HF 800

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I. FOREWORD

In recent years the scale of the electric power transmission systems in Japan has been ever expanding to meet a remarkably increasing power demand. With the overall regional expansion, power transmission systems are becoming more and more complicated. The duty of high voltage circuit breakers in these systems is becoming more severe. The circuit breakers must correctly perform their duties of breaking short-circuit currents, breaking short-line-fault, breaking under phase-opposition and thousands of opening and closing operations required by the complicated power transmission systems. Further, the high reliability as superior structual strength, easiness of maintenance and inspection, dielectric strength of salt-contaminated insulators, and lower noise are required.

As the pioneer among manufacturers of minimum oil circuit breakers, we have already supplied several thousand units to the market. To meet the requirements of modern power transmission systems, a New Expansion Circuit-Breaker, Type HF 800 has been developed and is being mass-produced. Making full use of the advantageous characteristics of the minimum oil circuit breaker, while successfully overcoming all of the weak points that have previously been considered defects, this equipment has made possible record-breaking performance. The new circuit-breaker, HF 800 is adaptable to all working conditions encountered in power transmission systems and is unaffected by severe conditions. On this new circuit breaker, thousands of short-circuit breaking tests have been performed in our laboratory and the Takeyama High Voltage Power Laboratory. Further, small current breaking tests and continuous operation tests (ten thousand times of opening and closing) were also performed. The results prove that the new circuit breaker's performance is more than sufficient and its capability is superior to its ratings.

The ratings and main specifications are indicated in *Table 1*.

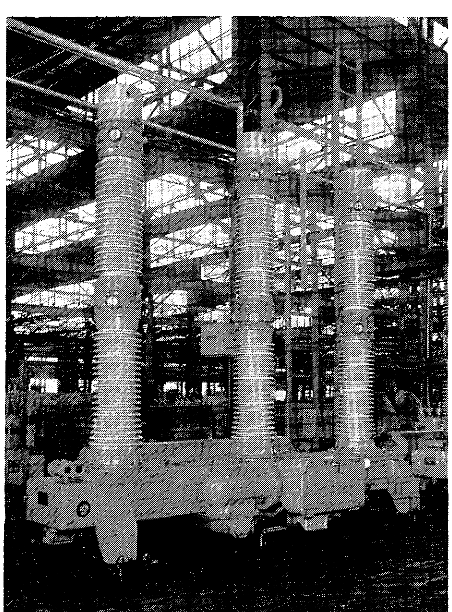


Fig. 1 View of ECB HF 800 G/100 at shop

Table 1 **List of Ratings and Main Specifications of ECB, Type HF 800**

Model		HF 800C /70	HF 800C /100	HF 800G /100
Rated Voltage (kv)		84/72	120	120
Rated Normal Current (amp)		1200	1200	1200
Rated Breaking Capacity (Mva)		3500	3500	5000
Rated Restriking Voltage	Amplitude Factor	1.3	1.3	1.3
	Natural Frequency (kc/s)	4/4.5	3	3
Make-time (sec)		0.20	0.20	0.20
Opening-Time (sec)		0.055	0.055	0.055
Total Break-Time (cycle)		5	5	5
Rated Operating Pressure (kg/cm²g)		5	5	7
Capacity of Air Reservoir (*l*)		1000	1000	1000
Rated Control Voltage (v) (dc)		100	100	100
Rated Operating Duty		0-1 min-CO-3min-CO		

II. CHARACTERISTICS

1) The new circuit breaker is capable of breaking certainly all kinds of faults of power transmission systems

It is an advantageous characteristic of oil circuit-breaker that not only small current, such as load current, charging and exciting current, and short-circuit current under the conditions rated in the JEC Specification, but also circuits with a more severe restriking-voltage, such as double-ground-fault, phase-opposition, and short line-fault (so called kilometer-fault), can be breaked without difficulty. This is possible since insulating oil used as the arc extinguishing medium is not influenced by the restriking-voltage, and also since its breaking ability is combined perfectly with an arc extinguishing structure which is superior in dielectric strength.

A pressurized type arc extinguishing recovering system (which displays powerful arc extinguishing ability regardless of the breaking current value) has been adopted in the arc extinguishing structure of this circuit-breaker. In this system, oil under pressure is impressed into the arc extinguishing chamber from both the upper portion of the arc extinguishing chamber and the head of the moving contact. Under this method, the gas generated inside the arc extinguishing chamber is compressed, the dielectric strength of the gas is increased, and recovering the dielectric strength across the contacts is developed.

2) Insulating strength of the arc extinguishing chamber strengthened

Carbon formation on the surface of the supporting tube (formerly used to prevent sliding of arc extinguishing chamber units) surface, owing to the exhaust of gas generated in the arc extinguishing chamber, drops the dielectric strength across the contacts. In this new circuit-breaker, the arc extinguishing chamber units are not supported by the supporting tube but by the bonded structure. Further, in the individual arc extinguishing chambers, several units of different diameters are used. In particular, a corrugated type unit is adopted for the gas exhausting portion, thereby increasing the length of outer leakage paths. This corrugation is also effective in preventing the adherence of precipitated carbonized particles and hence the insulating strength along the surface has been remarkably improved.

3) Problem of declining of insulating oil has been perfectly solved

Declining of insulating oil, especially lowering of its dielectric strength, depends greatly on humidity. In former types of circuit breakers tight packing was not provided for the exhaust valve in order to easily release gas produced during interruption and to improve the arc extinguishing ability. As it has been proven that the pressure generated in the arc extinguishing chamber is so high that the gas pressure created in the head portion does not appreciably influence on the breaking ability, a packing of the exhaust valve for this new circuit breaker has been made tight and hence the sealed valve prevents the penetration of humidity.

4) Contact wear has been reduced

Again in comparison to the former type of circuit breaker, the arc-duration has been reduced and contact wear has become very small through the employmen of the pressurized type arc extinguishing system. Further, as the arc extinguishing chamber is pressurized by the moving contact even at closing operation, the initial arc-duration has been considerably shortened. The tulip shaped type fixed contact does not bring spark discharge by jumping, and contact life has been greatly prolonged.

5) Spouting of oil during breaking has been completely prevented

On the upper portion of the arc extinguishing chamber, a gas separator equipped with several spiral-shaped blades has been installed. The gas generated during breaking is provided with a centrifugal force by these blades as it goes to the upper gas chamber, while the fine-grained oil is separated from the gas and adheres to the interior of the upper gas chamber.

In the center of the upper gas chamber an exhaust valve with labyrinth structure, connected with the exhaust opening, and a safety valve which is opened when the pressure reaches to a certain value, are provided. Further separation of the gas and fine-grained oil is also performed in this area. Thus the exhaust of gas is delayed and the spouting of oil has been perfectly prevented.

6) Dielectric Strength of salt-contaminated insulators is increased

Based on the fact that a larger diameter insulator has a lower flash-over-voltage in contaminated condition, this circuit breaker uses a so-called "Contamination-Proof Insulator" in which the body diameter is small and the leakage path is long. By the employment of this insulator, ill effects from salt content of the air when used in sea-side areas, or from dirt when used in factory zones, have been reduced.

7) Amount of compressed air used is very small and highly compressed air is not required

Compressed air is used only when a closing operation is performed; hence, the amount used is very small. In comparison to air blast circuit breakers of the same rating, the usage value is only about 10%. Further, as compressed air is used for the air drive only, the compressed air generating equipment is very simple.

8) Noise during Operation has been largely eliminated

This noise is mainly due to the exhaust of compressed air out of the air drive. However, as the operating pressure is low, the amount of air used is small and the air is released to the outside only briefly; hence, the operating noise of this circuit breaker is very small. Even when this circuit breaker is used in a city area, there will be no trouble.

9) Maintenance and inspection are very easily performed

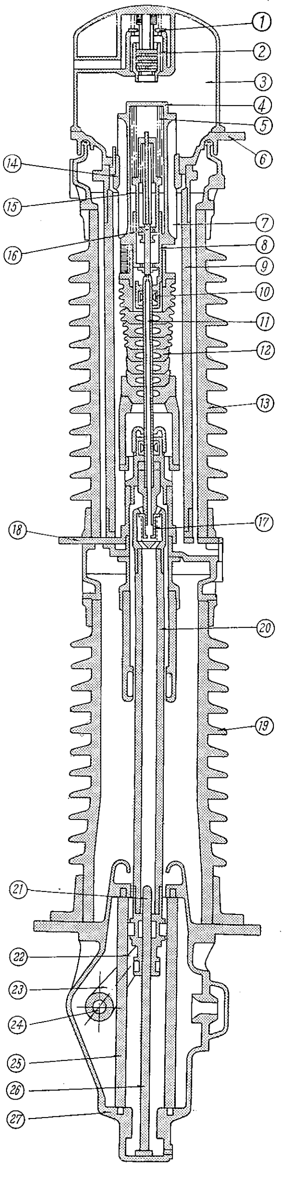
By the adoption of the pressurized type arc extinguishing system, the circuit breaker with a one-point breaking system has become possible. Because of this, link mechanisms (usually installed in the upper portion of the circuit breaker) are not required. Accordingly, the inside structure of the breaking chamber has been simplified and the weight of inspection portions has been reduced. In addition to these points, a bayonet structure has been employed in the parts requiring inspection and removal and lifting tools have been prepared. The operating efficiency has been improved and only two hours are required to inspect one circuit breaker.

10) Practicality of the operating mechanism has also been improved

An air drive has been specially designed for this circuit breaker, with much consideration given toward simplifying its structure and improving its practicality in handling, and in maintenance and inspection. A link mechanism is not adopted for its tripping device, in order to reduce the mass as much as possible. Instead of this, a mechanism in which a ratchet and a strong mechanical roller are combined has been employed. Because of the employment of this new mechanism, no adjustment is required and very smooth, constant tripping actuation is obtained. Ten thousand time life tests were performed on this tripping device with no unusual occurrence.

III. STRUCTURE AND SUMMARY OF ACTIVATION

This circuit-breaker employs a single pillar structure in which a contamination-proof insulator is used as the support for each pole. These are installed on the base of the lower portion and are connected by link mechanism. The air drive and the terminal box are also installed on the base. Closing operation is performed by compressed air and opening operation



① Non-return valve
② Safty valve
③ Gas chamber
④ Arc extinguishing device
⑤ Power spring
⑥ Upper terminal
⑦ Gas separator
⑧ Hydraulic power device
⑨ Insulating cylinder
⑩ Fixed contact
⑪ Moving contact
⑫ Expansion arc extinguishing chamber
⑬ Insulator
⑭ Supporting ring
⑮ Hydraulic piston
⑯ Power rod
⑰ Non-return valve
⑱ Lower terminal
⑲ Supporting insulator
⑳ Operating rod
㉑ Hydraulic power device (lower)
㉒ Reversible lever
㉓ Operating lever
㉔ Link mechanism
㉕ Guide rod
㉖ Hydraulic power rod
㉗ Link mechanism housing

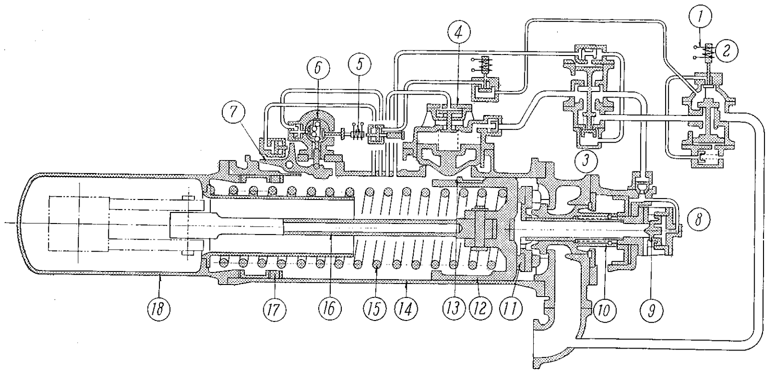
Fig. 2 **Explanatory drawing of main parts of ECB**

is accomplished by means of a main spring in common for 3-poles.

The breaking chamber unit consists of one set of moving and fixed contacts and the arc extinguishing device. The gas separator, for prevention of oil spouting, is also provided in the breaking chamber. All these units are protected by an insulating cylinder so that inside pressure is not directly impressed on the insulator.

The arc extinguishing device consists of the hydraulic power device on the upper portion, the expansion arc extinguishing chamber and the fixed contact. During closing operation the power spring is compressed by the moving contact and in opening operation, the insulating oil is forced into the expansion arc extinguishing chamber by the compressed power of the power spring without regard to the value of breaking-current.

The moving contact is an empty tube, on the



① Closing coil
② Closing valve
③ Control valve
④ Exhaust valve
⑤ Tripping coil
⑥ Tripping device
⑦ Ratchet lever
⑧ Operating valve
⑨ Air damper
⑩ Valve piston
⑪ Rubber damper
⑫ Piston
⑬ Ratchet
⑭ Cylinder
⑮ Main spring
⑯ Piston rod
⑰ Rubber damper
⑱ Crank housing

Fig. 3 Explanatory drawing of air drive

head of which several oil spout openings are provided. During breaking insulating oil is forced into the arc extinguishing chamber by actuation of the hydraulic power device provided on the lower portion of the circuit breaker, providing a superior breaking ability.

The operating rod, which drives the moving contact, passes through the center portion of the supporting insulator and is connected to the link mechanism unit in the lower portion of the circuit breaker. The hydraulic power device is located under the operating rod; when the operating rod is moved down (at the time of opening operation) it sends insulating oil to the moving contact.

In the lower link mechanism, a rotating motion, given to the operating lever by the air drive, causes the operating rod to move linearly (through the reversible lever) along the guide rod.

A simple cylindrical structure has been employed for the air drive. The cylinder is installed directly on the base with bolts. The closing valve, control valve, tripping device, exhaust valve, and other control valves are installed outside the cylinder. These valves are covered by a common housing. The operating valve is built up in front of the cylinder. Inside the cylinder, a piston and a main spring are contained. The piston is connected with the operating lever for each pole through the piston rod and the lower link mechanism unit.

The closing motion is initiated by compressed air forced into the cylinder, causing the piston to move down for compressing the power spring and, at the last stage, hooking the ratchet. The opening motion is started immediately as soon as this hooked condition is released.

The free tripping system uses both electric and pneumatic control. As the control valve maintains a locked condition after the closing operation, reclosing operation can be performed only after excitation of the closing coil is released.

IV. SHORT-CIRCUIT BREAKING TEST

We have already completed the single-phase load test, a synthetic test by the Fuji testing method, and a synthetic test using Weil's circuit. These tests were performed utilizing company-provided, short-circuit testing instruments to prove the breaking ability of the expansion circuit breaker, Type HF 800. In consideration of the recent tendency among manufacturers to require that the breaking ability be insured by testing with an instrument of larger capacity, additional short-circuit testing of this circuit-breaker has been performed at Takeyama High Voltage Power Laboratory. Results of the various tests follow.

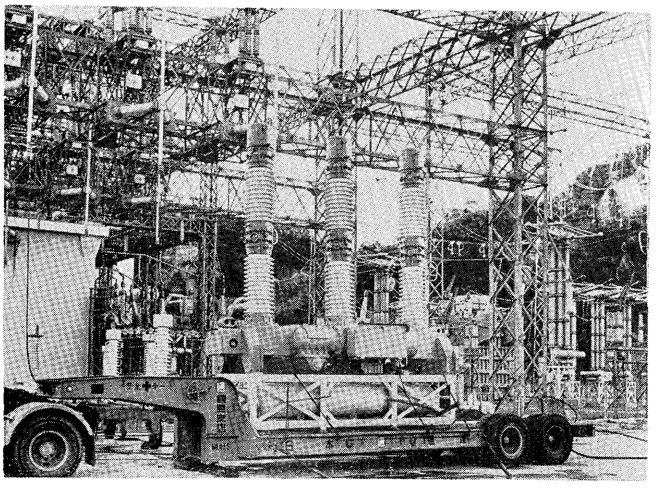


Fig. 4 View of new type ECB at Takeyama High Voltage Power Laboratory

1. Ratings of the Tested Circuit Breaker

Model:	HF 800 C/70/1200 D
Rated Voltage:	84/72 kv
Rated normal current:	1200 amp
Rated breaking-capacity:	3500 Mva
Total break-time:	5 cps

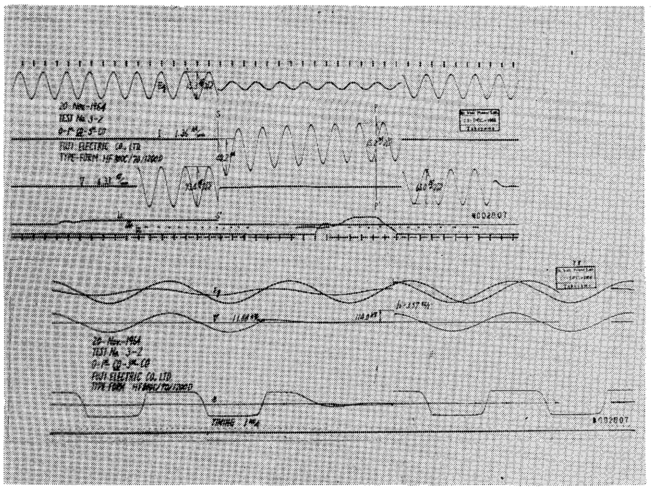
2. Test Results

The short-circuit breaking test has been performed in single-phase. The test conditions aimed at an amplitude factor 1.3 of the restriking-voltage in accordance with JEC 145 Specification. In cases of reduced voltage, the frequency of the restriking-

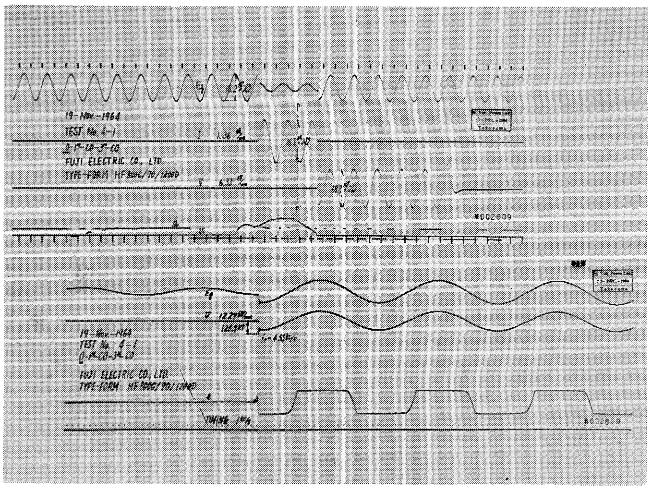
Table 2 **Results of Short-circuit Breaking Tests**

Test No.	Operating Duty	Test Voltage (kv)	Breaking Current (ka) Sym-metrical	Breaking Current (ka) Asym-metrical	Making Current (ka)	Arc Duration (cps)	Restriking Voltage Amplitude factor	Restriking Voltage Frequency (kc/s)
1-1	O } 1 min	73.0	2.51	2.52	—	1.04	1.66	3.12
1-2	O	73.0	2.53	2.53	—	1.05	1.72	3.12
1-3	O } 3 min	73.0	2.56	2.62	—	1.35	1.76	3.12
2-1	O } 1 min	73.4	7.57	7.68	—	1.04	1.68	4.16
2-2	O	73.0	7.57	7.57	—	1.21	1.75	4.16
2-3	O } 3 min	73.0	7.57	7.60	—	1.36	1.79	4.16
3-1	O } 1 min	73.4	16.5	16.7	—	1.00	1.23	3.57
3-2	CO	73.4	15.2	15.5	40.2	1.10	1.26	3.57
3-3	CO } 3 min	74.0	15.8	15.9	33.2	1.08	1.24	3.57
4-1	O } 1 min	73.0	16.3	16.3	—	0.84	1.34	4.55
4-2	CO	74.0	15.3	16.5	46.8	0.73	—	—
4-3	CO } 3 min	73.8	15.4	16.0	41.9	0.64	—	—
5-1	O } 1 min	48.3	24·9	24.9	—	1.15	1.18	1.92
5-2	CO	50.2	23.0	24.2	60.2	1.28	—	—
5-3	CO } 3 min	50.2	23.2	24.6	64.9	0.85	—	—
6-1	O } 1 min	48.5	24.8	24.8	—	1.10	1.32	6.66
6-2	CO	50.3	23.1	25.6	72.9	1.29	1.25	6.66
6-3	CO } 3 min	50.3	22.9	24.8	71.4	1.61	1.41	6.66
7-1	O } 1 min	48.5	18.1	18.1	—	1.01	1.43	7.14
7-2	CO	48.5	18.0	18.0	—	1.01	1.45	7.14
7-3	CO } 3 min	49.3	18.1	18.1	—	1.02	1.42	7.14
8-1	O } 1 min	73.0	16.6	16.7	—	1.28	1.36	4.55
8-2	O	74.0	16.2	16.2	—	1.15	1.33	4.55
8-3	O } 3 min	74.8	16.7	16.7	—	1.16	1.30	4.55
9-1-1	O } 3 min	85.1	13.8	13.9	—	0.95	1.37	3.03
9-1-2	O	84.5	13.5	13.5	—	1.22	1.35	3.03
9-2-1	O } 3 min	85.1	13.9	13.9	—	1.44	1.35	3.33
9-2-2	O	85.1	13.7	13.7	—	1.20	1.48	3.13
10-1	O } 1 min	36.5	30.9	31.0	—	1.09	1.36	1.43
10-2	CO	37.0	29.2	30.1	73.6	1.36	1.34	1.52
10-3	CO } 3 min	36.9	29.3	29.4	57.3	1.04	1.40	1.52
11-1	O } 1 min	36.5	31.0	31.0	—	1.07	1.38	9.10
11-2	CO	37.2	29.2	29.4	59.5	1.40	—	—
11-3	CO } 3 min	37.0	28.9	28.9	46.3	1.21	1.27	10.00
12-1	O } 1 min	100.6	9.38	9.38	—	1.56	1.60	2.28
12-2	O	100.6	9.35	9.37	—	1.21	1.51	2.28
12-3	O } 3 min	100.6	9.30	9.30	—	1.40	1.52	2.28
13-1	O } 1 min	143.0	4.72	4.74	—	2.08	1.70	2.21
13-2	O	145.0	4.80	4.87	—	1.22	1.64	2.21
13-3	O } 3 min	145.0	4.83	4.90	—	1.41	1.59	2.21

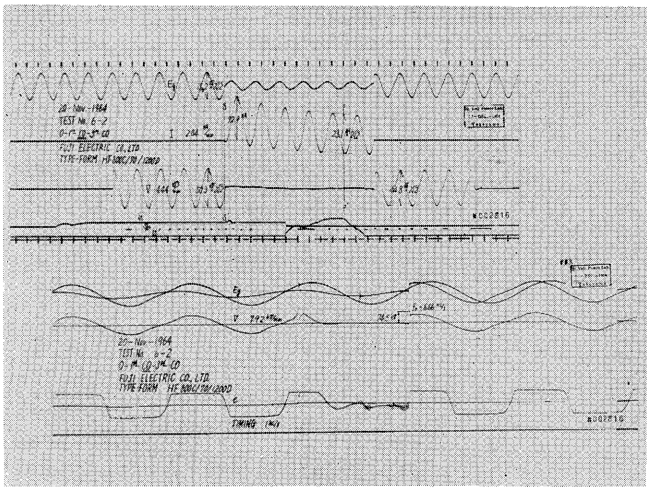
Note: The arc-duration for this testing data is based on 50-cycle operation.



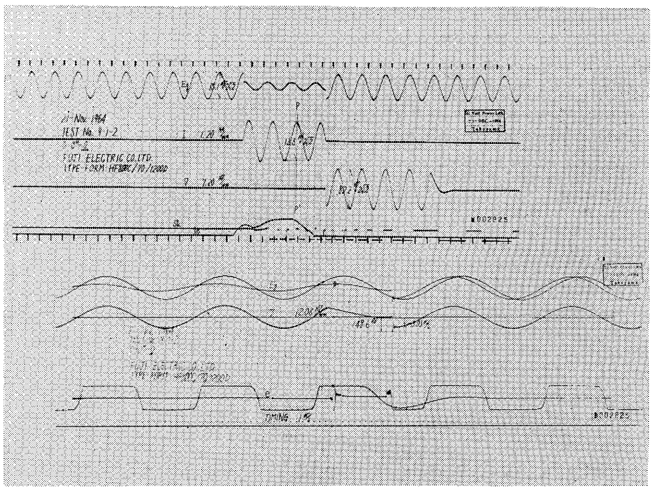
(a) Test No. 3-2



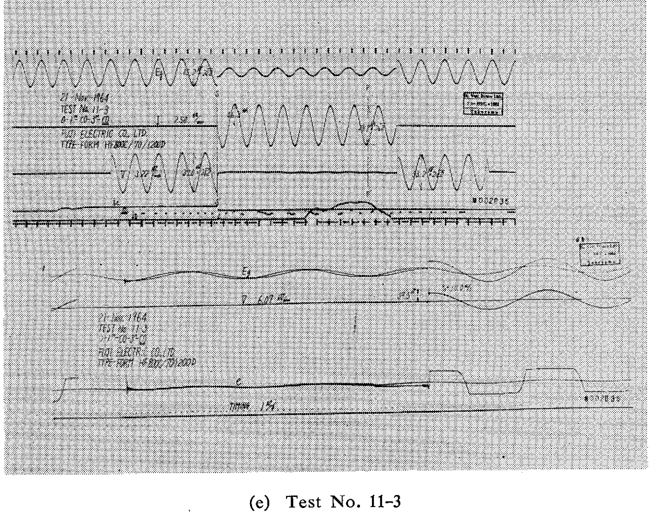
(b) Test No. 4-1



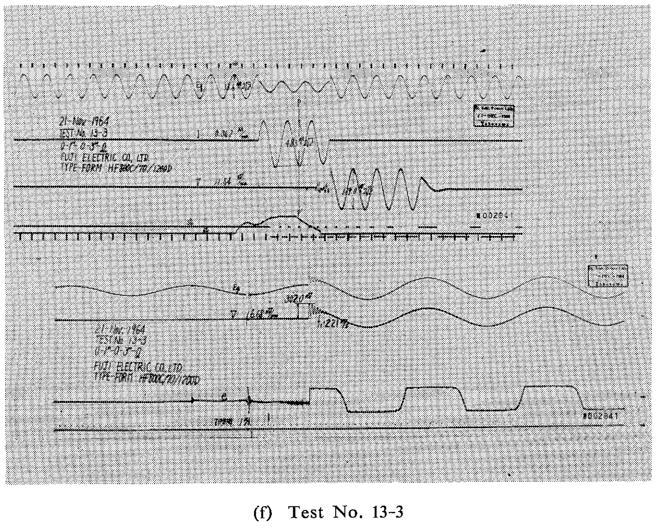
(c) Test No. 6-2



(d) Test No. 9-1-2



(e) Test No. 11-3



(f) Test No. 13-3

Fig. 5 Oscillograms of breaking short-circuit current voltage was corrected so that the rate-of-rise of restriking-voltage became equal to that of the rated voltage and the frequency of rated restriking-voltage. *Table 2* indicates the results of these tests. In this table the data given for test No. 1–1 through 8–3 and 10–1 through 11–3 are the results of short-circuit breaking tests under rated and reduced voltage, and test No. 9–1–1 through No. 9–2–2 give the results of breaking under double-ground-fault. The information given under test No. 13–1 through 13–3 indicates the results of breaking performed when two 84 kv systems were under phase-opposition of 180 degrees without ground fault. This breaking test is equal to the test performed under the severe condition where, in the case of the 72 kv system, the voltage across contacts of sound pole under phase-opposition accompanying double-ground-fault becomes twice the line-voltage. The oscillograms in *Fig. 5* are typical examples of these cases. Performance of these tests assures that this circuit-breaker has sufficient extra capacity in its rating as a 5-cycle circuit-breaker. After this testing, dielectric strength test was performed by charging the pole tested at 126 kv during 10 min. This test proved that there are no imperfections in the dielectric strength of the breaking chamber. Throughout all tests, there was no spouting or burning of insulating oil; further, decline of dielectric strength of the oil was very minor. It was also demonstrated that damage and wear of the parts provided in the breaking chamber, such as the insulating cylinder, fixed contact, arc extinguishing chamber, such as the insulating cylinder, fixed contact, arc extinguishing chamber and the moving contact, were negligible.

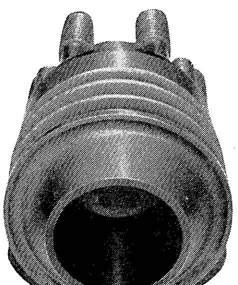
Fig. 6 shows several parts of the breaking chamber, both before and after the testing indicated in tests No. 11–1 through 11–3.

Table 3 **Results of Charging Current Breaking Test**

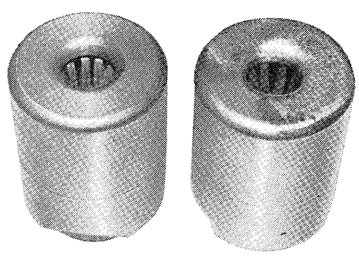
Test No.	Test Voltage (kv)	Breaking Current (amp)	Arc Duration (cps)	Over-voltage Factor	Reignition or Restriking of Arc
1	72.8	7	0.21	1.16	0
2	72.8	7	0.17	1.09	0
3	72.8	7	0.38	1.19	0
4	72.8	14	0.38	1.37	0
5	72.8	14	0.47	1.24	0
6	72.8	14	0.37	1.19	0
7	72.8	30	0.51	1.77	0
8	72.8	30	0.20	1.15	0
9	72.8	30	0.21	1.44	0

Table 4 **Results of Exciting Current Breaking Test**

Test No.	Test Voltage (kv)	Breaking Current (amp)	Arc Duration Time (cps)	Overvoltage Factor
1	72.8	0.6	0.23	1.00
2	72.8	0.6	0.13	1.29
3	72.8	0.6	0.23	1.00
4	72.8	6.5	0.23	1.00
5	72.8	6.5	0.17	1.00
6	72.8	6.5	0.19	1.09
7	72.8	11.6	0.17	1.00
8	72.8	11.6	0.15	1.00
9	72.8	11.6	0.27	1.00

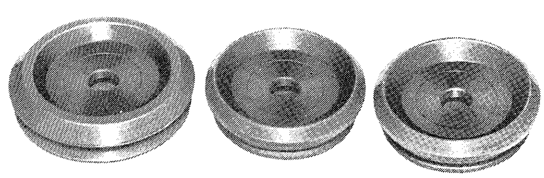


(a) Insulating cylinder

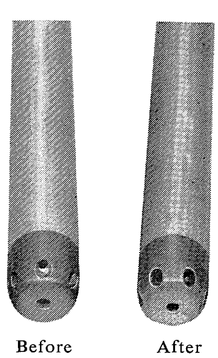


Before breaking After breaking

(b) Fixed contacts



(c) Cells of arc quenching chamber



Before breaking After breaking

(d) Moving contacts

Fig. 6 **View of insulating cylinder, arc extinguishing chamber, and contacts before and after breaking**

V. SMALL CURRENT BREAKING TESTS

These tests were performed in our laboratory using single-phase. The results of tests show that there was no reignition or restriking of arc and no large overvoltage.

Table 3 and *4* indicate the results of charging current breaking tests and exciting current breaking tests respectively.

VI. CONCLUSION

In the above paragraphs we have explained the features of construction and functions of the expansion circuit-breaker, Type HF 800, and reported the results of the breaking tests.

These are further summarized as follows:

1. This circuit-breaker is capable of breaking without difficulty, not only short-circuit currents, load currents, and charging and exciting currents as rated in J.E.C. Specification, but also the fault currents under conditions of severe restriking-voltage such as double-ground-fault and phase-opposition.
2. This circuit-breaker shows such a sufficient reliability as dielectric strength of salt-contaminated insulators, practically superior structural strength, easiness of maintenance and inspection, and lower noise.

We believe users can employ this circuit-breaker with complete confidence.

In closing this paper we express our gratitude to the members of Takeyama High Voltage Power Laboratory for their valuable assistance and advice during testing of this circuit-breaker.