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DEVELOPMENT OF 7.2 KV, 2000 AMP RATED LOAD BREAK SWITCHES

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I. INTRODUCTION

In 1959, Fuji Electric developed load disconnecting switches for interrupting small load current, exciting current of the transformer, and charging current of the transmission line.(1) In 1962, Fuji Electric developed load break switches that interrupt rated current or current two times that of rated current.(2)

We have recently developed load break switches with an electromagnetic device for interrupting load current of 2000 amp and for 150 Mva shortmaking capacity at a rated voltage of 7.2 kv, delivered to the Kansai Electric Power Co. in Japan. This paper is a report on test results of load break switches as well as present and future status of load break switches.

Until the new type 7.2 kv, 2000 amp load break switches were developed, no switches had ever been manufactured in Japan having such a capacity. The previous highest capacity switches were rating of 1200 amp.

However, with the trend toward increased capacity in entire networks, there has been an increased demand for load break switches with large capacity.

II. CURRENT STATUS OF LOAD BREAK SWITCHES

In the past few years, vacuum, air, and oil type load break switches have been developed for individual purposes. However, in Japan, load break switches are not as frequently used as in Europe.

On the other hand, some electric power companies in Japan have employed load break switches in loop circuits. Load break switches have been used with power fuses on imported equipment instead of circuit breakers.

Under the circumstances, Load Break Switch Committee was established within the Japan Electric Machine Industry Association and progress has been made in development of load break switch standards. Standards for load break switches are expected to be compeleted during the first half of 1967. Thus, load break switches have been gradually recognized in Japan and further development in the utilization of load break switches are indicated.

III. RATINGS AND SPECIFICATIONS

The external view and ratings of the recently developed load break switch are shown in *Fig. 1* and *Table 1*, respectively.

Features of this load break switch are as follows:

1) This switch has a highly effective arc extinguishing chamber, which provides stable breaking performance.

Since the arc extinguishing chamber consists of a highly efficient arc extinguishing insulating plate applied to an asbestos insulating plate, reduced per-

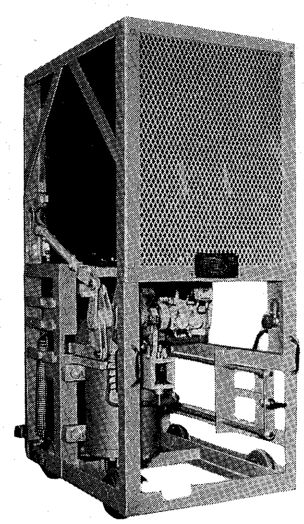


Fig. 1 External view of load break switch

Table 1 Load Break Switch Ratings

Model	RF 248 Ⅲ/6/2000 H (B-B)
Rated Voltage	7.2 kv
Rated Current	2000 amp
Interrupting Current	2000 amp (pf. 0.7) at recovery voltage 7.2 kv
Interrupting Current	1200 amp (pf. 0.15) at recovery voltage 600 v
Load Making Current	5000 amp (Peak value)
Short-circuit Making Current	44.5 ka (Peak value)
Class of Insulation	No. 6 A
Method of Operation	Direct current electromagnetic operation

formance resulting from breaking current is minimized and durability is improved.

Arc extinguishing material used in the load break switch is not affected by ambient temperature or humidity, and the size of the arc extinguishing chamber remains constant.

2) By using the load break switch with a power fuse, this switch can be used as a load breaker.

Since this switch can break load current as well as exciting, charging, and loop current, it can be used with a fuse as a breaker, with load current and defective current respectively cut off by the load break switch and power fuse.

This load break switch can break a load current of 2000 amp, through short-making with a making capacity of 150 Mva at rated voltage.

3) This load break switch has simple construction, greatly facilitating maintenance and inspection.

This load break switch consists of a conventional breaker equipped with an arc extinguishing chamber and arc contact.

Since no oil is used, maintenance and inspection are greatly simplified.

4) Contact wear caused by switching is extremely limited.

Since anti-arcing metal is applied to the arcing portion, contact wear due to arcing at the time of opening and closing of the contacts is effectively minimized.

Furthermore, since the main contact element has an arcing contact, it is protected from damage by high current during making and breaking of the contact. Therefore, there is no noticeable heating (temperature rise) from making and breaking of the contacts.

IV. UNITS SUPPLIED TO DATE

Since the early stages of development of load disconnecting switches and load break switches in 1959, a total of 200 isolators and switches have been supplied for applications in various fields, many of which have been supplied to electric power companies, iron works, electric railway companies, etc., with gratifying results. *Table 2* lists the types of switches supplied to date.

Switches used for breaking rated current or current greater than rated current and switches used for breaking current smaller than rated current are referred to by this company as " load disconnecting

Table 2 **Supply List of Load Break Switches**

Model	Rated Voltage (kv)	Rated Current (amp)	Rated Inter-rupting Capacity (kva)	Supply Quantity
RF248Ⅲ/3/600	3.6	600	900	3
RF248Ⅲ/6/600	7.2	600	1800	18
RF248Ⅲ/10/600	12	600	3000	21
RF248Ⅲ/20/600	24	600	3000	32
RF248Ⅲ/30/600	36	600	3000	1
RF250Ⅲ/3/600	3.6	600	3600	18
RF250/Ⅲ/6/600	7.2	600	7200	33
RF250Ⅲ/10/600	12	600	12,000	16
RF250Ⅲ/20/600	24	600	24,000	55
RF248Ⅲ/6/2000	7.2	2000	25,000	4

Table 3 **Results of Continuous Switching Test**

(1) Before continuous switching test

Working Voltage or Control Voltage	Closing Time (sec)	Average Closing Speed (mps)	Opening Time (sec)	Initial Opening Speed (mps)	Average Opening Speed (mps)	
					Main contact element	Arcing blade
75%	0.670	1.7	0.095	3.67	3.2	10.5
100%	0.412	2.7	0.085	3.47	3.0	11
110%	0.366	2.9	—	—	—	—
125%	—	—	0.080	3.42	2.9	11

(2) After continuous switching test (1000 switching action)

Working Voltage or Control Voltage	Closing Time (sec)	Average Closing Speed (mps)	Opening Time (sec)	Initial Opening Speed (mps)	Average Opening Speed (mps)	
					Main contact element	Arcing blade
75%	0.602	1.8	0.098	3.56	3.0	11
100%	0.389	2.5	0.092	3.84	3.0	11
110%	0.347	2.7	—	—	—	—
125%	—	—	0.085	3.75	3.0	11

switches" and "load breakers". However, all are expected to be referred to as "load breakers" in JEM standards.

V. TEST RESULTS

At present no standards have been established for load breaking switches. As previously stated, standards are currently under development by the Japan Electric Mashine Industry Association. Since there is no set standard, tests have been conducted as based on Disconnecting Switch Standard JEC–165 for no-load tests and Circuit Breaker Standard JEC–145 and IEC Draft Standards for current switching tests. Tests were also performed with reference to Load Break Switch Standards (draft) developed by the Japan Electric Machine Industry Association.

These tests include all major tests specified in Disconnecting Switch Tests, loop current breaking tests, load current breaking tests, and load current making tests.

Test results are as follows:

1. No-load Test

Switching and continuous switching tests were performed as based on JEC–165. Results of switching tests are shown in *Table 3*.

2. Temperature Rise Test

Individual temperature rise tests were performed for both the load break switch body, load break switch, and for the case in which the case was placed in a switchgear cubicle employing a testing cuircuit having three single-phase power sources connected in series. The test circuit with single-phase source imposed more severe operating conditions than those normally encountered in actual operation. However, the temperature rise of each component was considerable lower than the standard value.

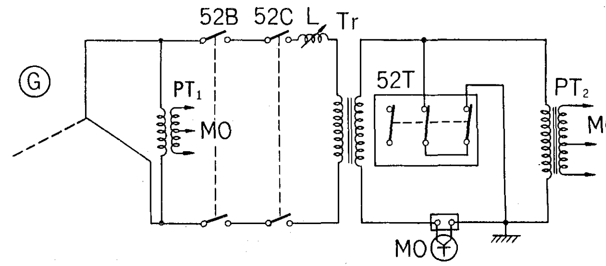
3. Short Time Current Test

1) Test circuit

This test was performed with two single-phase power sources connected in series. The test circuit is shown in *Fig. 2*.

2) Test results

Current of 22 ka and 32 ka were applied. *Table 4* shows results of the test applying a current of 32 ka and *Fig. 3* shows the oscillogram.



G: Short-circuit generator
52B: Protective breaker
52C: Contact (make) switch
L: Current control inductance
Tr: 1000 kva large current transformer (3 in parallel)
52T: Switch tested
PT_1: Generator voltage measuring power transformer
PT_2: Load break switch terminal voltage measuring power transformer
MO: Electromagnetic oscillograph

Fig. 2 Test circuit for short time current

***Table 4* Results of Short Time Current Test**

Item	Standard Value (JEC-165)	Measured Value
Short Time Current Effective Value	32 ka	32.5 ka
Initial Wave Peak Value	80 ka	82.5 ka
Time Applied	2 sec	2.24 sec

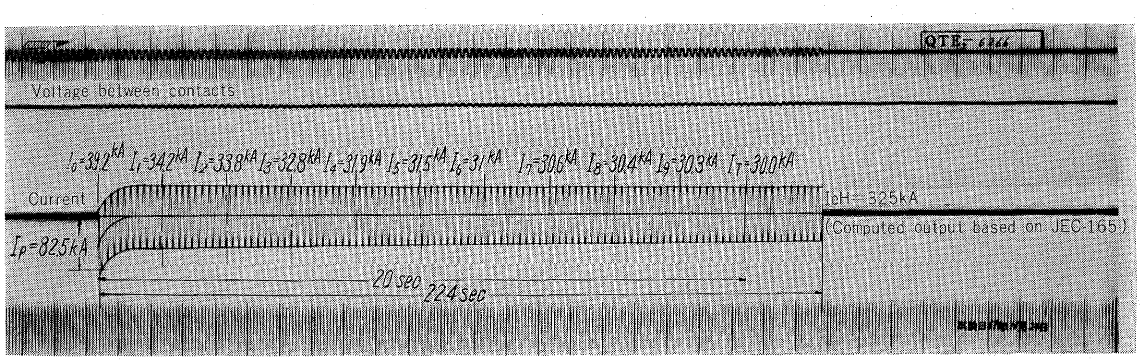
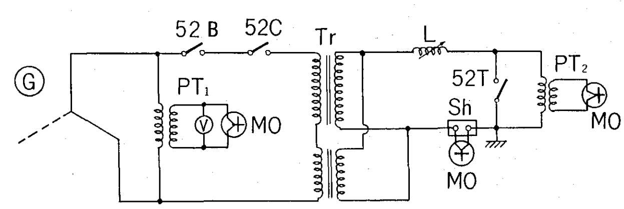


Fig. 3 Oscillogram of short time current test with 32,000 amp

4. Loop Current Interruption Test

1) Test current

Fig. 4 shows the test current employed for this test.



Tr: 33 Mva 88 kv/11 kv
G: 10 Mva short-circuit generator
L: Current control inductance
52B: Protective breaker
52C: Contact (make) switch
Sh: Shunt
PT_1: Generator voltage measuring power transformer
PT_2: Load break switch terminal voltage measuring power transformer
52T: Load break switch (for testing)
MO: Electromagnetic oscillograph

Fig. 4 Test circuit for loop current interruption

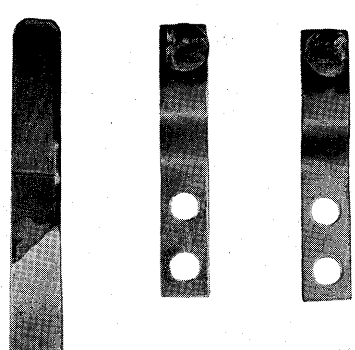
Table 5 Results of Loop Current Interruption Tests

Test No.	Applied Voltage (v)	Recovery Voltage (v)	Interrupting Current (amp)	Contact Opening Time (~)	Arcing Time (~)	Interrupting Time (~)	Power Factor (delay)
1	520	520	1290	6.00	0.30	6.30	0.17
2	520	520	1290	6.15	0.60	6.75	0.17
3	520	520	1290	6.05	0.40	6.45	0.17
4	520	520	1270	6.00	0.55	6.55	0.17
5	520	520	1270	6.05	0.50	6.55	0.17

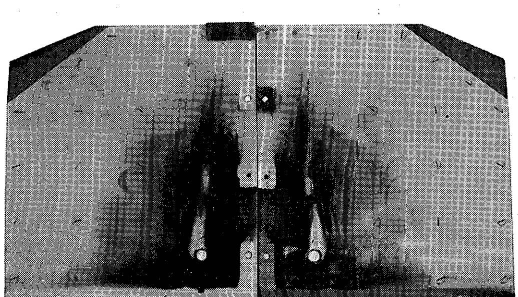
2) Test results

This load current interruption test was performed for current up to 1290 amp with a recovery voltage of 520 v, single phase (corresponding to 600 v, three phase). As a result, interrupting time was almost constant, and arcing time was minimized. Thus, this load break switch proved to have excellent interruption performance. No tests were conducted for interrupting current greater than this above value since no such tests are specified under the principal items in the Breaker Tests.

For reference, a curability test was conducted by interrupting loop current one hundred times, with results showing that arcing time was constant, and wear of the arcing contacts and arc chutes was negligible as shown in *Fig. 5*. *Table 5* shows the results of this test, and *Fig. 6* shows a typical oscillogram of the test.



(a) Arcing contacts



(b) Internal view of arc chute

Fig. 5 View of arcing contacts and arc extinguishing chamber after interrupting loop current one hundred times

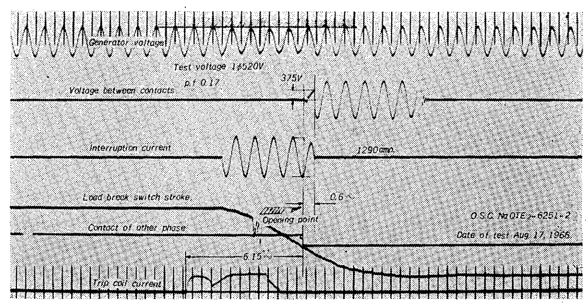


Fig. 6 Typical oscillogram of loop current interruption test

5. Load Current Interruption Test

1) Test circuit

The test circuit used for this test is shown in *Fig. 7* and is based on IEC Draft Standards.

2) Test results

Load current interruption test was conducted with a single-phase 6.25 kv voltage (corresponding to 7.2 kv three-phase) with current up to 650 amp and for 6.9 kv voltage with current up to 2260 amp. Arcing time was below 1 cycle, and interrupting time was constant. This shows that this load break switch can also be effectively used for load current interruption. Principal results of this test are shown in *Table 6*. *Figs. 8* and *9* show oscillograms obtained during load current interruption tests for currents of 648 amp and 2260 amp.

Fig. 10 shows the current-arcing time characteristics with respect to load current interruption.

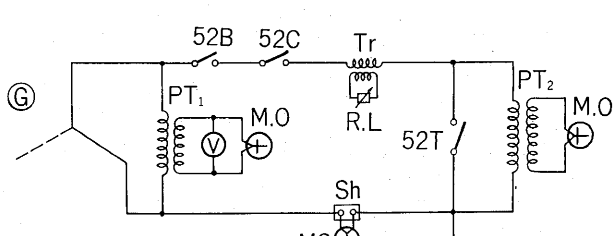


Fig. 7 Test circuit for load current interruption

Table 6 Results of Load Current Interruption Tests

Osc. No.	Applied Voltage (kv)	Recovery Voltage (kv)	Interrupting Current (amp)	Contact Opening Time (~)	Arcing Time (~)	Interrupting Time (~)	Power Factor (delay)
11	6.25	6.25	639	6.00	0.81	6.81	0.67
12	6.25	6.25	658	6.00	0.90	6.90	0.67
13	6.25	6.25	643	6.00	0.65	6.65	0.67
16	6.90	6.25	2250	5.80	0.85	6.65	0.56
17	6.90	6.25	2260	5.80	0.60	6.40	0.56
18	6.90	6.25	2250	5.80	0.55	6.35	0.56

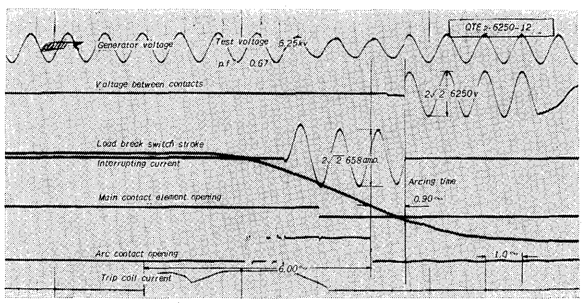


Fig. 8 Typical oscillogram of load current interruption tests

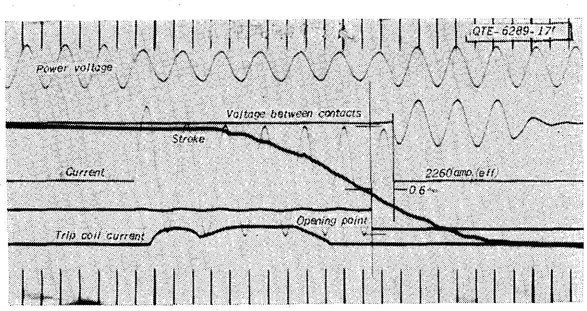


Fig. 9 Oscillogram for 2260 amp load current interruption

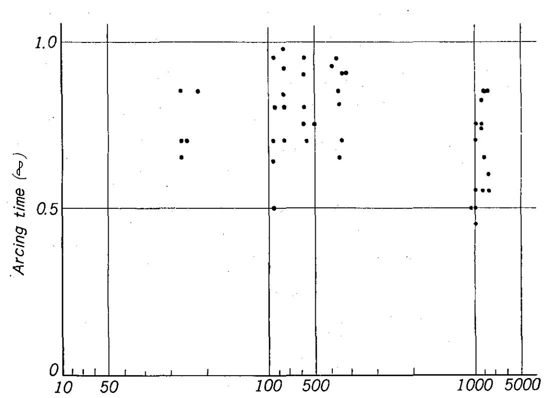


Fig. 10 Current-arc time characteristics of load current interruption

6. Load Current Making Test

1) Test circuit

The test circtit used for this test is shown in *Fig 11.*

2) Test results

This test was conducted with single-phase 4.16 kv voltage (corresponding to 7.2 kv × 1/√3 three-phase) with a load making current of 5000 amp (peak value). Load current up to 2000 amp was easily made with no difficulties encountered.

For reference, a load current making test (twenty repetitions) was conducted to check the extent of wear of the anti-arc metal with slight traces of arcing observed.

Table 7 shows the test results. A typical oscillogram obtained from this test is shown in *Fig. 12.*

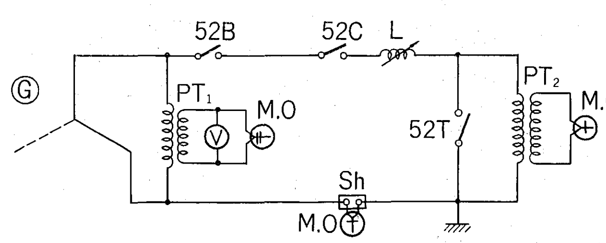


Fig. 11 Test circuit for load current making

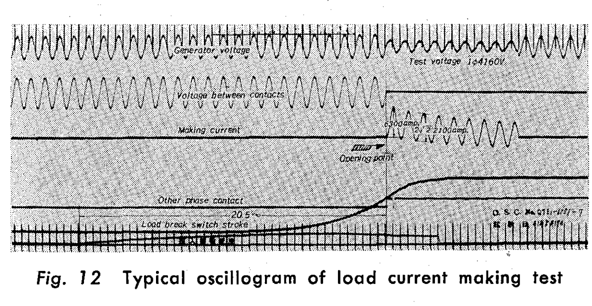


Fig. 12 Typical oscillogram of load current making test

Table 7 Results of Load Current Making Tests

Test No.	Applied Voltage (v)	Making Current Effective Value (amp)	Making Current Peak Value (amp)	Making Current Peak Value / Effective Value	Current Making Time (~)	Power Factor (pf)	Working Voltage (%)
6	4160	2040	5230	2.56	19.3	0.17	100
7	4160	2100	6300	3.00	20.5	0.17	100
8	4160	2050	5760	2.81	19.7	0.17	100
9	4160	2050	6290	3.07	20.7	0.17	100
10	4160	2050	3970	1.93	20.8	0.17	100

7. Short-circuit Current Making Test

1) Test circuit

Fig. 13 shows the test circuit used for this test.

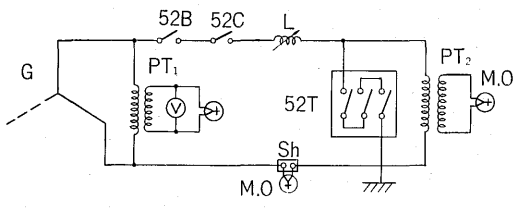


Fig. 13 Test circuit for short-circuit current making

2) Test results

This test was performed with single-phase power source by connecting three-phase in series. Since the amount of repulsive electromagnetic force caused by short-circuit current acts upon the three phases equally, the sample switch underwent more severe conditions than those normally employed by a three-phase power source. However, as shown in *Table 8*, test results proved that short-circuit current making is readily accomplished.

Fig. 14 shows the oscillogram obtained from this test, and *Fig. 15* shows an external view of the equipment used for the short-circuit current making test.

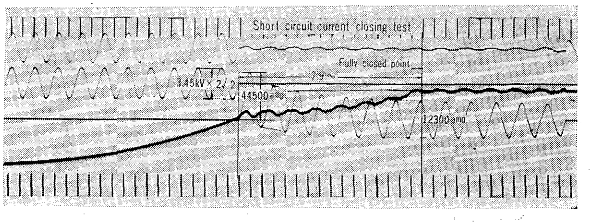


Fig. 14 Oscillogram of short-circuit current making

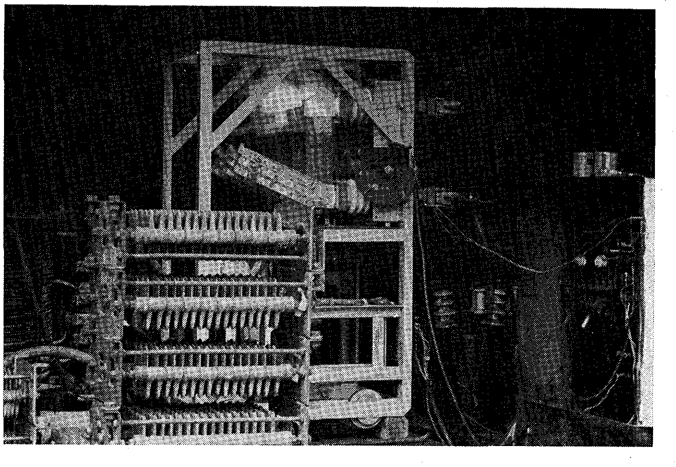


Fig. 15 External view of equipment used for short-circuit current making tests

Table 8 Characteristics of Short-Circuit Current Marking

Test No.	Applied Voltage (kv)	Making Current Peak Value (ka)	Making Current Effective Value (ka)	Results
19	3.45	44.5	12.3	good
20	1.83	32.7	14.5	good

VI. CONCLUSION

This paper principally deals with the status of development and future prospects of load break switches and the ratings, features, and test results on the recently developed 7.2 kv, 2000 amp load break switch.

The author hopes that information contained in this article will be widely used with respect to future expanded application of these load break switches which should prove to be a highly effective replacement for various types of circuit breaker now employed in various fields.

References

(1) H. Mizutani, S. Hata and T. Omori: "New Type Indoor Use Load Break Switch," *Fuji Electric Journal* Vol. 32, No. 6, p. 459 (1959)

(2) T. Omori, H. Ishikawa and M. Kaneda: "Interrupting Capacity Test of Load Break Switch," *Fuji Electric Journal*, Vol. 35, No. 8, p 682 (1962).