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MAKING AND BREAKING TESTS OF LB TYPE LOAD BREAK SWITCHES

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I. INTRODUCTION

Load break switches have been increasing rapidly popular recently because of the technical progress made with current limiting fuses for power use. Demands for the type of current limiting fuse has been particularly great since they possess greater current limiting effects and larger breaking capacities than can be obtained from circuit breakers. Therefore there are many cases where load break switches and power fuses are used in combination, with the fuses serving as the main breaking equipment in place of circuit breakers. The characteristics required of such equipment are as follows.

1) The small-current breaking capability of the power fuse must have full-range clearing ability.

2) The load break switch must be very safe and must be able to perform short circuit making.

3) The switching life of the load break switch must be long. Articles concerning point 1) have already been published in Fuji Electric Journal.(1)(2)(3) Points 2) and 3) will be discussed here.

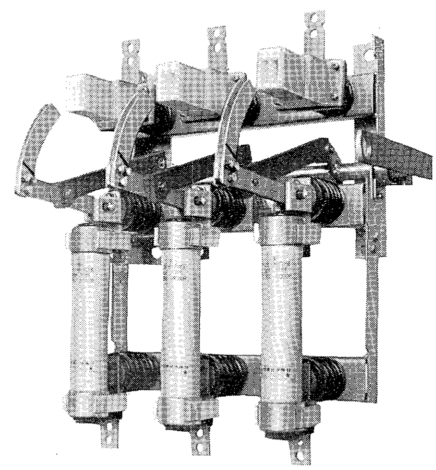


Fig. 1 Load break switch with fuse

Table 1 **Ratings of Load Break Switch**

Name	Indoor type 3-pole single-closing high-voltage load break switch with current limiting fuse
Model	LB(F)III6/200
Rated voltage	7.2 kv
Rated current	200 amp
Rated frequency	50/60 Hz
Insulation class	6
Rated switching current	
Load current	200 amp
Loop current	200 amp
Exciting current	50 amp
Capacitor current	100 amp
Rated short-time current	10 ka 2 sec

II. RATINGS OF LOAD BREAK SWITCHES

Fig. 1 shows an external view of the LB type load break switch LBF III/200 with fuse and *Table 1* gives the ratings for this switch.

The switches tested contain a special small arc quenching chamber with excellent arc quenching capacity. Therefore the breaking capacity can be kept stable so that deterioration due to current breaking is small and the life of the switch is long. If the fuse holder shown in the lower part of *Fig. 1* is removed, the switch can be used as an open type load break switch with a type designation of LB III6/200.

III. SWITCHING LIFE TEST

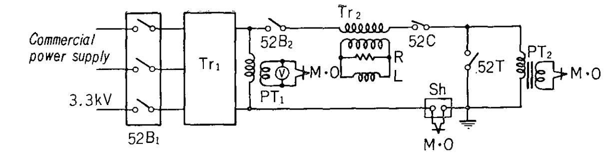
This test is based on the JEM 1219 standard "Ac load switches" and IEC publication 265 "High voltage switches." The test circuit is shown in *Fig. 2*. The test was conducted using a single phase circuit under conditions more severe than with a 3-phase circuit. The test conditions are as listed below.

1) The test voltage was $7.2\,\text{kv} \times \sqrt{3}/2 = 6.25\,\text{kv}$ or over.

2) The time indication was based on 50 Hz.

3) The switching frequency was 1 time per 2 minutes.

4) The operation duty was close/open for one time.



$52B_1$, $52B_2$: Protective breakers back-up equipment
Tr_1: Source voltage adjustment transformer
$52C$: Closing switch
Sh: Shunt
PT_1: Transformer for measuring source voltage
PT_2: Transformer for measuring terminal voltage of load break switch
R, L: Resistor and reactance for circuit current adjustment
$52T$: Load break switch (for testing)
$M{\cdot}O$: Magnetic oscilloscope
TR_2: Load transformer

Fig. 2 Life test circuit for load current switching

5) Switching was performed manually using an operating rod.

Generally, CO operation is almost never performed continuously by load break switches and there is often breaking during the closing period. Particularly when CO operation is carried out without any time interval between closing and opening of the switch, there is a continuous connection between the prior closing arc and the breaking arc. Therefore, the period which the arc quenching chamber and the contacts are subjected to high temperatures is continuous and since there is no time for cooling, damage to the arc contacts and arc quenching chamber is greater than under conditions of normal operation.

However, since the test period was very short, even more severe conditions were necessary to obtain precise results concerning the life of the switch, and therefore the test was conducted for various current values with one CO operation every two minutes, as previously mentioned.

One method of determining the life is by means of the length of the arc time and the degree of separation (the ratio of the arc time to the time until the movable contact is outside the arc quenching chamber after opening) only, but if deviation in the arc time etc. are considered, damage of the contacts and arc quenching chamber is visible up to the time switching becomes impossible. Therefore, the life in this case was determined mainly according to the amount of damage done to the contacts. The degree of separation was also measured when the life was being determined. The results of making and breaking tests for the main current are given in the sections which follow.

1. 200 Amp Switching Life Test

For this test, switching of a current of 200 amp was conducted under the conditions mentioned previously. *Fig. 3* is a photograph of the 110th continuous switching CO operation at 200 amp which took place in the phase nearest the camera.

Fig. 4 and *5* are oscillograms of the first and 100th CO operation respectively, while *Fig. 6* shows the conditions of the contacts and arc quenching chamber after the 100th switching.

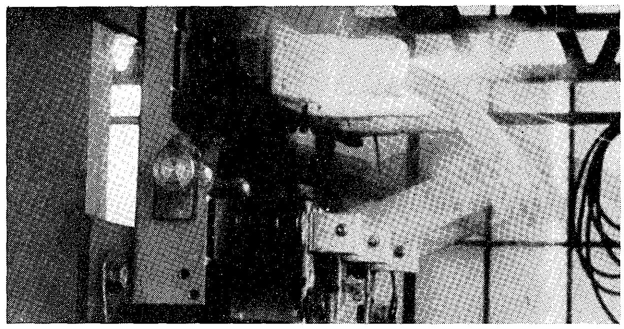


Fig. 3 Switch undergoing 200 amp switching (110th time)

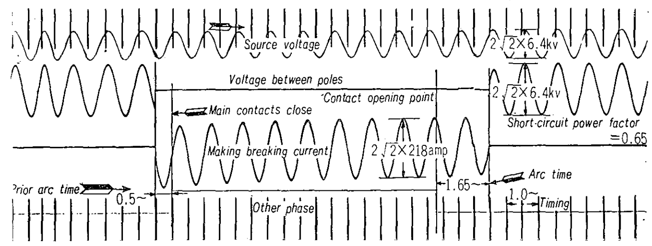


Fig. 4 Oscillogram of 200 amp switching (1st time)

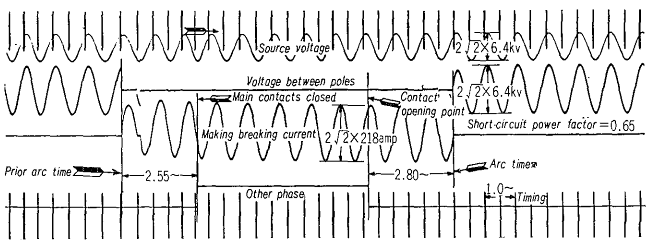
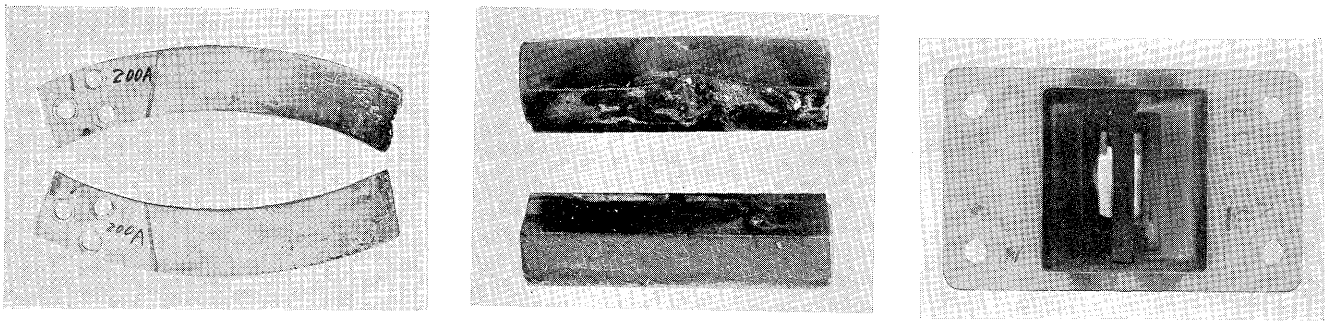


Fig. 5 Oscillogram of 200 amp switching (100th time)

The inner wall of the arc quenching chamber is indented considerably due to the arc heat, while the tips of the movable contacts and front of the stationary arcing contacts are damaged somewhat.

When the arc times for the first and 100th switching are compared from the oscillograms, the 100th arc time is a little longer for close/open. Since the degree of separation can not be measured in relation to the measuring equipment when CO operation is performed, the breaking test alone was carried out several times after the 100th switching and when the degree of separation was measured, it was always within 60–90%. Since there was no damage to the current carrying parts of the contact, switching was still possible electrically but since the arc quenching chamber and especially the front tips of the movable contacts were damaged beyond the safety limit, the 200 amp switching life was set at 100 times. *Fig. 7* shows the oscillogram which shows the worst " bluntness " from the results of the breaking tests.

Even when the " bluntness " is great, it can be seen that the degree of separation is within 100%. The test circuit, test voltage and aforementioned conditions used for the CO operation test were more severe than actual use (conditions).



(a) (b) (c)

Fig. 6 Contacts after 100 switchings at 200 amp

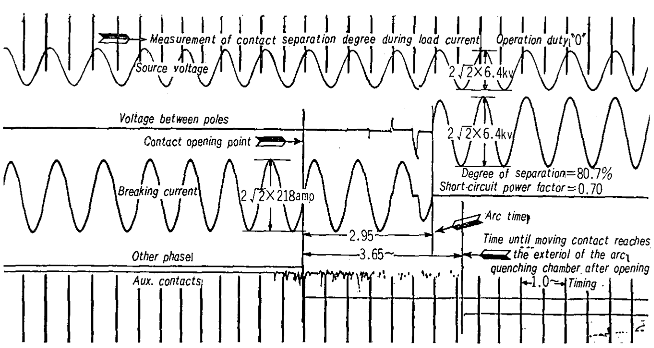


Fig. 7 Oscillogram of degree of contact separation

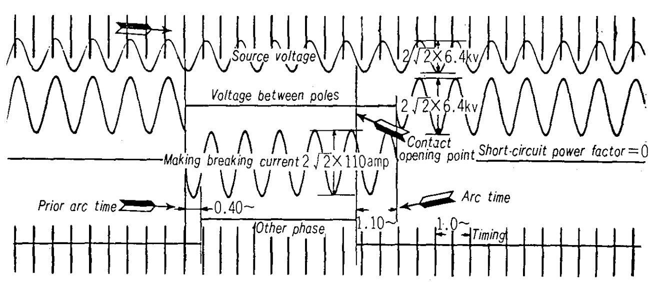


Fig. 8 Oscillogram of 100 amp switching (1st time)

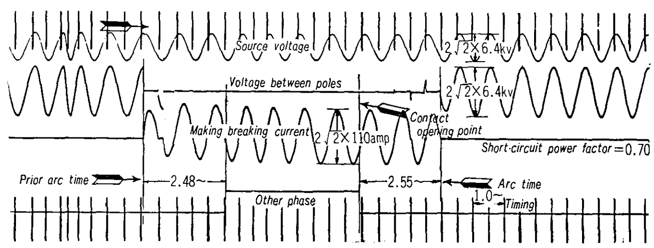


Fig. 9 Oscillogram of 100 amp switching (200th time)

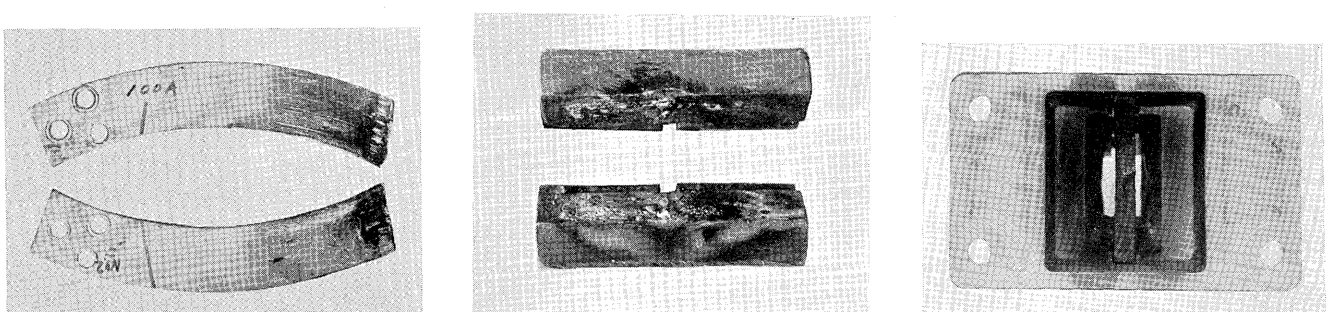
2. 100 Amp Switching Life Test

Except that the operation duty was CO-1 minute-CO, all other conditions for this test were the same as those described in III. 1. Due to the test circuit used, the switching current for this test was 110 amp. *Fig. 8* and *9* are oscillograms of contact switching for the first and 200th times, while *Fig. 10* shows the condition of the contacts and arc quenching chamber after 200 switchings. The contact and arc quenching chamber wall damage are both greater than in the case of 200 amp switching.

As in the case of the 200 amp test, the degree of separation is within 100% so that there is a margin in respect to electrical life and the current carrying parts of the contacts are not damaged, but after the 250th or 300th switching, the damage in the movable contact tips and arc quenching chamber is in excess of the safe limits and therefore the life for 100 amp switching was chosen as 200 times.

3. 30 Amp Switching Life Test

The LB type load break switch is often used as a PFS type as per JIS standard C 4620 "Cubicle-type High Voltage Power Receiving Equipment." Since the switching current value in such cases is over 20 amp, switching life tests were conducted at 30 amp. These tests were carried out under the same conditions as those used for the 100 amp test. The arc quenching gas emission was much less at 30 amp



(a) (b) (c)

Fig. 10 Contacts after 200 switchings at 100 amp

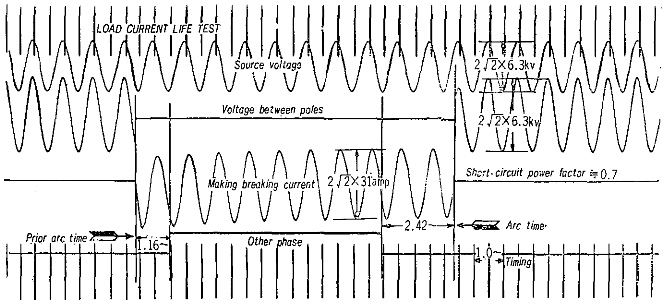


Fig. 11 Oscillogram of 30 amp switching (1st time)

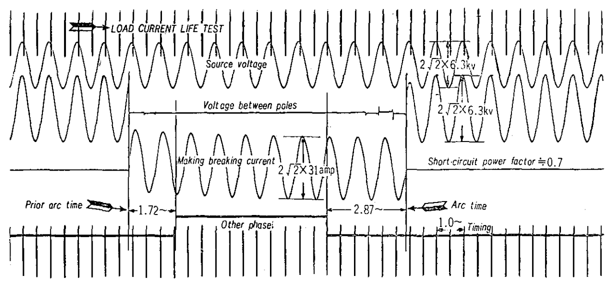
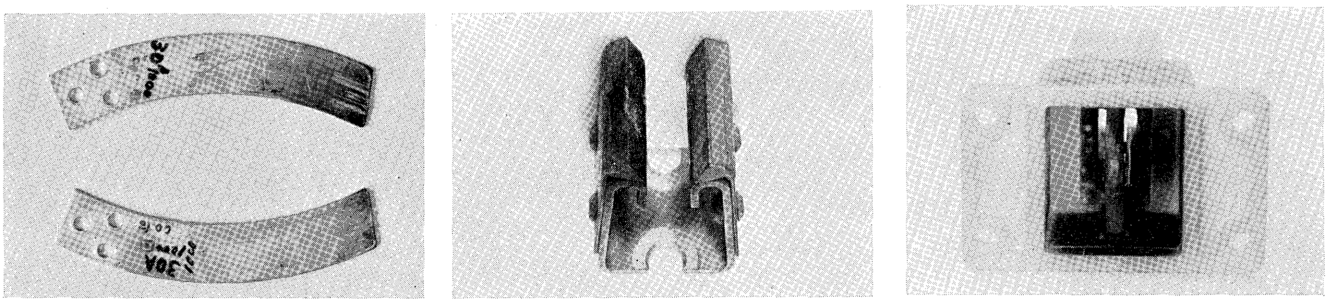


Fig. 12 Oscillogram of 30 amp switching (100th time)



(a) (b) (c)

Fig. 13 Contacts after 1000 switchings at 30 amp

than at either 200 amp or 100 amp.

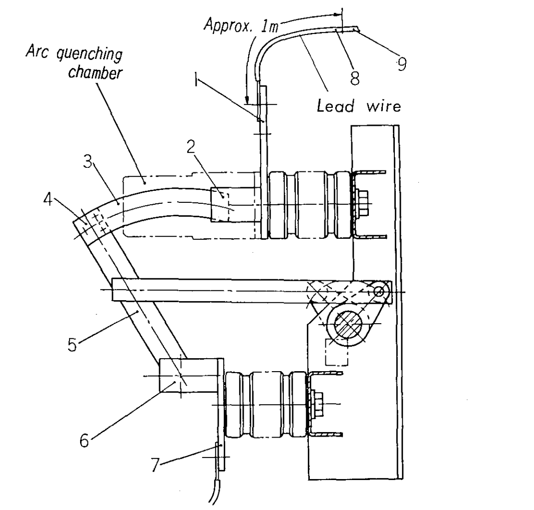
Fig. 11 and *12* show oscillograms for the first and 1000th switching test respectively, while *Fig. 13* shows the condition of the contacts and arc quenching chamber after the 1000th test. As is clear from this figure, there is almost no damage to the tips of the movable contacts after 1000 tests, but the front edges of the stationary arcing contacts are bent in a little. Therefore, the life of the switch at 30 amp was selected as 1000 times since damage to the arc quenching chamber walls exceeded the safe limits after the 1500th or 2000th switching. The degree of contact separation after the 1000 switching test was still within 100%.

When comparing the damage to the contacts at the three current values tested from *Figs. 6, 10* and *13*, the wear in the movable and stationary contacts was greater at the higher current values and therefore, the life should be decided almost entirely by the contacts, but at lower current values, contact wear was negligible and the life should be determined on the basis or wear in the arc quenching chamber.

After the current switching life tests were carried out at these three current ratings values, the temperature rise at a continuous rated current of 200 amp was measured, and comparisons were made with temperature rise values before the tests. The temperature rise in the contacts of the tested switches was in each case small and well within the specified limits. *Fig. 14* shows the results of this test.

Fig. 15 is a life curve of the LB type load break switch which was made from the results of the various current switching tests.

The life curve for CO operation is almost twice as long for C operation only. Not only are the CO operating conditions very severe as was described before, but the arcing contact and arc quenching



Condition \ Measuring point	Temperature rise value (deg) 1	2	3	4	5	6	7
Before test	19.5	22	19	18.5	17.5	14	15.5
After 100 switchings at 200 amp	21	30	22.5	23	16.5	15	15.5

Note: 1. Temperature was measured by the alcohol method.
2. Measuring points are numbered in drawing above.
3. Measurements were made at point 2 with the arc quenching chamber removed.

Fig. 14 Typical results of the temperature test

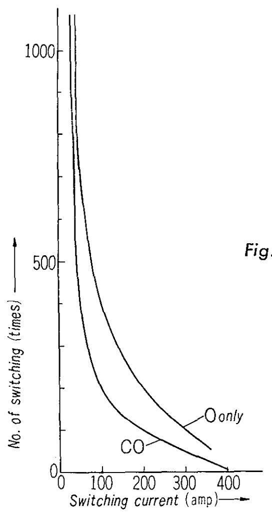
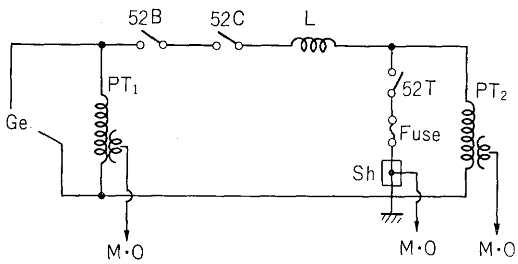


Fig. 15 Life curve (cos φ=0.7~0.8)



Ge: Short-circuit generator
52B: Protective breaker
52C: Closing switch
L: Current limiting reactor
52T: Device tested (load break switch)
Fuse: Fuse for device tested
PT_{1-2}: Measuring transformer
Sh: Current measuring shunt
M·O: Magnetic oscilloscope

Fig. 16 Test circuit for short-circuit current

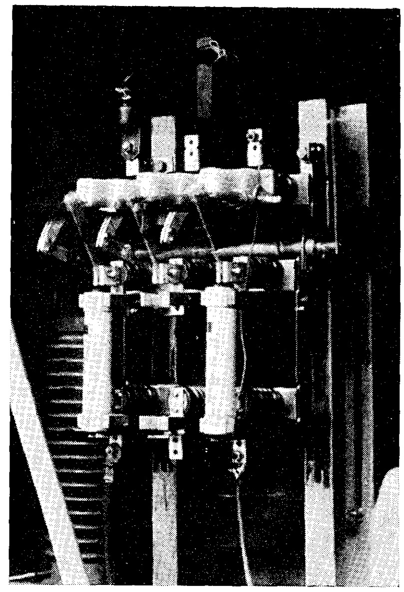


Fig. 17 Test conditions of short-circuit current (with 20 amp fuse)

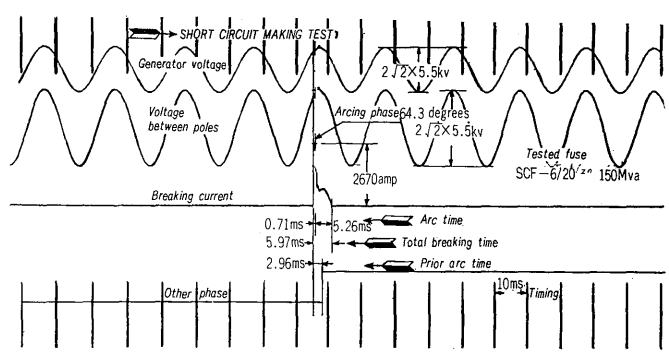


Fig. 18 Oscillogram of short-circuit current (with 20 amp fuse)

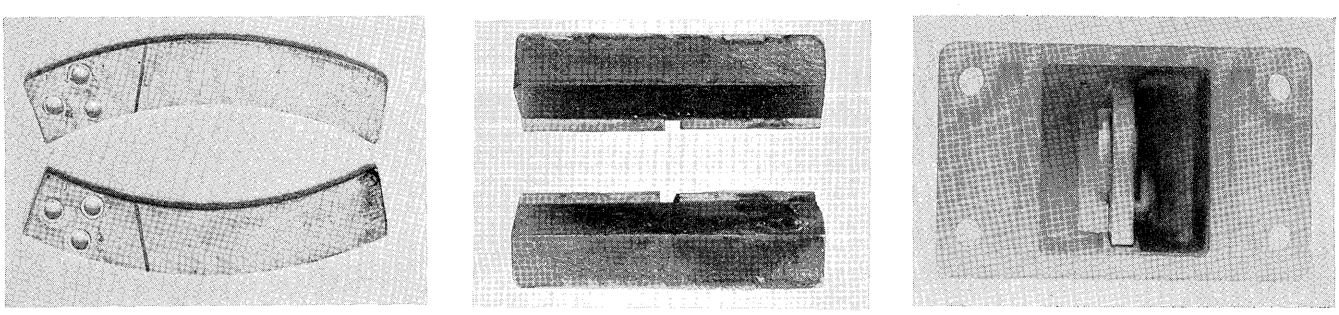
chamber are thought to be damaged by the prior arc which occurs at closing.

IV. SHORT-CIRCUIT TESTS

The short-circuit test is performed for the following reason. If there is a short-circuit on the load side of switch, there is danger to humans due to the arc which occurs in the switch during making. In the former oil immersed switches which had no short-circuit capacity, there were even greater hazards to humans because the switch might explode due to the arc generated during making.

According to the IEC standards, if make action can take place during short-circuits without danger to humans, it does not matter even if the contacts weld for example.

The short-circuit tests were conducted at 6 kv and 150 Mva or its equivalent both with and without fuses. The test method was to close a short-circuit by means of the load break switch and the test circuit was shown in *Fig. 16*. A switch



(a) (b) (c)

Fig. 19 Contacts after short-circuit current (with 20 amp fuse)

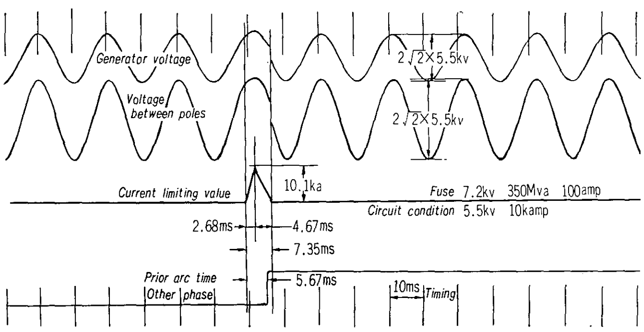


Fig. 20 Oscillogram of short-circuit current (with 100 amp fuse)

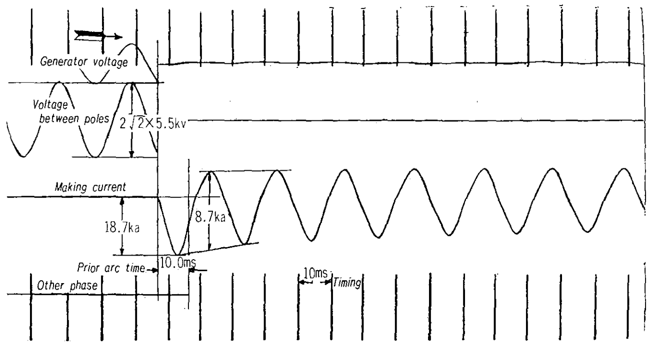
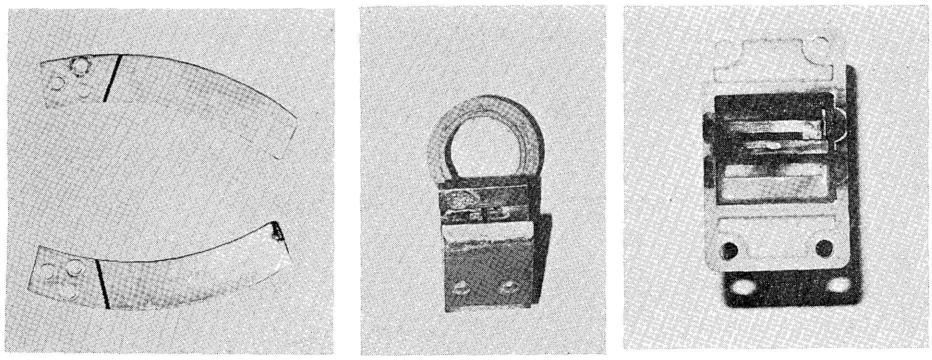
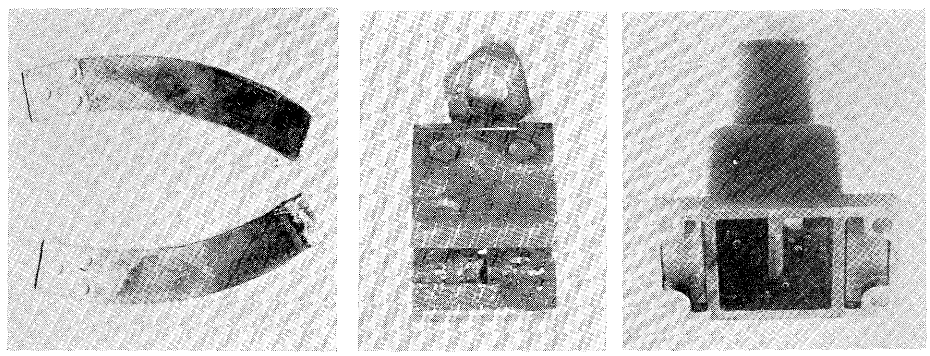


Fig. 21 Oscillogram of short-circuit current (without fuse)



(a) (b) (c)

Fig. 22 Contacts after short-circuit current (with 100 amp fuse)



(a) (b) (c)

Fig. 23 Contacts after short-circuit current (without fuse)

undergoing the test is shown in *Fig. 17* and *Figs. 18* to *23* show typical oscillograms and the conditions of the contacts after the tests under various conditions.

When the 20 amp fuse is used, the current limiting fuse operates even when there is short circuit and therefore as can be seen from the oscillogram in *Fig. 18*, the influence due to short circuit making is only slight since only a current equal to the fuse limit value flows. *Fig. 19* also shows that there is almost no damage to the contacts. There was no problem even when short-circuit was conducted continuously up to 10 times.

When the fuse rating is large, the current limit value is also large, so that contact damage due to arcs can not be disregarded. When the fuse rating is 100 amp, there was considerable damage to the tips of the contacts when short-circuit making occurred about 10 times, but the contacts did not weld. With a 200 amp fuse, part of the contacts was welded after 10 tests. Whenever a current limiting fuse was used, the current was low with manual short-circuit making due to fuse operation even and therefore the conditions were not severe.

However, when this test was conducted on the breaker alone without any fuse, the full short-circuit current flowed as can be seen from the oscillogram in *Fig. 21*. Therefore damage to the contacts was considerable and the movable contact was welded to the stationary contact. However, conditions were never such that there was any danger to humans due to arcs.

The results of the above test have proven that the LB type load break switch is highly stable.

V. CONCLUSION

This article has described the results of current switching life tests and short-circuit tests performed on the newly developed LB type load break switch. It is hoped that this article will facilitate cubicle design and maintenance.

References

(1) Ohmori, Ishikawa, Shimizu: Fuji Electric Journal **40**, No. 4
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(3) Ohmori, Kitamura: Fuji Electric Journal **42**, No. 3