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DEVELOPMENT OF AIR TYPE LOAD BREAK SWITCH FOR OVERHEAD DISTRIBUTION LINES

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I. INTRODUCTION

In Japan, mainly oil immersed switches were formerly used as section switches in 6,600 V overhead distribution lines but because oil immersed switches are often subject to explosions, there is now a trend towaids " oilless " switches, i.e. air switches are often subject to explosions, there is now a trend towards " oilless " switches, i.e. air switches and vacuum switches.

Large cubicle makers consider overall characteristics such as functions, economy, etc. even for the JIS C-4620, " High Voltage Receiving Equipment " which are commonly known as simple cubicles. Since air type load switches are now generally used as load switches in such main switching equipment, the spotlight has suddenly befocussed on air type load switches.

Fuji Electric has a long history of research on air type load switches and already several new products have been developed. The load switch with current limiting fuse developed in 1968 has a high-level performance and is both compact and inexpensive. It is therefore ideal as a main switch as specified in JIS C–4620, " High Voltage Receiving Equipment " and last year it received the Minister of Construction's prize for main switching equipment for use in cubicle type high voltage receiving equipment.

This LB (load break) type switch is now used for the majority of load switches in simple cubicles in Japan. However, a part of the LB type switch has now been improved (contacts and insulation materials in respect to electrical life) and a new pole air-type load break switch contained in a box has been developed. It is described in this article.

II. CONDITIONS REQUIRED OF POLE SWITCHES

The conditions required of pole switches are as follows:

(1) There must be no danger to the public.
(2) There must be no fires or explosions.
(3) They must have a long life.
(4) They must have the isolating requirements specified for disconnector
(5) Charged parts must not be exposed.
(6) They must be light weight
(7) Pole installation work must be easy.
(8) Maintenance and inspection must be easy.

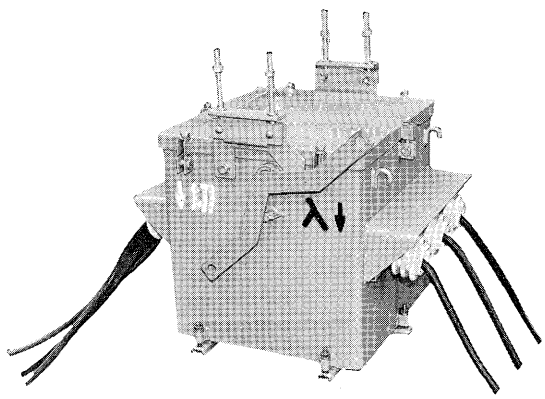


Fig. 1 Outdoor type pole air switch for general use

This newly developed pole switch completely fulfills all of the above conditions.
The features are as follows:

III. RATINGS AND FEATURES

Fig. 1 shows an outer view of this pole-type load break switch and its ratings are given in *Table 1*.

Table 1 Ratings of pole air switch

Item		Outdoor type 3-pole single-throw pole air switch		
Type		PAS-100	PAS-300	PAS-400
Rated voltage		7.2 kV		
Rated current		100 A (200 A)	300 A	400 A
Rated frequency		50/60 Hz		
Rated insulation level		No. 6 A		
Rated breaking capacity	Active load breaking capacity	100 A	300 A	400 A
	Transformer off-load breaking capacity	50 A		
	Closed loop breaking capacity	400 A		
Rated short-time current		10 kA (2 sec)		
Rated short-circuit making capacity		11 kA	21.8 kA	21.8 kA

1) The switch has a special safety design whereby the arc is completely enclosed during switching.

2) It has stable breaking characteristics.

The materials used in the arc quenching chamber are such that there is no danger of deformation due to external temperatures and humidity and therefore the narrow dimensions of the arc quenching chamber always remain constant.

3) The arc quenching chamber is small and has a long life.

The arc quenching chamber is smaller than previous models and it is made from materials with excellent arc quenching capabilities. These capabilities are decreased very little when current is interrupted so that the life is long.

4) In the contacts, the contact resistance changes little with time and materials with good withstand against arcs are use.

5) Disconnecting functions are reliable

There is reliable isolating requirement after breaking due to the inclusion of an air disconnecting section, and therefore maintenance is safe.

6) Construction is simple and maintenance and inspection are easy.

7) Charged parts are not exposed.

Unlike in former models with charged parts were exposed, there are no short circuit faults due to air-borne objects when the circuit is open. It is also very safe since there is no danger of shocks.

8) There is no danger to the public.

This switch is constructed so that there is no danger to the public due to air-borne objects as was the case in former pole switches when inter-phase short circuits occurred.

9) Dust-proof and gas-proof characteristics are excellent.

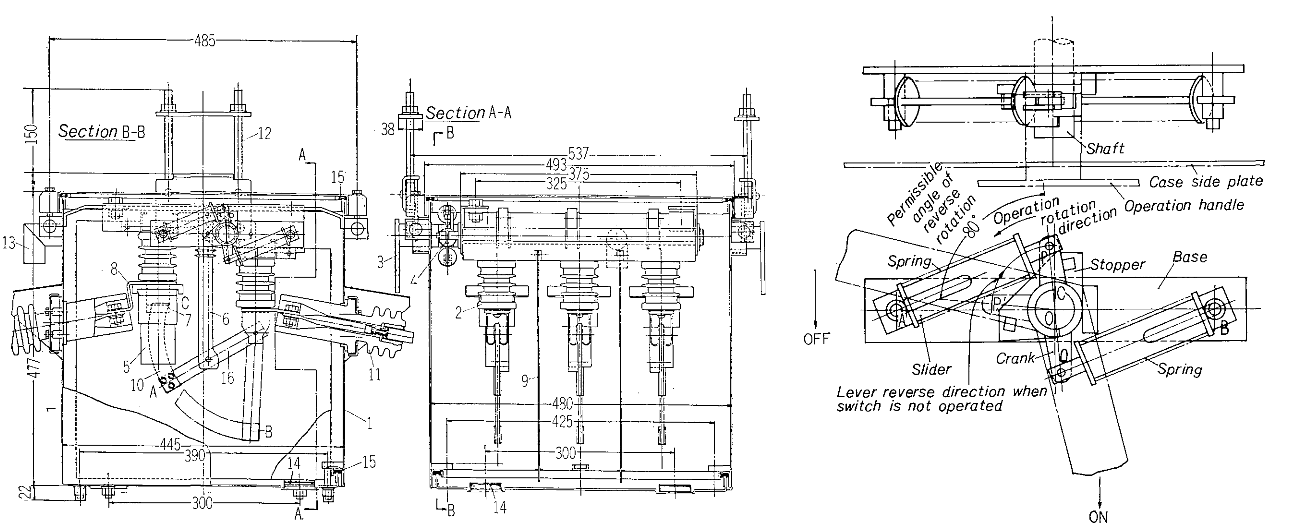
10) It is small and lightweight.

11) No oil is used.

It is not necessary to protect against oil leaks or changes due to deterioration of the oil and there is no need to worry about explosions due to sparks.

IV. CONSTRUCTION AND OPERATION

The construction is shown in *Fig. 2* (a). The arc quenching principle is as follows : the arc is extended, gas is generated from the arc quenching chamber insulation plate due to the arc heat, the arc is cooled by this gas and is extinguished. This principle employs the effects of the narrow arc quenching chamber and gas. The relation between the switching speed and the breaking capacity is such that even if the speed is low, the breaking capacity remains the same and the opening degree (ratio of arc time and time after movable contact 10 opens until it leaves arc quenching chamber 5) is generally less than 100% (refer to *Figs. 9* (a) to (c)). This unit is inside a box and the disconnecting part C is not visible. Therefore, a spring is used as shown in *Fig. 2* (b) to prevent incomplete closing or disconnection due differences in operating pressure. Thus no matter what the operating pressure from the outside, switching of the disconnecting part is performed at constant closing and opening speeds due to the spring tension. *Fig. 2* (a) shows case 1, support insulatar 2, operation handle 3, operating mechanism 4 (refer to *Fig. 2* (b) for details), arc quenching chamber 5, operating rod 6, fixed contact 7, terminal plate 8, inter-phase insulation barrier 9, movable contact 10, bushing assembly 11, pole hanger bolt 12, air exhaust part 13, air intake port 14, water-proof packing 15 and blade 16. Inter-phase insulation barrier 9 allows for a decrease in the dimensions in the inter-phase directions as well as for greater overall compactness because the barrier is inside the case. A shows the switch in the closed condition and B shows it in the break condition. Operating rod 6 is made of epoxy resin and has excellent tracking, arc and contamination withstand characteristics. Air exhaust port 13



(a) Main dimensions (b) Operating mechanism

Fig. 2 Outline dimensions of pole air switch and air intake port 14 are provided in order to prevent moisture from accumulating on parts of the switch and the inside walls of case assembly 1 because of differences between the temperatures inside and outside the case. Several layers of fine wire mesh are inserted at the top of these opening to allow some air to enter the case and also to keep out all dirt and insects (utility model right applied for). *Fig. 2* (b) shows the operating mechanism in detail. When the operating handle is turned in the arrow direction as shown in this figure, the crank is turned simultaneously in the arrow direction around point C. When this occurs, the spring is compressed by the slider and when the point P is shifted to point P′, the crank makes contact with the stopper which is held in position by the unit operation shaft. When the operating handle is turned, the crank pushes the stopper and the switch gradually begins to operate. When P comes over AO, the tension on the spring reaches a maximum and when P exceeds the dead point after several more turns, the switch closing/breaking operation is completed by the spring tension.

A special toggle construction is used (utility model right applied for) by which the operation handle is always returned to the " cut " position when the switch does not interrupt in the 80° permissible reverse angle range so that the outside operating handle and the switch closing and breaking condition generally agree.

V. TEST RESULTS

These tests were based on two standards: JEM 1219, AC Load Switches and JIS C–4502, High Voltage Oil Immersed Switches. The main test results are as follow.

1) Temperature test

The temperature test is performed using a circuit in which 3 phases are connected in series with a

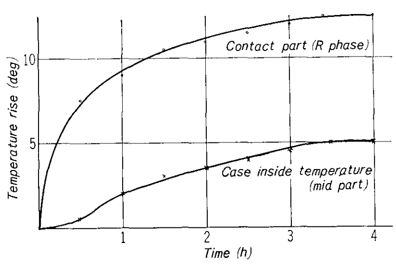


Fig. 3 Switch temperature rise characteristics (100 A)

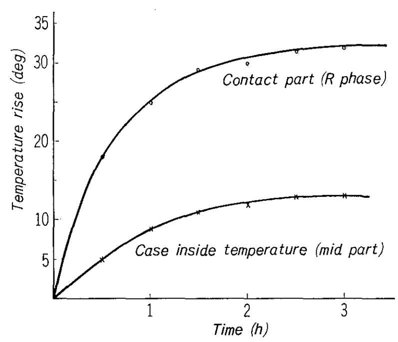
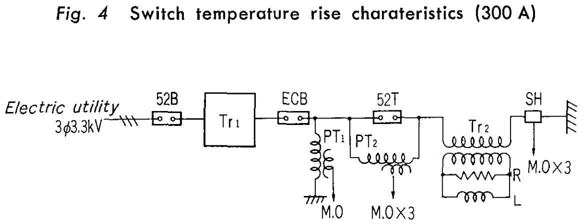
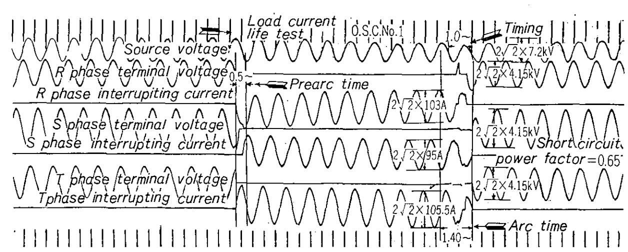


Fig. 4 Switch temperature rise charateristics (300 A)

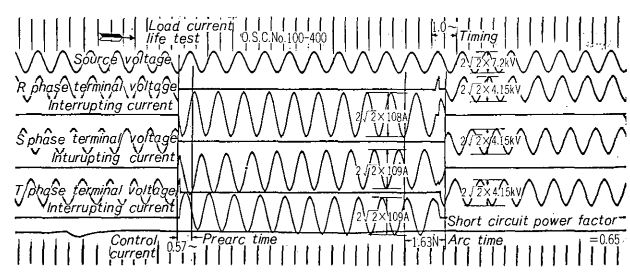


52B : protective breaker subsequent to ECB
Tr_1 : transformer for source voltage regulation
52T : load switch (test piece)
Tr_2 : load transformer
R,L : resistance and inductance for circuit current regulation
SH : shunt
PT_1 : potential transformer for measuring source voltage
PT_2 : potential transformer for measuring terminal voltage
NO : Magnetic oscilloscope

Fig. 5 Making and breaking life test circuit

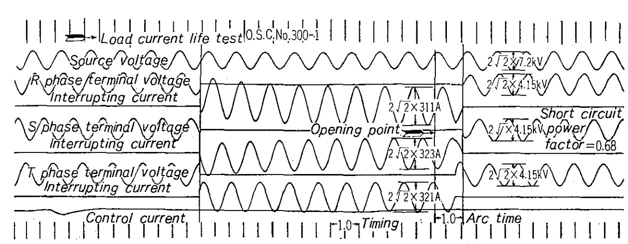


(a) One-time oscillogram

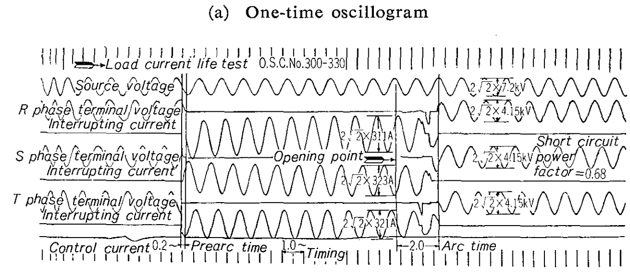


(b) 400 times oscillogram

Fig. 6 Oscillograms of 100 A making and breaking life tests

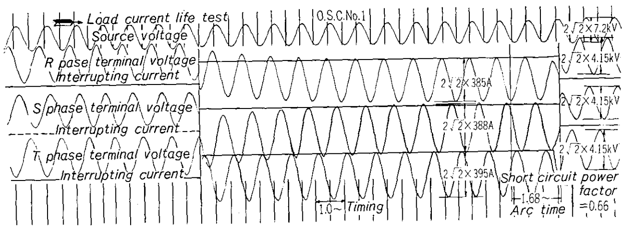


(a) One-time oscillogram

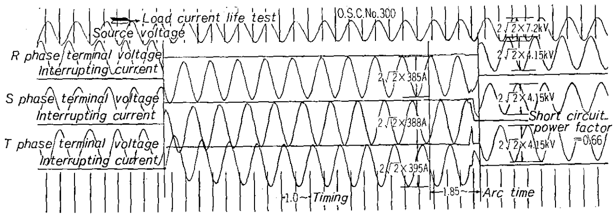


(b) 330 times oscillogram

Fig. 7 Oscillograms of 300 A making and breaking life tests

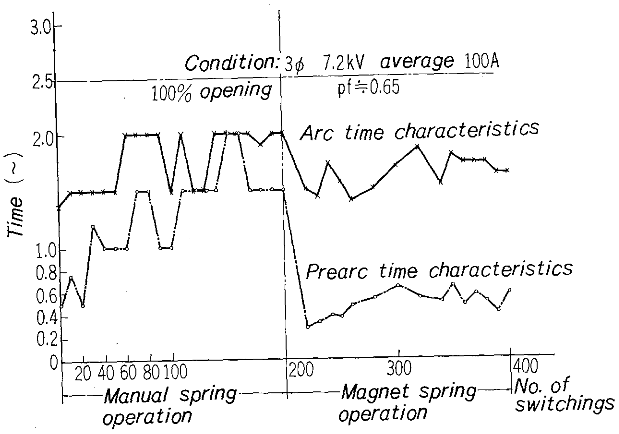


(a) One-time oscillogram

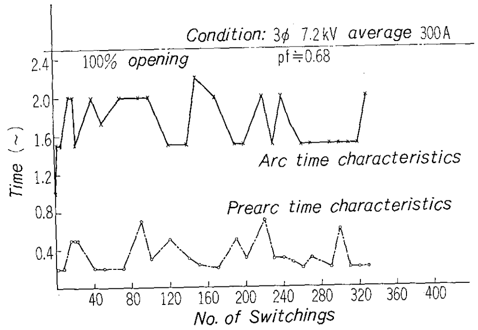


(b) 300 times oscillogram

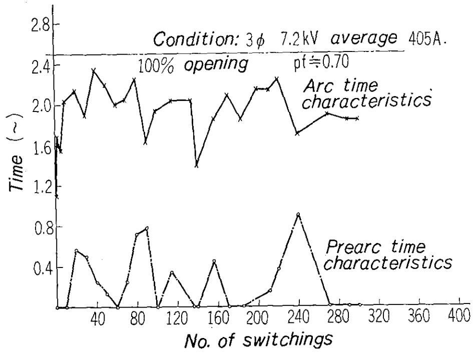
Fig. 8 Oscillograms of 400 A making and breaking life test



(a) PAS-100 type

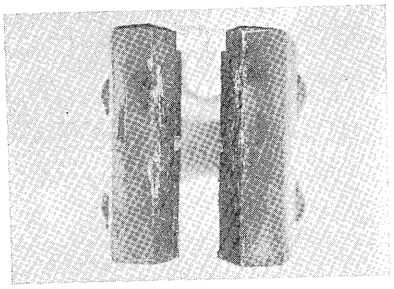


(b) PAS-300 type

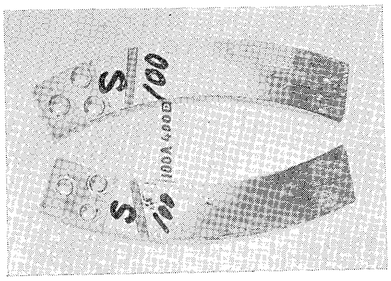


(c) PAS-400 type

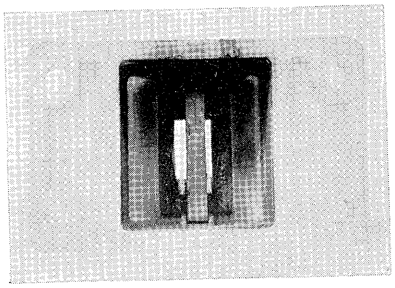
Fig. 9 Characteristics of making and breaking life test of pole air switch



(a) Fixed contact

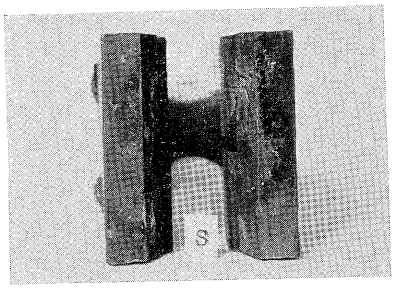


(b) Movable contact

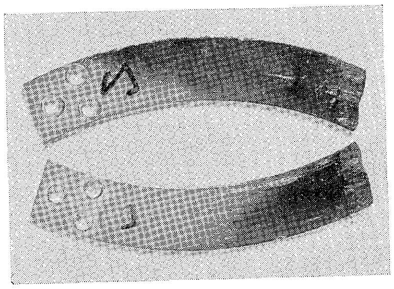


(c) Arc extinguishing chamber

Fig. 10 Conditions in all parts after 400 times of 100 A making and breaking tests

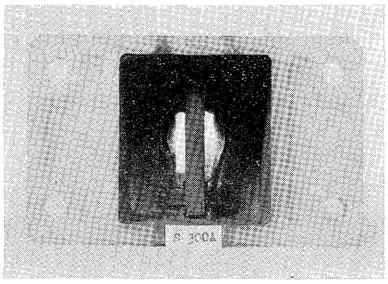


(a) Fixed contact



(b) Movable contact

Fig. 11 Conditions in all parts after 330 times of 300 A making and breaking test



(c) Arc extinguishing chamber

Fig. 11 Conditions in all parts after 330 times of 300 A making and breaking tests

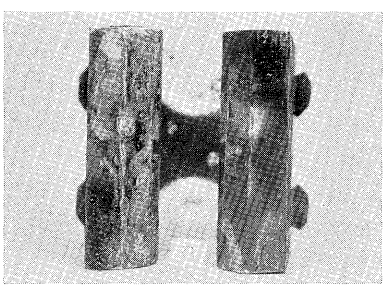
single phase power source. *Figs. 3* and 4 show typical temperature rise curves at separate points with currents of 100 A and 300 A. The temperature rise curves at separate points with currents of 100 A and 300 A. The temperature rises in all parts have sufficient margins in respect to specified values.

2) Making and breaking life test

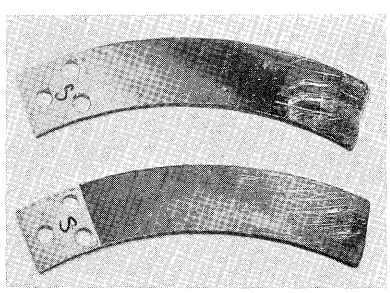
(1) The test circuit is shown in *Fig. 5*.

(2) Test results

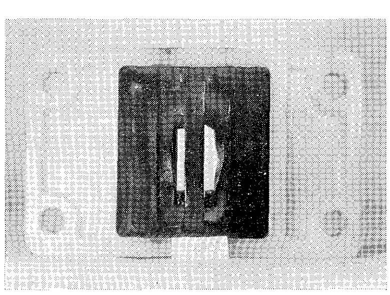
The making and breaking life test was performed with 3 phases and 7.2 kV for currents of 100 A, 300 A



(a) Fixed contact

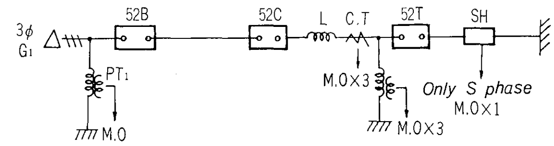


(b) Movable contact



(c) Arc extinguishing chamber

Fig. 12 Condition in all parts after 300 times of 400 A making and breaking tests



52B, 52C : subsequent protective breakers
CT : current transformer
52T : load switch (test piece)
L : inductance for circuit current regulation
SH : shunt
PT_1 : potential transformer for measuring source voltage
PT_2 : potential transformer for measuring terminal voltage
MO : magnetic oscilloscope

Fig. 13 Test circuit for short-circuit making capacity

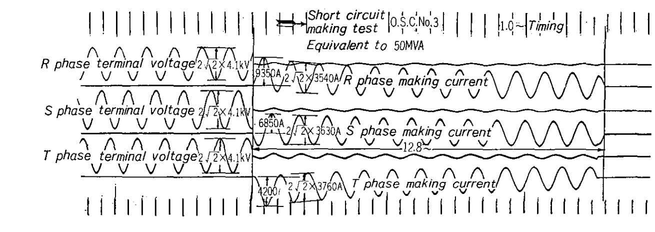


Fig. 14 Typical oscillogram of 50 MVA short-circuit making capacity

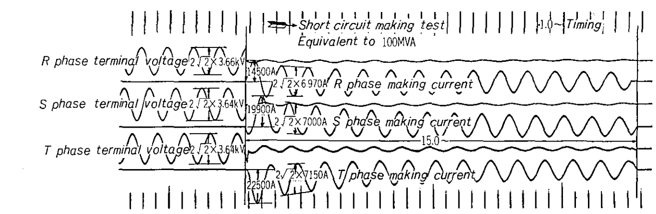


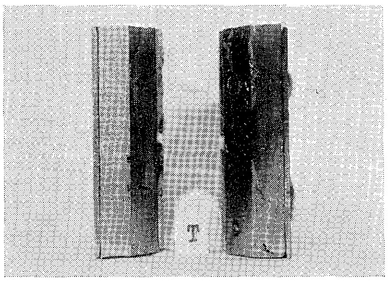
Fig. 15 Typical oscillogram of 100 MVA short-circuit making capacity

and 400 A. The test duty was " open ", " close ", one-minute stop, and " open "—" close ". The results indicated that the degree of opening was always less than 100%. Typical oscillograms for 1 and 400 times at a switching current of 108 A (average) are shown in *Figs. 6* (a) and (b), for 1 and 330 times at a switching current of 319 A (average) in *Figs. 7* (a) and (b), and for 1 and 300 times at a switching current of 390 A (average) in *Figs. 8* (a) and (b) respectively. *Fig. 9* (a) shows the making and breaking life characteristics for the PAS–100 type. *Fig. 9* (b) for the PAS–300 type and *Fig. 9* (c) for the PAS–400. In *Fig. 10* (a), the fixed contacts are shown after 400 making and breaking life tests at 100 A, *Fig. 10* (b) shows the movable contacts and *Fig. 10* (c) the arc quenching chamber after the same test. The same parts after 300 making and breaking life tests at 300 A are shown in *Figs. 11* (a), (b) and (c) respectively and after 300 making and breaking life tests at 400 A in *Figs. 12* (a), (b) and (c) respectively.

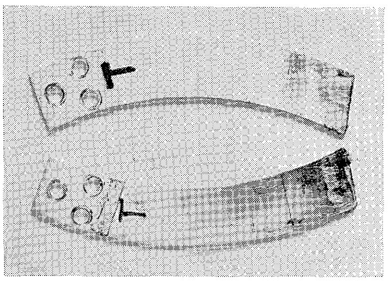
3) Short circuit making capacity test

(1) The test circuit is as shown in *Fig. 13*.

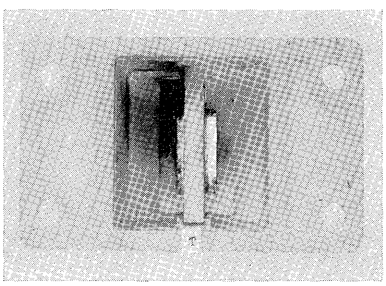
(2) *Fig. 14* shows a typical oscillogram of a short-circuit making capacity tests at 7.2 kV and 50 MVA, and *Fig. 15* shows a typical oscillogram



(a) Fixed contact

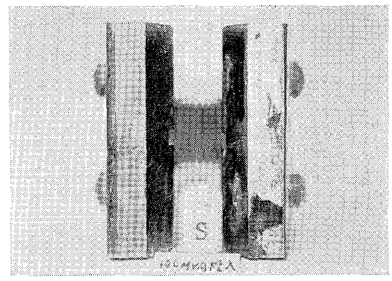


(b) Movable contact

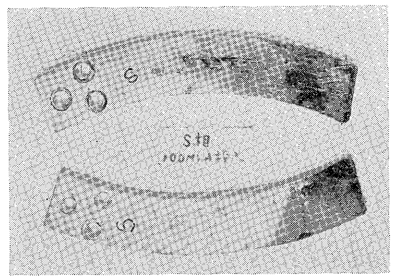


(c) Arc extinguishing chamber

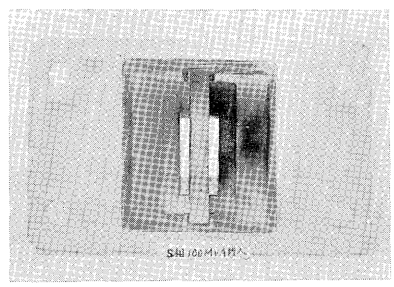
Fig. 16 Conditions in all parts after 50 MVA short-circuit making capacity test



(a) Fixed contact



(b) Movable contact



(c) Arc extinguishing chamber

Fig. 17 Conditions in all parts after 100 MVA short-circuit making capacity test

for the same test at 7.2 kV and 100 MVA. In these tests, the short circuit power factor 0.1 and there were 3 closings at intervals of 3 minutes. No abnormalities were found in the contacts or any other parts. *Fig. 16* (a) shows the fixed contact after the 7.2 kV, 50 MVA short circuit making capacity test, while the movable contact and the arc quenching chamber after the same test are shown in *Figs. 16* (b) and (c) respectively. The same part after the 7.2 kV, 100 MVA short circuit making capacity test are shown in *Figs. 17* (a), (b) and (c) respectively.

VI. CONCLUSION

In recent years, there has been a demand to improve the reliability, of load switches as section switches since the number of faults in distribution lines has been decreasing.

In this article, the air type switch, which has excellent safety, reliability, etc. in comparison with the oil-immersed type switches, is described. These switches are better than vacuum switches in respect to overall characteristics such as economy and performance and their popularity will no doubt increase in the future.