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ROS 26 MINIMUM OIL SWITCHES AND RO 26 OIL CIRCUIT BREAKERS

Koreyuki Taketani

Kin-ichi Yoshio

Fukiage Factory

I. INTRODUCTION

In accordance with increases in the popularity of buildings and houses with high power requirements, a standard concerning cubicle type unit substation, JIS C4620 (1968), has been established in order to insure economical high voltage substations with highly simplified internal equipment. For this reason, there is now a stronger demand than ever before that the main switches and breakers in the substations be highly economical, reliable and safe.

Previously, the switches for PF. S type cubicle specified in this standard were almost always pole oil switches (hereafter referred to as POS). These switches were selected because they are inexpensive but the POS is intended for outdoor use and it is heavy and large for attachment to poles. It is therefore troublesome to install, operate and maintain in cubicles. There are also handling problems such as the difficulty of operation. Because of defects in insulation, there is a chance of accidents such as fires due to internal shorts and explosions.

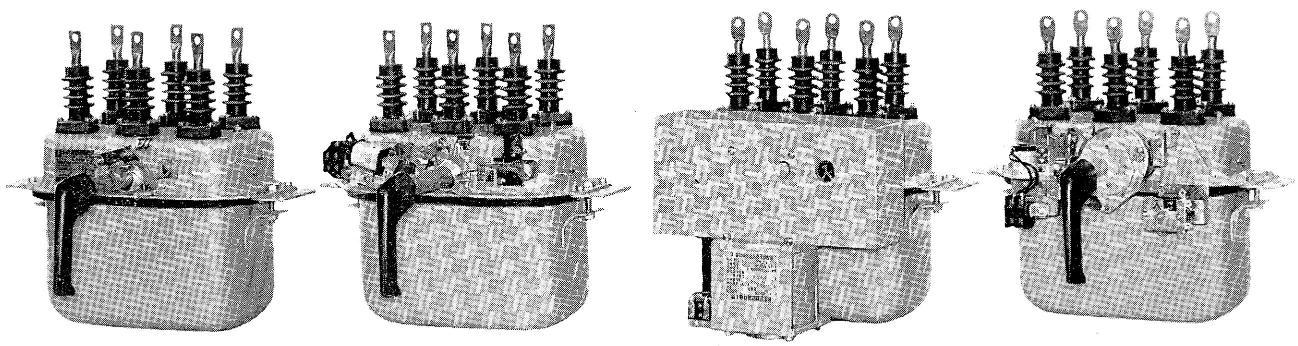
For these reasons there is now a trend to switch from the POS to air blast and vacuum switches. However, oil is an excellent arc quenching medium, is very cheap and easy to use. If the appropriate design is employed, the above mentioned faults can be prevented.

In oil-immersed switches, the contacts and arc-quenching mechanism are not influenced by the surrounding atmosphere and there is no need to worry about salt damage. Considerable technical data has been accumulated since the arc quenching phenomena in oil has been sufficiently explained. Oil is also familiar to users and easy to handle. The switch stroke is long, insulation and operating reliability are high and maintenance and inspection are familiar.

With all these features, the demands for such switches is increasing. Therefore, Fuji Electric has developed and is now mass producing a series of minimum oil switches as shown in *Fgi. 1*. These switches have been designed so as to throw off the image of the former POS. Their features are:

(1) They are economical because of their small size, lightweight and have a minimum oil volume.
(2) Point contacts are used.
(3) The insulation cross bar which caused so many problems formerly has been eliminated.
(4) An epoxy resin bushing is used.
(5) There are excellent breaking characteristics in spite of the small size.
(6) The drive mechanism is simple.
(7) Maintenance and inspection are easy and no adjustments are needed for assembly.

Equipment for use inside buildings where there are high power requirements has been increasing because of the large scale of factories recently and the diversity of such equipment has also become complex. This equipment is not only suitable for



a) Manually operated oil immersed load switch
(b) Manually operated oil immersed load switch (with shunt tripping device)
(c) Magnetically operated oil immersed load switch
(d) Manually operated oil circuit breker

Fig. 1 Minimum oil switches and oil circuit breakers use in cubicles but it can also be appiled as various types of switches to divide circuits appropriately, in power capacitors and in transformers and motors. When combined with power fuses it can take the place of breakers.

II. RATINGS AND TYPES

This equipment consists of breakers and load switches. The breakers are trip free and have breaking capacities of 25 MVA at 7.2 kV. The switches are not trip free since the trip free mechanism has been removed and is replaced by a quick breaking mechanism.

Otherwise the switching functions are the same as those of the breakers. The breaking capacities are not indicated but there is an overload current switching capacity of 2,000 A.

The types and standard specifications are shown in *Table1.* *Fig. 2* shows an external view of a manually operated oil switch and *Fig. 3* shows a magnetically operated switch.

III. CONSTRUCTION AND FEATURES

Fig. 4 shows the construction of the switch unit. There are a tank and cover made of drawn steel plates and six bushings and movable parts which pass through the cover. The construction is thus

Table 1 **Ratings**

	Oil immerced load switch	Oil immerced breaker
Type	ROS 26-1 ROS 26-2 ROS 26-2T	RO 26-1 RO 26-2 RO 26-2T
Rated voltage (kV)	7.2	7.2
Note ① Rated current (A)	*100 200 200 (With arc resistant contacts)	100 *200 200 (with arc resistant contacts)
Rated frequency (Hz)	50/60	50/60
Rated short-time current (kA)	5 (1 sec)	2 (2 sec)
Rated interrupting MVA	Note ②	25 (10 at 3.6 kV)
Rated interrupting time (cycles)	—	8
Oil volume (*l*)	7	7
Weight (kg)	15...Manual 30...Electro-magnetic	18...Manual
Standard	JEM 1219	JEM 1198

Note ① The rated current shown with the *is standard.
② When a shunt tripping device and electromagnetic operation system are used, overcurrents of 2,000 A can be interrupted.

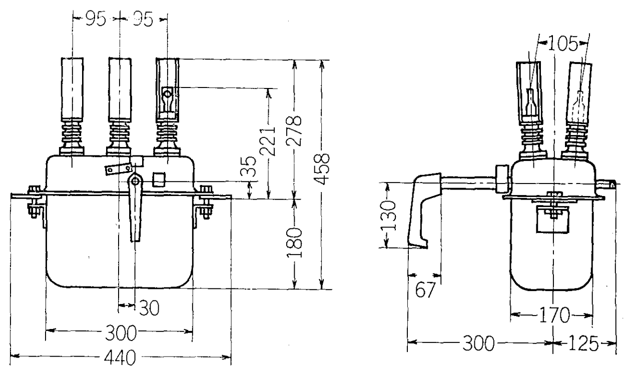


Fig. 2 **Manually operated oil switch**

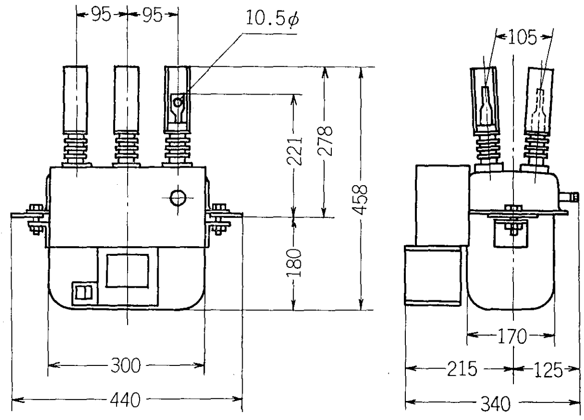
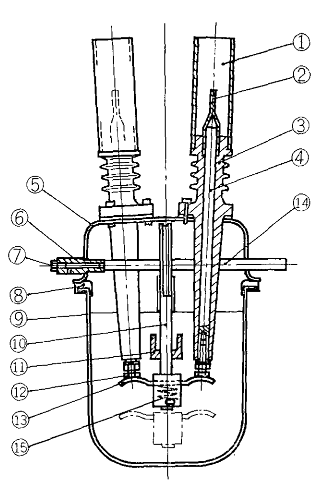


Fig. 3 **Magnetically operated oil switch**



① Insulating pipe (hard vinyl chloride pipe)
② Terminal (copper)
③ Bushing (epoxy resin)
④ Conductor
⑤ Cover (steel plate)
⑥ Gas removal
⑦ Ground terminal
⑧ Packing (oil-proof rubber)
⑨ Tank (steel plate)
⑩ Pull rod (phenol resin)
⑪ Guide (phenol resin)
⑫ Stationary contact
⑬ Movable contact
⑭ Switch shaft
⑮ Contact spring

Fig. 4 **Construction**

both simple and compact. By attaching either quick breaking mechanism or trip-free mechanism, and a manual operating handle or a magnetic operating device, switches of types (a) to (d) in *Fig. 1* can be constructed. In all cases, they are for indoor use.

The features include (1) economy because of the compactness, light weight and small oil volume and

(2) the use of the point contact system. Considering the latter, there are three types electrical contacts: point, line and surface contacts. Of these three, surface contacts would seen to be the most reliable and in the former POS switches, wedge type surface contacts were generally used. However, the contact units are bulky and if the thermal diffusion rate is good and the contact pressure is appropriate, there are many cases where the reliability of line and point contacts is higher. In two matched metal electrode surfaces, there is always some unevenness even when the surfaces appear flat when they are slid over one another. In practice the contact area is smaller than it appears and in theory, a contact condition is established when there are as few as three contact points on the surface.

Therefore, when the contacts have three or less contacts points and the overall resistance when current is flowing through each of these points is considered, the permissible current can be determined. However, since the contact duty consists of overcurrent closing and interrupting as well as flow through and switching of the load current, suitable thermal capacity, materials and contact pressure must be selected so that there will be no loss of current carrying capacity or ability to open due to wear or fusion resulting from such severe duties. As the subsequent test results show, all of the functions have been verified by basic and practical tests which confirms that the most appropriate design has been used.

In the former POS, the contact base was attached to a crossbar and there were many points to be tightened such as the points of attachment on the sides of the contacts, output cable etc. This meant that the construction was complex and also the charged part occupied considerable space in the oil. Since the contact pressure is inherent pressure applied by the elasticity of the sides of the contact, wear in the contact sides could lead to a deterioration of contact conditions and there were many accidents resulting in damage to the contact sides. As shown in *Fig. 4,* this equipment has no tightening points except the screw used to attach the stationary contact, and the reliability is improved since parts which can cause accidents are completely eliminated due to the simple construction. The space occupied by the charged parts has also been reduced.

(3) The crossbar which caused many problems in the former POS has been eliminated. This crossbar which supported the stationary and movable contacts in the POS was made of wood such as cherry or oak which would provide insulation against the boiling oil. When the insulation of this crossbar deteriorated due to immersion in water etc., the crossbar would be carbonized by leak currents and its mechanical strength was reduced. An accident would then occur due to loss so that during starting only one pole would remain.

Under the most adverse conditions, the conducting track on the crossbar surface would cause an interphase short circuit in the tank, and this could lead to an explosion.

In this equipment, the dangerous crossbar has been eliminated and the charged parts in the oil are supported independently by six bushings so that the insulation reliability is improved.

There is absolutely no danger of short circuit faults inside the switch due to the building up of moisture absorbant sludge as in the former switches where all the charged parts were connected together by a wooden crossbar.

(4) The bushings are made of epoxy resin. In the former POS, the terminals were of the cable output type and the cable connections required time. There were many cases of insulation faults due to deterioration of the cable and also many accidents due to damage of the porcelain support insulators in the output parts. In this equipment, the bushings are made of epoxy resin which has both excellent mechanical and electrical properties and such problems have been eliminated.

(5) There are excellent breaking characteristics in spite of the small size. As was described in section I, there have been many tests and investigations concerning the arc quenching phenomenon in oil and it has been easy to insure the required functions by means of the technical data collected up to now. The chief consideration in design has always been to increase the reliability and practical capabilities economically no matter how small the size.

Due to the arc, a large part of the oil is decomposed by hydrogen gas and this hydrogen gas exhibits excellent arc-quenching effects due to the high insulation yield strength of the oil and oil vapor, and is also used for cooling and spraying. With the compact size the arc quenching effect is a maximum and it is necessary to complete breaking with a minimum arc energy. However, it is thus necessary that the hydrogen gas pressure and spray effect during breaking be the most suitable. This is closely related construction of the gas removal part, the capacity of the air space above the surface of the oil and the breaking speed.

When this equipment was developed, tests were repeated several times on various types of test pieces and the most suitable relations for each of the above conditions were found for breaking at the minimum arc energy. The very small oil volume of 7 *l* used in the switch not only assures stable characteristics but also allows for a sufficient safety factor in respect to the breaking capacity.

(6) The operating mechanism is very simple. Since the switching operations of the movable parts have a great influence on the characteristice, it is necessary that normal operation be both smooth and highly reliable. In order to fulfill such requirements, the operating mechanism in this equipment has been simplified as much as possible and the number of

parts has been minimized.

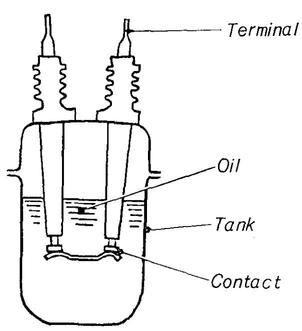
(7) Maintenance and inspection are easy and no-adjustments are needed for assembly. In this equipment, the crossbar has been eliminated and the point contacts and operating mechanism have been simplified as much as possible. All parts have been manufactured by machine tool, pressing and moulding processes so that accuracy is high in all cases and accuracy tests have also been performed on all parts. Therefore, the parts can be assembled without adjustment and production is such that high capabilities can be maintained. Since life characteristics have been clarified by life tests; maintenance, inspection and replacement of parts are all easy.

IV. TEST RESULTS

The tests performed were the type tests as per standards JEM 1219 "AC Load Switches" and JEM 1198 "Manual AC Circuit Breakers", and various other tests to confirm safety and practical functions.

1. Temperature Rise Test

This test was conducted after the load current switching test. There were no major differences after the test and there was sufficient tolerance in respect to all standard values. *Fig. 5* shows an example of temperature rise test results.



		Rated current	100 A		200 A	
		Conditions	Connection wire 38 mm² Before test	Connection wire 38 mm² After 200 switching of 100 A	Connection wire 100 mm² Before test	Connection wire 100 mm² After 200 switchings of 20 A
Temperature rise value (C°)	Contacts	R	17	14	22	24
		S	19	15	20	24
		T	15	14	23	25
	Terminal	R	9	11	17	17
		S	11	11	16	17
		T	—	—	16	16
	Oil		9	10	13	14
	Tank		7	11	12	14

Fig. 5 Temperature test

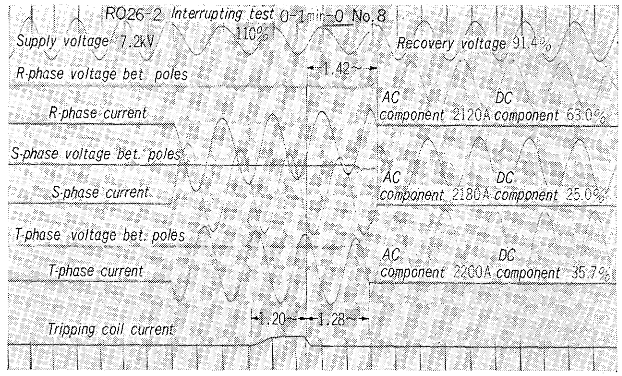


Fig. 6 Oscillogram of interrupting test 25 MVA at 7.2 kV

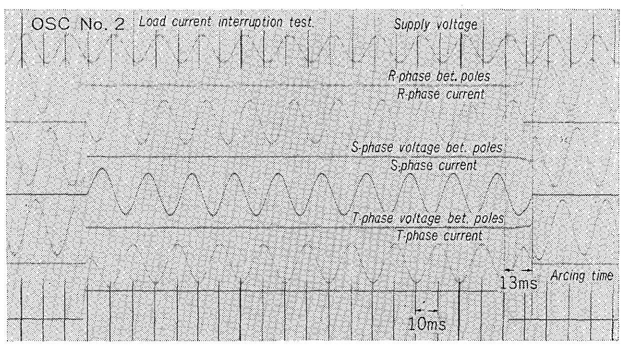


Fig. 7 Oscillogram of load current interruption 110 A at 7.2 kV

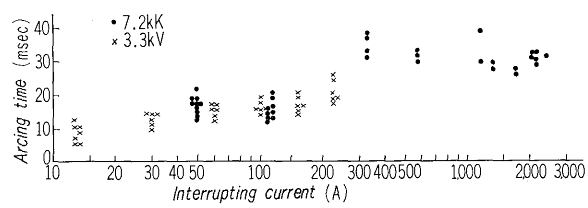


Fig. 8 Current/arcing time characteristics

2. Short Circuit Interrupting Test and Load Current Switching Test

Short circuit interrupting tests were carried out according to the operating duty in JEM 1198 and good results were obtained. The tests included an interrupting test for a 7.2 kV, 25 MVA breaker and an overcurrent load switching test for a 7.2 kV, 2,000 A switch.

Fig. 6 is an oscillogram for interrupting of 2,200 A which is equivalent to 110% of the ratings of the 7.2 kV 25 MVA breaker.

The load current interruption test used a 3-phase circuit, the test voltages were 7.2 kV and 3.3 kV and the power factor was 0.1 to 0.3. *Fig. 7* shows the oscillogram for the 7.2 kV, 110 A load current interruption test. It was shown that the characteristics were stable with no differences in arcing time because of test voltages.

3. Capacitance Current Switching Test

The test was for up to 167 A, but there was no restriking and arcing time was 0.5 cycles or less.

Fig. 9 is a typical oscillogram showing the results of this test and *Fig. 10* shows the arcing time characteristics.

4. Life Test

The mechanical life test consisted of no-load switching: 10,000 times using the manual operating system and 100,000 times employing the magnetic system. No parts were replased during the tests.

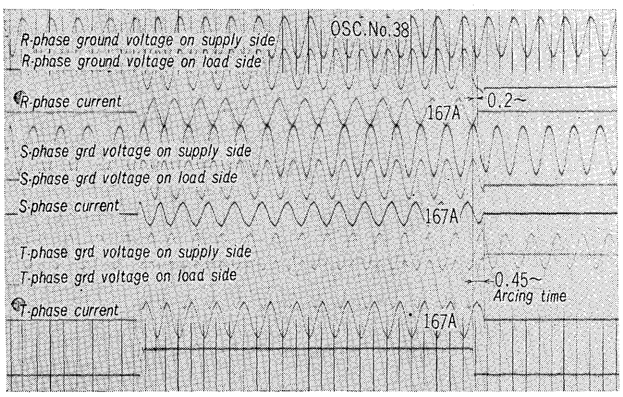


Fig. 9 Oscillogram of capacitor current 160 A open/close

The electrical life test consisted of current switching at various test current values using a 3-phase, 6.6 kV circuit with a power factor of 0.1 to 0.3. Such things as contact wear and insulating oil deterioration were measured. *Fig. 11.* (*a*) shows the results of 800 switchings at 50 A in a device with a current rating of 100 A. The life was found to be about 2,000 times from the amount of wear in the contacts which was measured according to changes in the amount of contact wipe. In the new equipment, the wipe is 5 to 6 mm and when this decreases to 3 mm, that is considered to be the life of the equipment and it must be replaced. *Fig. 12* shows the contact wear of a 100 A rated device after 500 switchings at 100 A.

Fig. 11 (*b*) shows the results of 1000 switchings at 200 A of a device rated at 200 A. The life is 1,000 switchings and the conditions of the contacts after the test can be seen in *Fig. 13.*

Fig. 11 (*c*) shows the results of 10,000 switchings at 150 A of a 200 A device with arc resistant contacts. The life was found to be 10,000 times. *Fig. 11* (*d*) shows the results of a typical charging switching life test with 20,000 switchings of a 3-phases, 6.6 kV

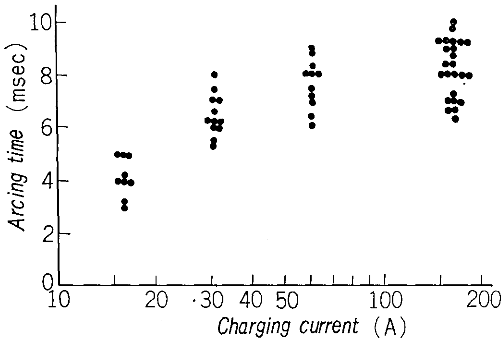


Fig. 10 Current/arcing time characteristics of charging current

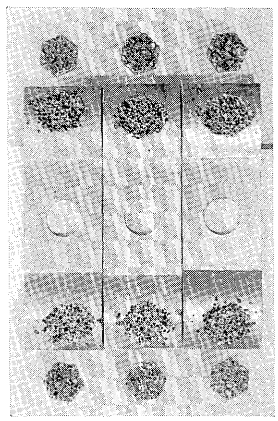
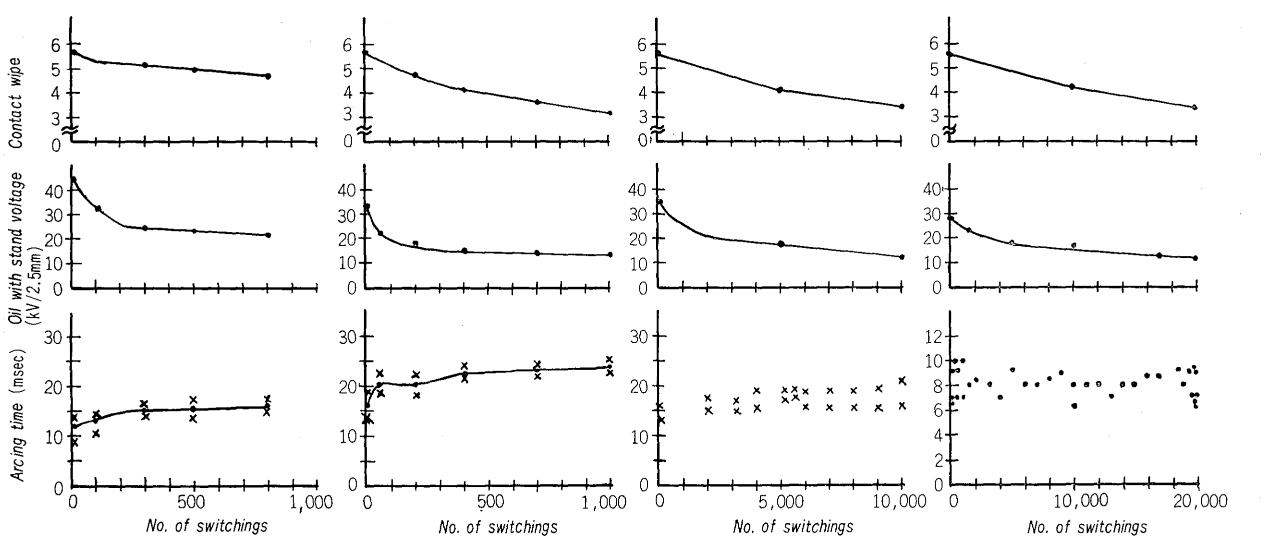


Fig. 12 Contacts after 500 switchings of 100 A (100 A, brass contacts)



(a) 800 switchings at 50 A, 100 A rated device (brass contacts)
(b) 1,000 switchings at 200A, 200A rated device (copper contacts)
(c) 10,000 switchings at 150A, 200A rated device (arc resistant contacts)
(d) 20,000 switchings of 160 A charging current, 200 A rated device (arc resistant contacts)

Fig. 11 Results of electrical life test

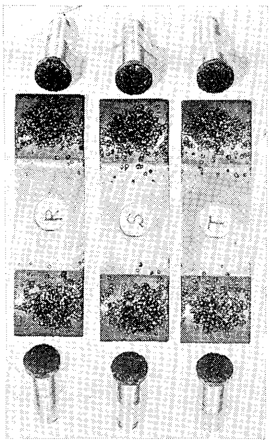


Fig. 13 Contacts after 1,000 switchings of 200 A (200 A, copper contacts)

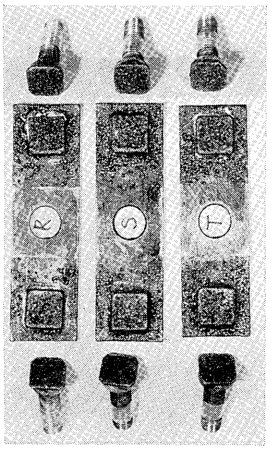


Fig. 14 Contacts after 20,000 switchings of 160 A charging current and 2,000 switchings of 150A load current (200 A, Ag-W contacts)

1,800 kVA capacitor using a 200 A device with arc resistant contacts. *Fig. 14* shows the contacts after 2,000 load switchings at 3.3 kV and 150 A.

The insulation oil becomes black after a certain number of switchings and when the life of the contacts is almost reached, is becomes sticky. However, since decreases in the insulation resistance of the oil have almost no influence on the breaking chracteristics, the life of the oil can be said to be the same as that of the contacts.

Fig. 15 shows the electrical life characteristics compiled on the basis life test results at various current values. If the characteristics are maintained with these as a standard, mainenance and inspection can be carried out correctly with no problems. The characteristics in *Fig. 15* are made in consideration consideration of safety and application convenience, and show straight lines which are less than the lifes given by the test results.

5. Breaking Test with Fuse

The 7.2 kV 150 MVA breaking test was carried out with a fuse combined for each rated current. Since the fuse limitted the current flow only in the swith unit, the mechanical and thermal influence of the breaking current was small and presented no problem. When the breaking current flowed with the switch in the closed condition, there was no contact damage up to current limitting values of 10.5 kA for a 100 A rated fuse. With 150 A and 200A rated fuses at current limitting values of 13.8kA and 15.8 kA respectively, there was slight contact damage. Almost the same results were obtained when the switch closed the shorted circuit. In the test with a 200 A fuse and current limitting up to 13.4 kA, the contacts were fused and damaged by continuous flow of the current.

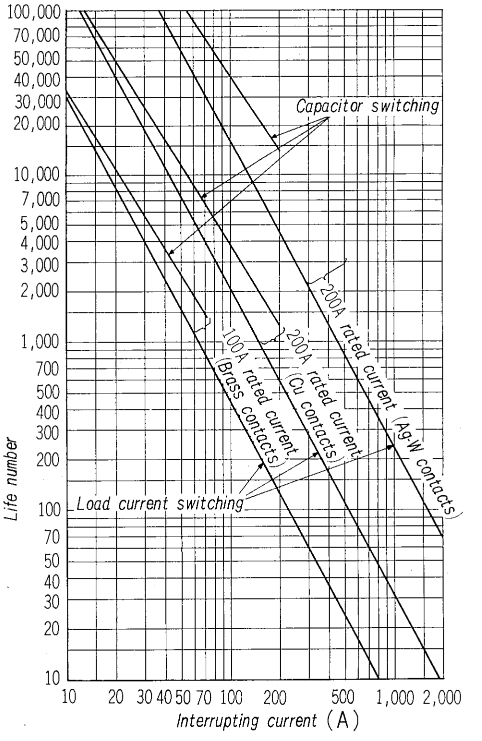


Fig. 15 Electrical life

To confirm that there was absolutely no danger when the shorted-circuit is carelessly closed with weak power or at a slow speed, the short circuit current was allowed to flow with the breaking spring removed and the switch operating part free (but with rubber bands lightly stretched over the parts to protect the contacts). The movement of the movable parts due to the electromagnetic force

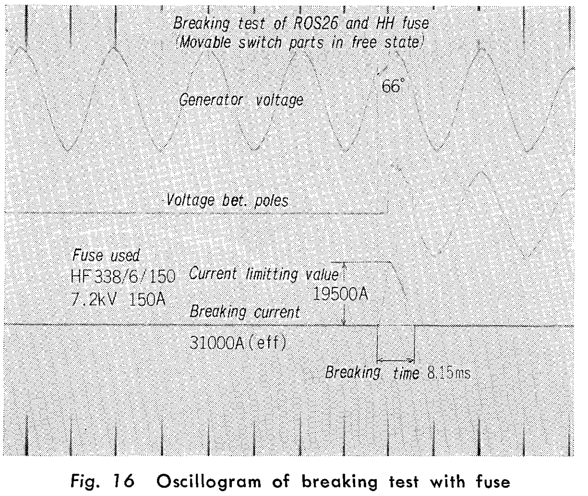


Fig. 16 Oscillogram of breaking test with fuse

received by the movable contact was investigated. In a 3-phases shorted-circuit equivalent to 7.2 kV, 31 kA and 350 MVA, the results of tests using a 150 A rated fuse showed that the movement of the movable contact due to electromagnetic force was never more than 20 mm or half the total stroke of 40 mm.

The electromagnetic force received by the movable contact is a momentary force with a very small energy and can be absorbed by the contact spring. Therefore, even in the free condition, the lightweight movable parts are moved only slightly. Since the contacts are separated, an arc arises but because the arc length and time are very short, the arc energy is small and the amount of gas which arises is the same as that when a load current is interrupted. *Fig. 16* shows the oscillogram for this test.

The above tests confirmed that practical functions of up to 350 MVA can be assured when a fuse is used. It is very safe since there is no danger to the operator even when the shorted circuit is closed.

V. CONCLUSION

This article has outlined the features, construction and capabilities of minimum oil switches and oil immersed breakers in which all the defects present in the former pole oil switches have been solved. These switches and breakers are not only suitable as the main switching equipment in JIS cubicle type high voltage substations but also as circuit dividing switches in transformers, motors and power capacitors. The authors are confident that they will fulfill all users' requirements.