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DEVELOPMENT OF 72/84 KV LOAD BREAK SWITCHES

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I. INTRODUCTION

In the old standard for disconnecting switches, JEC–125, the following current interrupting capacities were specified:

1) Transformer exciting current
2) Charging currents of lines or bus lines and insulation material attached to these lines
3) Loop currents arising in lines or apparatus
4) Light load currents

The magnitude of the currents was given in a single test example in the appendix, and was expressed clearly only as the maker's guaranteed value during business transactions. In the new disconnecting switch standard, JEC–165, items concerning the interruption of small currents have been eliminated from the explanations of the applicable ranges. However, in actual practice, interrupting small currents is common and the use of circuit breakers in such cases is not economical. Now, in place of circuit breakers inserted in circuits where short circuits are few, load break switches connected to the power fuse can be used. In this system short circuit fault are cleaned by means of the power fuse and load current are switched by means of load breaking switch. In accordance with this trend, Fuji Electric developed an indoor-type load break switch for interrupting relatively small currents in 1959. In 1962, the com- pany developed a load breaking switch which can interrupt currents of twice the rated current. Last year, Fuji Electric developed a load break switch with an interruption current of 2000 amp and a short circuit making capacity of 1500 Mva for use at 7.2 kv, one of the few of this type of load break switches anywhere in the world.

A series of the above-mentioned type of load break switches for 3.6∼36 kv has now been completed, and at present, 72/84 kv load break switches for both indoor and outdoor use are being developed. These will be described in the following article.

II. RATINGS AND FEATURES

An external view of one of these recently developed load break switches is shown in *Fig. 1* and ratings are given in *Table 1*. The features are as follows:

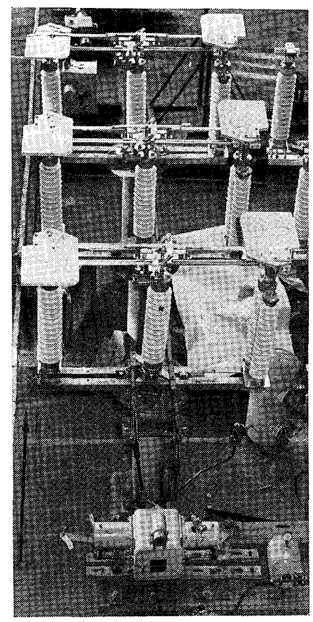


Fig. 1 Load break switch

Table 1. **Ratings of Load Break Switch**

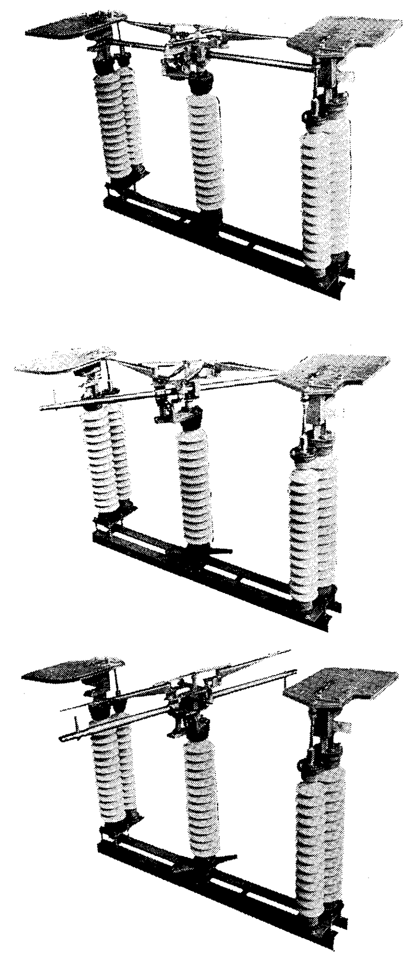
Main Unit	Model		RFB 225Ⅲ/70/800, 1200D
	Rated voltage		84 kv
	Rated current		800, 1200 amp
	Degree of insulation		No. 70
	Current interruption capacity	Load current	200 amp (power factor 0.7)
		Loop current	800 amp (at 8.4 kv)
		Excitation current	30 amp
		Charging current	30 amp
	Rated short time current		22 ka
Operating Device	Model		R 288/1826
	Rated operating pressure		5 kg/cm^2
	Rated control voltage		100 v dc
	Cylinder capacity		8.6 l

1) The new switch occupies the same space as the previous horizontal double break type and is much

more economical than a circuit breaker.
2) Special consideration has been given to outdoor use and the arc quenching chambers are made from a special epoxy resin. The switch thus has excellent arc quenching properties.
3) Since it has the functions of a disconnecting switch, the switch can also be used in that capacity.
4) Since the arc quenching chambers and the arcing contacts are of simple construction as in the usual double break type disconnecting switch, maintenance and inspection are easy.
5) Since load current interruption is possible for transformers with rated capacities of up to 25 Mva, the breaker on the primary side can be omitted.

III. CONSTRUCTION AND OPERATION

The construction of the load break switch for outdoor use consists of arc quenching chambers and arcing contacts as well as arcing blades attached to the common double break disconnecting switch. The chambers are provided with a space between 2 sheets of a special organic insulation material which is suitable for outdoor use. Porcelain insulators for air blast tubes are attached to the side of the porcelain insulators which support the switch. The current flows in through the contact section of the main blade. When the current will be interrupted, the main blade separates from the main contacts. When a certain angle is reached, the arcing blades are separated from the arcing contacts, the arc is then elongated in the narrow gaps of the arc quenching chambers by the rapid-action spring and jumps to to the exterior. At this time gas is generated from the 2 arc quenching plates in the chambers because of the arc heat, the arc temperature cools down and the current is interrupted. Just before the arcing blades are separated from the arcing contacts, compressed air passes through the air blast porcelain insulator and is blown into the arc quenching chambers containing the arc. The current is thus interrupted in conjunction with the arc quenching action described above. External views of an outdoor-type load break switch are shown in *Fig. 2(a)*, *(b)* and *(c)*. *Fig. 2(a)* shows the closed condition, *(b)* the condition just before operation of the arcing blades, and *(c)* the interrupted condition. *Fig. 3* is an explanatory diagram of the construction. In *Fig. 3*, base ①, support porcelain insulators ② ②′, rotating porcelain insulator ③, operating crank ④, blades ⑤ ⑤′, and contacts ⑥ are exactly the same as those used in standard outdoor-type disconnecting switches. The current will be interrupted as follows. When operating crank ④ is rotated by the operating device (which is connected to each phase by means of the remote control link mechanism) operating crank ④ and single rotating porcelain insulater ③ rotate, main blades ⑤ ⑤′ are turned and separate from contacts ⑥. Arcing blades ⑧ ⑧′ are held in



(a) Closed condition

(b) In the process of interruption

(c) Interrupted condition

Fig. 2 Action of load break switch

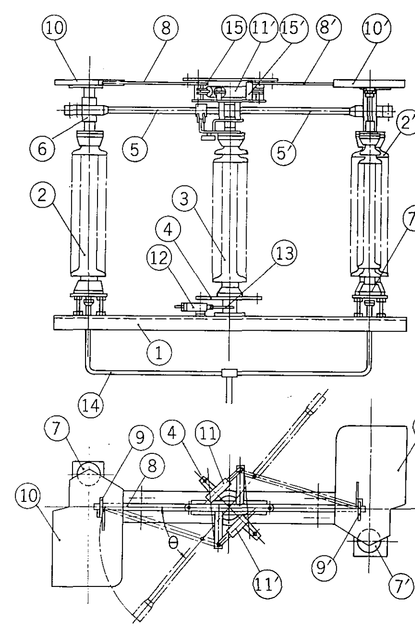


Fig. 3 Construction diagram

place by arcing contact ⑨ ⑨′ in the arc quenching chambers and cannot operate. When main blade ⑤ ⑤′ moves through operating angle θ, arching blades ⑧ ⑧′ are released from the arcing contacts, and are moved out of the arcing chambers by means of the energy contained in the rapid-action springs ⑪ ⑪′. At this time, the arc is elongated in the arc

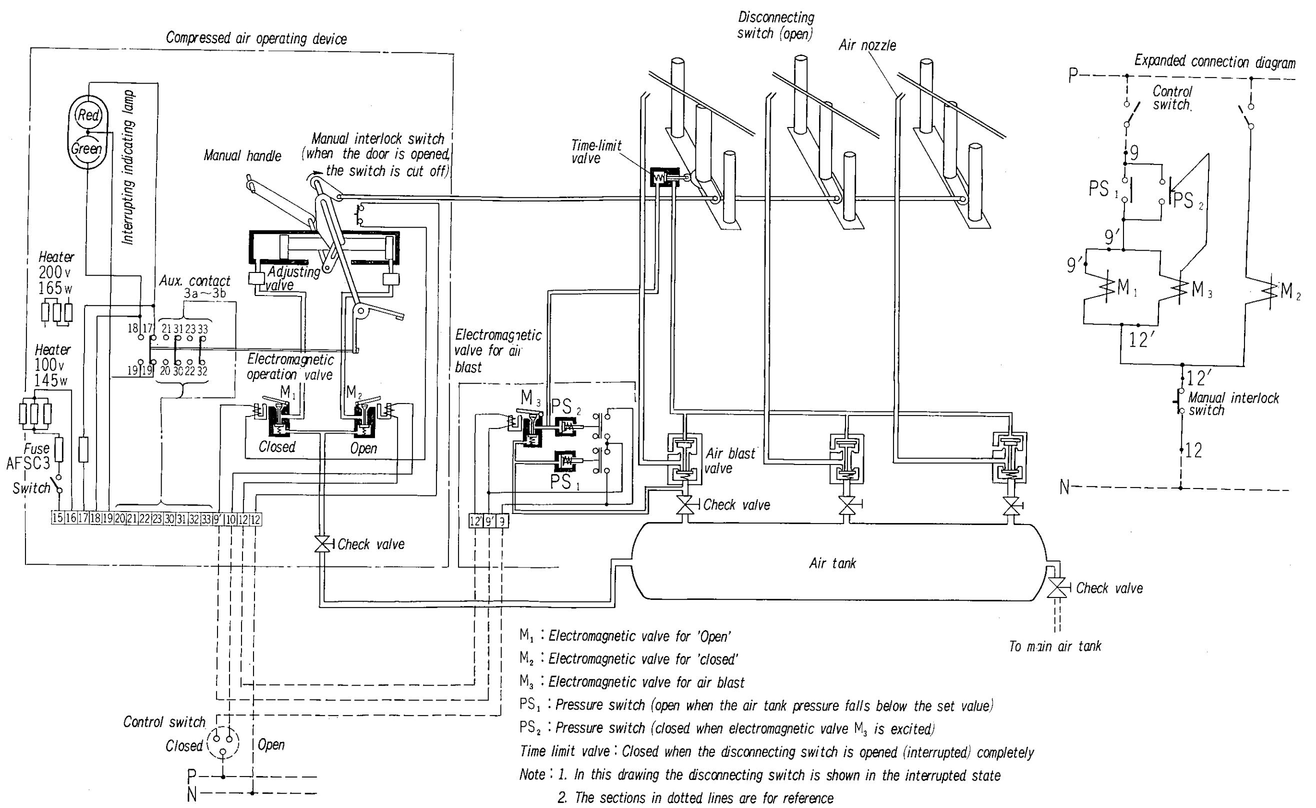


Fig. 4 **Operation control system of load break switch**

quenching chambers and the current is interrupted by means of arc quenching in the chambers. The time limit valve ⑫ is then rapidly rotated through angle θ, by means of cam ⑬ on the lower part of operating crank ④. Compressed air passes through tube ⑭ and air blast porcelain insulators ⑦ ⑦′, enters the arc quenching chambers and is blown at arcing contacts ⑨ ⑨′. When returned to the closed condition, main blade ⑤ ⑤′ makes contact with contacts ⑥ and at the same time arcing blades ⑧ ⑧′ strike stoppers ⑮ ⑮′ and enter arcing contacts ⑨ ⑨′ without bending. The operating circuit is shown in *Fig. 4*.

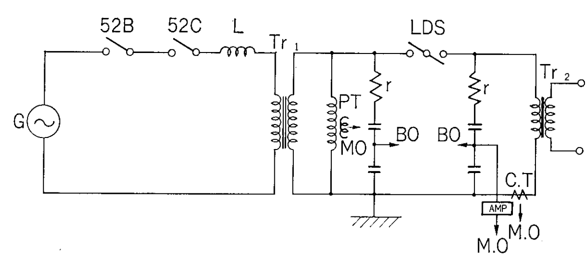
IV. TEST RESULTS

Interruption tests for exciting current, charging current, loop current and load current were carried out in accordance with Japan Electrical Equipment Industrial Standards (Guide to Ac Load Break Switches). The results of these tests are given below. These tests were all conducted for a single phase only.

1. Exciting Current Interruption Test

1) Test circuit

The test circuit is shown in *Fig. 5*.



G : 10 Mva short-circuit generator
52C : Switch for closing
PT : Power transformer for measuring
CT : Current transformer for measuring
BO : Oscillograph
MO : Electromagnetic oscillograph
52B : Protective circuit breaker
Tr_1 : Boosting transformer
Tr_2 : Transformer based on the load
L.D.S. : Load break switch

Fig. 5 **Test circuit for excitation current interruption**

2) Test results

This test was carried out with a single phase test transformer set at a constant 73 kv (equivalent to 3-phase 84 kv) and various current values. Tests were performed with and without air blast. Without air blast, the interruption current was 8.7 amp, and with air blast, 15 amp. Under the conditions used, interruption with a sufficient margin was possible in both cases without altering the interruption capacity. Under these test conditions the interruption test was not carried out at currents above 15 amp but interruption of 30 amp is possible as will be evident from the following test results. *Fig. 6* shows the current/arc time characteristics and *Fig. 7* shows a typical oscillogram of the results. The oscillogram indicates interruption of 15 amp with an arc time of 1.5 cycles, source voltage of single phase 73 kv and air blast pressure of 5 kg/cm^2.

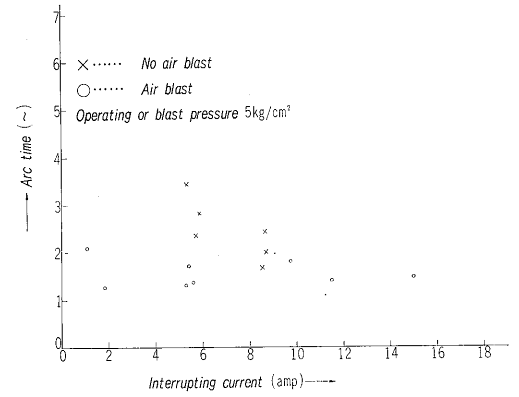


Fig. 6 Current/arc time characteristics of excitation current interruption

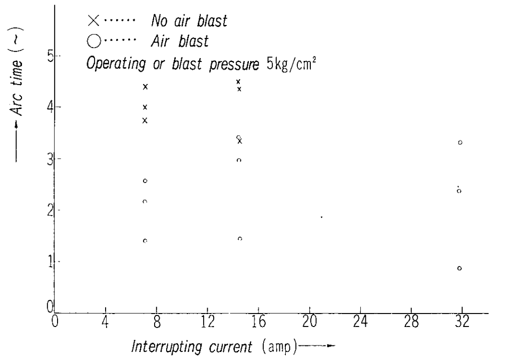


Fig. 9 Current/arc time characteristics of charging current interruption

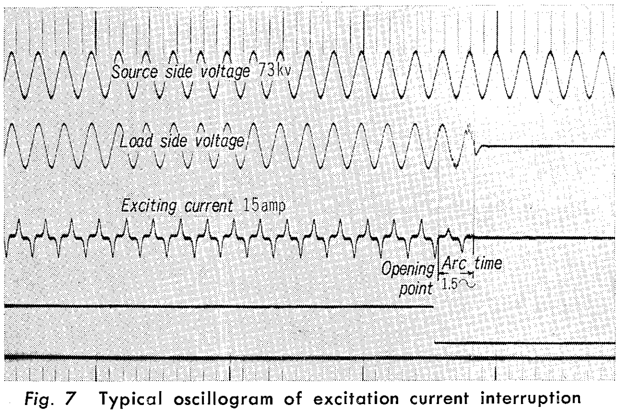


Fig. 7 Typical oscillogram of excitation current interruption

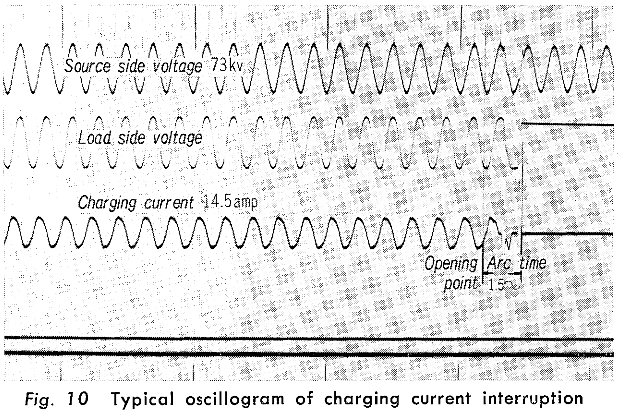


Fig. 10 Typical oscillogram of charging current interruption

2. Charging Current Interruption Test

1) Test circuit

The test circuit is shown in *Fig. 8*.

2) Test results

This test was carried out with constant single-phase 73 kv (equivalent to 3-phase 84 kv) and various current values. Tests were performed with and without air blast. Interruption current was 14.5 amp without air blast and up to 31.8 amp with air blast, but since the test was conducted without air blast at a current of 14.5 amp and arc time of 4.5 cycles (degree of opening 70%), it is considered best to limit the interrupting capacity to 15 amp for voltages equivalent to 3-phase 84 kv and no air blast. When air blast was used, breaking with a sufficient margin was possible at 31.8 amp and an arc time of 2.8 cycles (degree of opening 43%). No change in interrupting capacity was made as long as the air blast pressures was 75% of the rated value.

The emergency voltage during interrupting was generally 1.5 times the normal, with a maximum of 2.06 times the normal. *Fig. 9* shows the current/arc time characteristics and *Fig. 10* a typical test oscillogram. This oscillogram indicates interruption of a charging current of 14.5 amp with a single-phase test transformer of 73 kv, air blast pressure of 5 kg/cm² and arc time of 1.5 cycles.

3. Loop Current Interruption Test

1) Test circuit

The test circuit is shown in *Fig. 11*.

2) Test results

This test was carried out with voltages 5, 10, and 15% of 84 kv (3.7, 7.3 and 11 kv), a power factor of 0.31 and the interrupting capacity limited at each of the three voltages. Without air blast, the interruption capacity was limited to 700 amp at 3.7 kv,

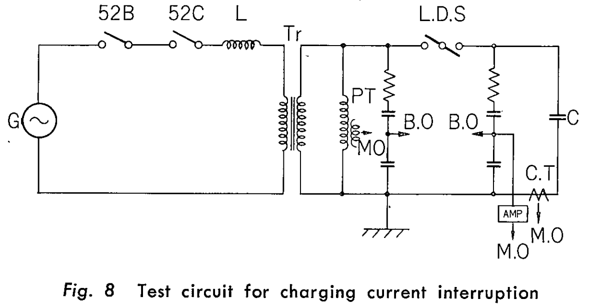


Fig. 8 Test circuit for charging current interruption

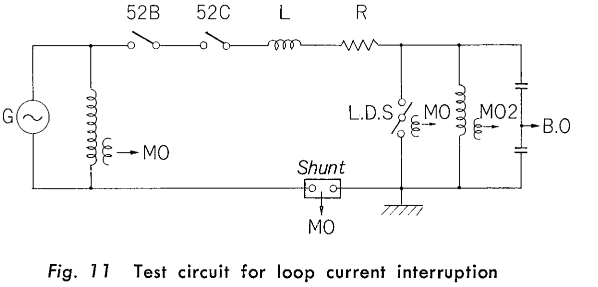


Fig. 11 Test circuit for loop current interruption

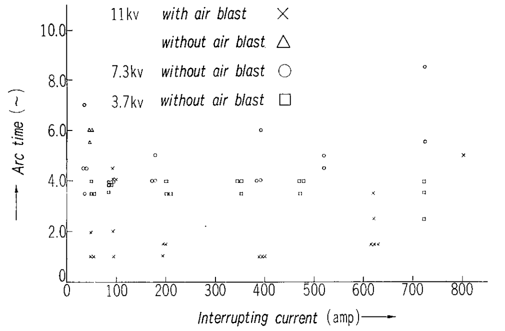


Fig. 12 Current/arc time characteristics for loop current interruption

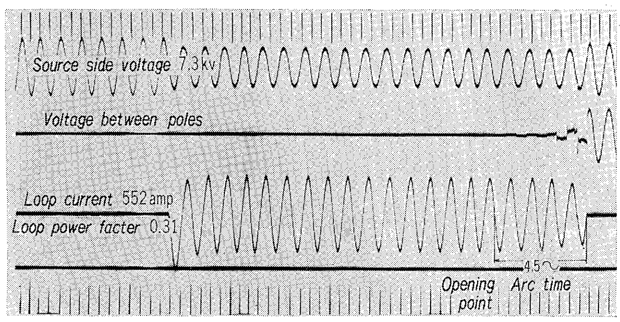


Fig. 13 Typical oscillogram of loop current interruption

150 amp at 7.3 kv, and 50 amp at 11 kv. When air blast was used, interruption was possible up to 800 amp at 11 kv. However, assuming that the atmosphere around the switch might be very bad, and contaminated liquid could enter the arc quenching chamber, interruption capacity should be limited to 600 amp at 11 kv when using air blast. Without air blast, interruption was possible up to 720 amp at 3.7 kv. *Fig. 12* shows the current/arc time characteristics and *Fig. 13* a typical test oscillogram. The oscillogram indicates interruption of 522 amp at 7.3 kv and an arc time of 4.5 cycles.

4. Load Current Interruption Test

1) Test circuit

The test circuit is shown in *Fig. 14*.

2) Test results

This test was carried out at voltages of 63.5 kv and 73 kv (equivalent to 3-phase 72 kv and 84 kv respectively), a power factor of 0.71, and current of up to 234 amp. All tests used air blast. At 234 amp, the arc time was 2.5 cycle and when converted to 3-phase, an interruption capacity of 34 Mva was shown to be possible. The load current interruption is limit 230 amp as mentioned above. However, load current closing tests (3-phase 84 kv, 260

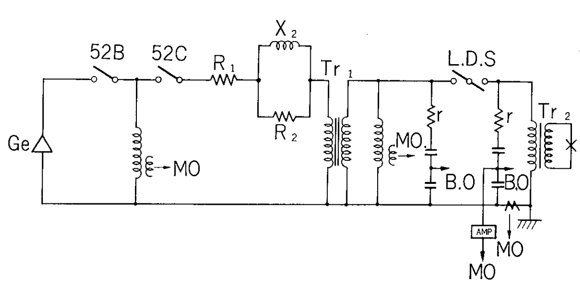


Fig. 14 Test circuit for load current interruption

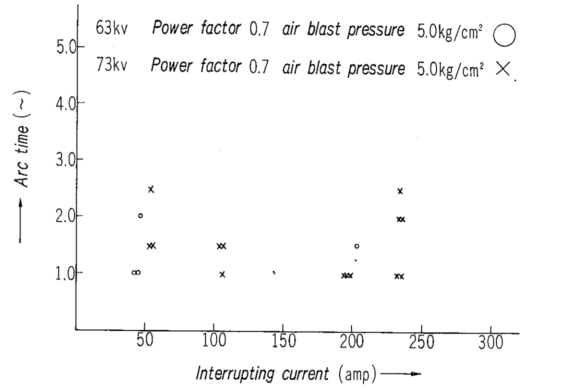


Fig. 15 Current/arc time characteristics of load current interruption

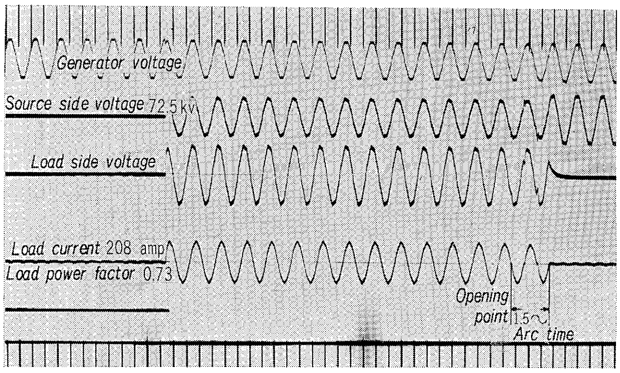


Fig. 16 Typical oscillogram of load current interruption

amp, power factor 0.77) were also carried out and complete closing was achieved. *Fig. 15* shows the current/arc time characteristics and *Fig. 16* shows a typical test oscillogram. The oscillogram shows interruption of a load current of 208 amp at 72.5 kv with a power factor of 0.73 and arc time of 1.5 cycles.

All of the above-mentioned tests were conducted outdoors in the actual operation. A load current interruption test was caried out during test operation of these devices in 1965. Another load current interruption test was conducted after about 2 years of actual operation and the interruption capacity was found to be uneffected. After 164 current interruptions (12 when the interruption limit was exceeded) and 10 cases of current closing, the quenching capacity of the chambers did not decrease and the arc quenching properties and wearability of of the special epoxy resin remained excellent. Heat damage to the arcing blades and contacts was so small as to require no replacements. However, it is considered desirable to replace the arc quenching chambers, arching blades and contacts after about 100 actual current interruptions.

V. CONCLUSION

This article contains the ratings, features and test results of the recently developed 70 kv class load break switch. This load break switch is useful instead of a circuit breaker for interrupting small currents at 100,140 kv and it is hoped that this article has been of use in providing this point.