UDC 621. 316. 53. 027. 5

NEW SERIES HIGH-VOLTAGE AC AIR BREAK CONTACTORS

By Koreyuki Taketani

Fukiage Factory

I. INTRODUCTION

Until a few years ago, steel tank type oil circuit breakers were the leading type used for breaking control of high voltage circuits. Their chief functions were receiving and distribution of the power and control of high voltage motors. Recently, however, these oil circuit breakers began to be replaced by high voltage air break contactors or high voltage combination switches composed of such contactors and current limiting fuses. This is due to the superior characteristics of high voltage air break contactors, such as capability of withstanding frequent operation (severe conditions of frequency of starting/stopping of high voltage motors and reversible operations), their electrical and mechanical long life and easier maintenance (oil circuit breakers require much time for replacement of oil, maintenance and inspection, while air break contactors do not need this). Air break contactors are completely without fire hazards because they do not use any oil. Because of these advantages, demands for the high voltage air break contactor are ever increasing, and we, to meet such heightening demands, have developed a series of contactors of high reliability, with distinguished characteristics in construction, circuit breaking system and insulation components. These are our new high voltage ac air break contactors, which are highly durable and compact. Their appearance is shown in *Fig. 1*.

Their main features are:

1) Epoxy resin molded parts are employed for insulation, and their distribution provides high insulation capability.

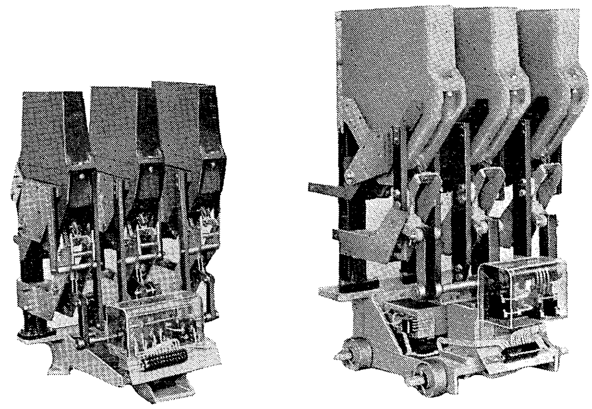
2) Series short gap arc extinction system and the arc extinction chamber made of anti-arc special resin are employed to provide high breaking reliability, precluding the possibility of humidification.

3) The direction of ionized gas spouting upon interruption of short-circuit is confined to the upper part of arc extinction chamber, and the arc space is so small that installation of the switchboard is easy with minimum danger of instruments contacting the breaking arc.

4) The contact system, with ample contact pressure and wiping capacity, precludes the possibility of contact welding even when subjected to frequent operation.

5) A powerful dc magnet provides noise-free operation. Also, the rectifier built into the main unit of the contactor enables ac source operation.

This series of contactor has been accepted favorably by customers and is achieving high operating efficiency.



Model RHC 13-1 (10 Mva 100 amp) — Model RHC 23-4 (25 Mva 400 amp)

Fig. 1 3.3 kv high-voltage ac air break contactors

II. RATINGS AND STANDARD SPECIFICATIONS

Table 1 illustrates ratings and standard specification of the 3.3 kv high-voltage ac air break contactor. All models have passed tests set forth by JEM 1167 (high-voltage ac air break contactor).

The standard models are the following four: RHC 13–05 (10 Mva, 50 amp), RHC 13–1 (10 Mva, 100 amp), RHC 23–2 (25 Mva, 200 amp) and RHC 23–4 (25 Mva, 400 amp). Others are D Class contactor and the latched contactor. The latched contactor is of such construction that, after closing of the main contact its condition is mechanically maintained, precluding the possibility of untimely opening of the contact due to momentary voltage drop in the active circuit. The D Class contactor is used for the reactor starter. It is not furnished with breaking capability, but a resin cover is used in place of the arc

Table 1 Standards of 3.3 kv High-voltage Ac Air Break Contactor

Model		RHC 13-05	RHC 13-1	RHC 23-2	RHC 23-4	RHC 23L-2	RHC 23L-4
Rated Voltage		3.3 kv (50/60 cps)					
Rated Current		50 amp	100 amp	200 amp	400 amp	200 amp	400 amp
Rated Breaking Capacity O-2 min-CO		10 Mva	10 Mva	25 Mva	25 Mva	25 Mva	25 Mva
Service Life	Mechanical	5 million times	2.5 million times	5 million times	2.5 million times	0.1 million times	0.1 million times
	Electrical	0.5 million times	0.25 million times	0.5 million times	0.25 million times	0.25 million times	0.25 million times
Rated Short-time Current		1800 amp 0.5 sec	1800 amp 0.5 sec	4400 amp 0.5 sec	4400 amp 0.5 sec	4400 amp 0.5 sec	4400 amp 0.5 sec
Frequency of Operations	Continuous	600 times/hr	300 times/hr	300 times/hr	120 times/hr	300 times/hr	120 times/hr
	Intermittent	1200 times/hr (5 min)	1200 times/hr (2 min)	1200 times/hr (5 min)	1200 times/hr (2 min)	1200 times/hr (5 min)	1200 times/hr (2 min)
Closing Time		3 cycles	3 cycles	4 cycles	4 cycles	4 cycles	4 cycles
Opening Time		1.5 cycles	1.5 cycles	2 cycles	2 cycles	2 cycles	2 cycles
Control Voltage		Ac 100/110 v, ac 200/220 v 50/60 cps				Dc 100/110 v Dc 200/220 v Ac 100/110 v, 50/60 cps Ac 200/220 v, 50/60 cps	
Tripping Voltage						Dc 100/110 v	Dc 100/110 v
Applicable Maximum Motor Capacity		200 kw	400 kw	750 kw	1500 kw	750 kw	1500 kw
Applicable Maximum Transformer Capacity		250 kva	500 kva	1000 kva	2000 kva	1000 kva	2000 kva

extinction chamber, resulting in low height of the unit. This construction is convenient for building the component into a compartment when piled up with main A Class switches.

III. CONSTRUCTION

These contactors are composed of a main switch that opens/closes a high-voltage circuit, operating unit of the main contact, arc-quenching system and auxiliary switches. The explanation of type RHC 23-2 is hereby given according to *Fig. 2.* The main high-voltage circuits are composed of input main terminals, blowout coil, fixed contact, moving contact, bearing block and output main terminal. Those parts burdened with high potential are insulated from the grounded assembly chassis by the insulating post. Input/output terminals are assembled together behind the contactor, making wiring of the high-voltage circuit easier when installed on a switchboard. Also the main unit of the contactor is wheel-mounted for easy stowage. The arc extinction chamber, blowout coil and insulating post are made of epoxy resin.

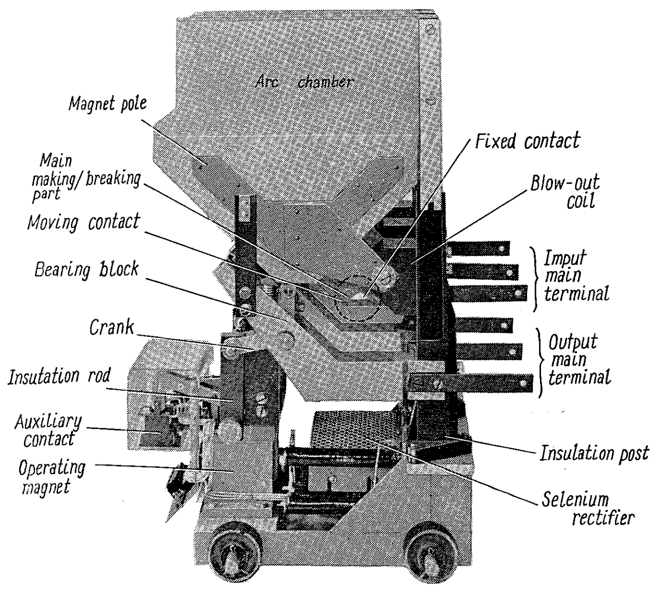


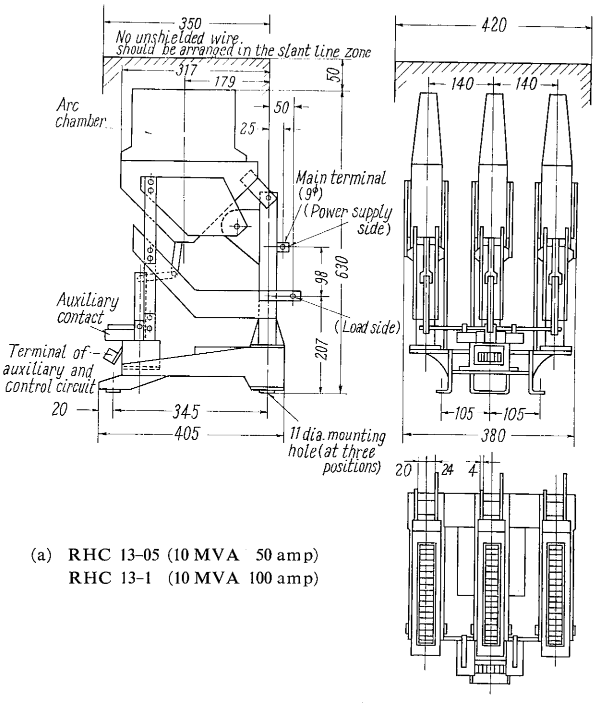
Fig. 2 Illustration of contactor

Main high voltage conductor assembly is constructed with each phase independently insulated from grounded parts, and there is no part horizontally connecting different phases with insulating material. This means all insulation components are vertical. Horizontal connection of different phases of high-voltage insulation material has the defect that dust accummulates on the surface of the material, which in the past often caused short-circuit accident between phases. These accidental short-circuit are more liable to occur on fixed contacts than on moving contacts. Our contactors completely eliminate this deficiency. Further, the 3 kv unit retains insulation capability equal to that of a 6 kv unit, and combined with epoxy resin insulation material, it promises high insulation reliability.

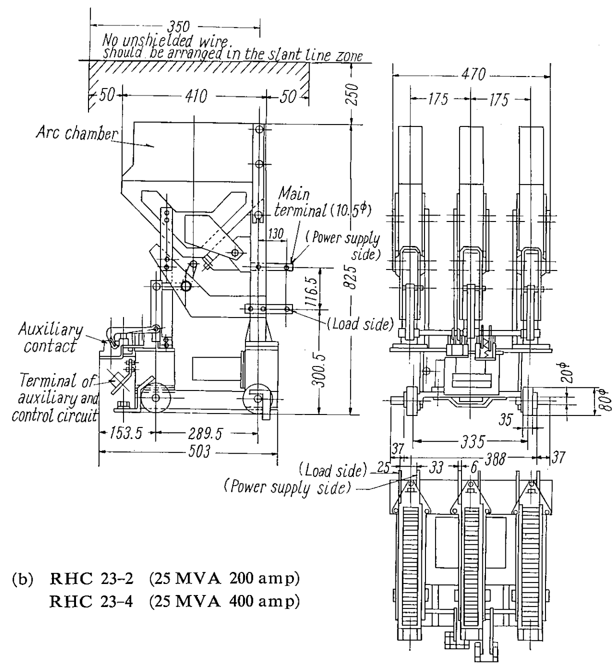
Main contacts are of the double pendulum system with one side breaking, with no specific arcing contact, a simple construction that serves the double purpose of current contact and arcing contact, making replacement of the unit easier. At the time the contact is closed, sliding action is provided to eliminate surface corrosion and vibration due to impact. Due to sufficient contact pressure and wiping with wider separation of the contact opening, there is no possibility of main contact welding upon large voltage changes or the bump of operating contacts in active circuits.

Operating magnet in *Fig. 2* shows a solenoid dc operating magnet. When this magnet is energized, the insulation rod is pushed upward, turning the crank clockwise around the fulcrum and closing moving contact. When the magnet is de-energized, the contact spring which works as the breaking spring opens the moving contact.

In case of large operating power is required, an ac magnet is not suitable because of its low power factor, high va consumption and large size. Also, a large ac magnet is likely to produce a chattering noise unless the magnet surface is in uniform and close contact, resulting in pulsating attraction. A dc magnet is free from this defect, and is mechanically sturdy due to its lump steel core. For these reasons the contactor employs a dc magnet. The built-in rectifier enables operation from an ac power source. At the initial stage of closing, all operating voltages are applied to the operating coils, effecting an increased closing capability, and at its final stage economic resistance are connected in series, minimizing loss of magnet capacity. *Fig. 3* shows the standard connection of the high voltage-contactor. Generally, a dc magnet has a tendency to lengthen the opening time of the contactor due to eddy current produced by the lump core, and to lengthen the closing time due to inductance of the operating coil. Our contactors, however, are designed properly, taking these phenomena into consideration, succeeding in limiting operating time to the same amount as that of an ac magnet. Further, we positioned the magnet in the center of the contactor to save space and to insure even distribution of operating force to each phase.



(a) RHC 13-05 (10 MVA 50 amp)
RHC 13-1 (10 MVA 100 amp)



(b) RHC 23-2 (25 MVA 200 amp)
RHC 23-4 (25 MVA 400 amp)

Fig. 4 Outline dimensions of high-voltage ac air break contactor

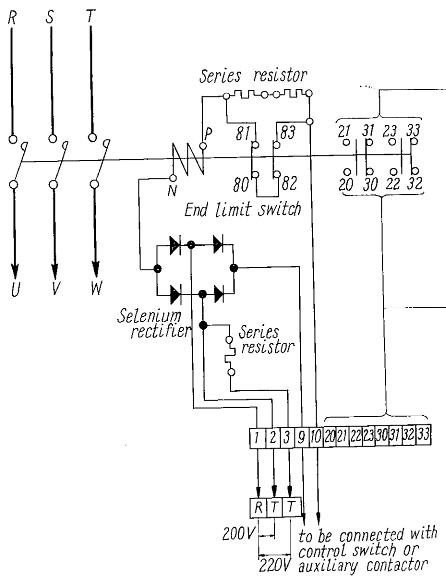
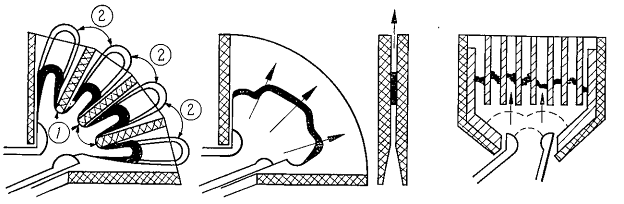


Fig. 3 Connection of high-voltage contactor

IV. PRINCIPLE OF ARC EXTINCTION

The arc extinction principles of high-voltage air break contactors are classified into the following 3 types. *Fig. 5* shows their models.

(*A*) Arc extension principle
(*B*) Slit arc extinction principle
(*C*) To extinguish arcs by dividing arc into many



(*A*) Radiation-type arranged rib (*B*) Fine arc chamber (*C*) Short-gap series arc extinction

Fig. 5 Principle of arc extinction in air break contactor

short gaps.

Principle (*A*) is a system in which insulation plates are distributed in patterns shown in *Fig. 5* (*A*), and absorb the arc into them by magnetic force, to extend arc length and shut it off. During arcing, the arc is fixed to the end of the rib ①, which causes the rib to be damaged. Also it is liable to induce re-ignition due to ionization of the atmosphere surrounding this part. Further, in case the length of the rib is insufficient, it is liable to cause a short-circuit in the part marked ② upon breaking large current. This model needs to be large in size to eliminate such defects and is now considered outmoded.

In principle (*B*), the arc extinction chamber wall has the shape shown in *Fig. 5* (*B*). It squeezes the arc into slits by magnetic force, and breaks by utilizing the deionization of insulation surface. Generally, this wall arc extinction effect and arc extension effect are combined effectively in the arc extinction chamber with these slits extending in a variety of directions. This principle is widely used, and damage of insulation material is less than with principle (*A*), but still cannot be completely free from damage due to intense arc heat. An heat-proof porcelain provides highly stable breaking capacity, but this is not economical when used in a high voltage contactor and therefore asbestos cement is mainly used instead. Experiments proved that this type of arc extinction chamber sometimes fails if it is made of asbestos cement. Moreover, due to humidity surface leakage occurs in the main contact open condition after load current breaking is effected, thereby causing overheating of the arc extinction chamber.

To reduce surface current leakage, resin insulation with heat-proof properties was applied to the surface and asbestos cement processed with the same material was used, but still favorable results could not be obtained as the resin-plastered surface produces harmful gas. Material like asbestos cement is likely to produce gas, and such material tends to provoke re-ignition due to the gas pouring on the contact upon breaking. This phenomenon has been confirmed by the inching test, a test of repeating closing/opening of current several times as strong as the rated current at regular intervals. This arc extinction principle, if applied, requires careful selection of the insulation material to be used.

In principle (*C*), the arc extinction chamber is separated by a number of metal plates, into which the arc is sent by magnetic force. This turns each of the metal plates into electric poles forming a series of short arc gaps. During this short gap arcing, the surface of each metal plate electrode retains approx. 200 v dielectric strength, and the required number of metal plate electrodes effect arc extinction. In this principle, the arc does not contact the surface of the insulation material as in slit arc extinction and therefore it does not damage the chamber interior wall, and the amount of gas produced is sufficiently small.

Having studied these phenomena, we employed the series short gap arc extinction system in our high voltage air break contactors, and used anti-arc epoxy resin for insulation of the arc extinction chamber. This provides high breaking reliability without danger of moisture absorption which causes accidents. Further, to minimize the area required for this unit upon installation of the switchboard, the direction of ionized gas spouting is limited only toward the top of the chamber.

V. TESTS

We conducted several tests set forth by JEM 1167, high-voltage ac air break contactor tests, according to the Japanese Electric Manufacture Standards with other auxiliary tests.

1. Operation Tests

Passed the test with the values indicated in *Table 2*.

Table 2 **Operating Test**

Minimum Operating Voltage	Less than 85% of rated voltage
Drop-out Voltage	20~60% of rated voltage

2. Dielectric Strength Test

Applied voltage shown in *Table 3* for one minute and confirmed that the contactor could withstand this voltage.

Table 3 **Dielectric Strength Test**

When the contactor is open, first across each of the poles and the input terminals connected together and output terminals connected together	10,000 v
When the contactor is closed, across all the poles connected together and to the frame of the contactor	17,000 v (equivalent to rated 6600 v)
Across all the control and auxiliary circuits connected together and to the contactor frame	1500 v

3. Making and Breaking Test

Conducted the test under the following conditions:

Operating duty: CO–30 sec–CO–30 sec–CO–30 sec–CO–30 sec–CO
Test circuit: Recovery voltage 3.3 kv
Current: 10 times rated current
Power factor: below 0.1

Operating circuit voltage is the rated voltage. All models passed the test with sufficient margin, producing no abnormal condition.

4. Inching Test

Conducted the test under the following conditions:

Operating duty: CO–10 sec–CO . . . 15 consecutive times
Test circuit: Recovery voltage 3.3 kv
Frequency: 50 cps
Current: 2 times rated current
Power factor: below 0.1
Operating circuit voltage: Rated voltage

As the result, all models passed the test successfully. *Fig. 6* shows its oscillogram.

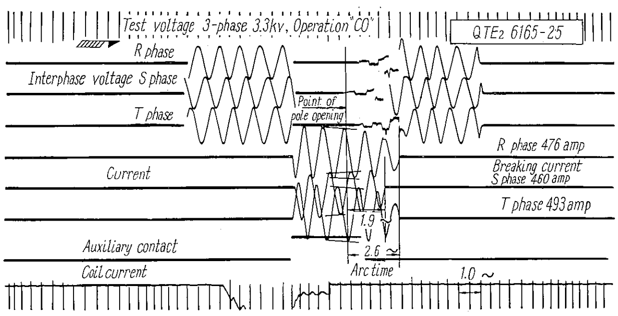


Fig. 6 Oscillogram of inching test (RHC 23–2)

5. Interrupting Test

Conducted the test under the following conditions:

Operating duty: O–2 min–CO
Test circuit: Recovery voltage 3.3 kv
Frequency: 50 cps
Current: Rated interrupting current
Power factor: below 0.1
Operating circuit voltage: Rated voltage

As the result, all models have passed the test without producting any abnormal condition as far as arc emission, welding of the contact and mechanical impact are concerned. Especially concerning the power factor, this test sets the severe part of below 0.1 against the standard setting 0.3∼0.4 as in JEM 1167.

Figs. 7 and *8* show an oscillogram depicting this test. *Fig. 9* is a photograph illustrating arc blowing in the interrupting test of 3.3 kV 25 MVA conducted on model RHC 23–2 contactor. In depicts an high temperature gas protruding slightly above the upper portion of the arc extinction chamber. *Figs. 10* and *11* show pictures of contacts of model RHC 23–2 after it underwent the abovementioned series of tests and the lower part of the interior wall of the arc extinction chamber, respectively.

They demonstrate that the extent of wear is negligible. *Figs. 12* and *13* show the interruption characteristic curves.

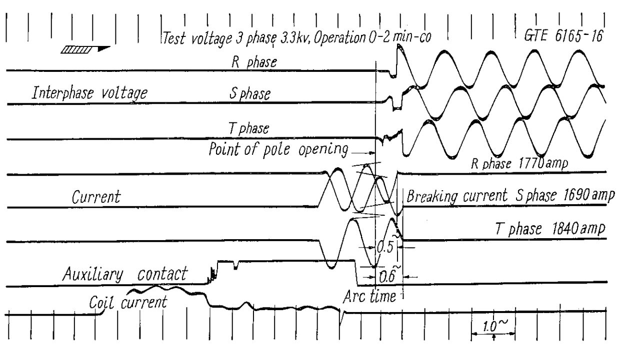


Fig. 7 Oscillogram of interrupting test under CO duty (RHC 13–05)

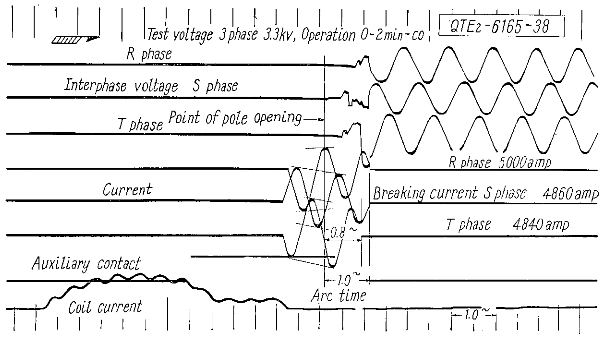


Fig. 8 Oscillogram of interrupting test under CO duty (RHC 23–2)

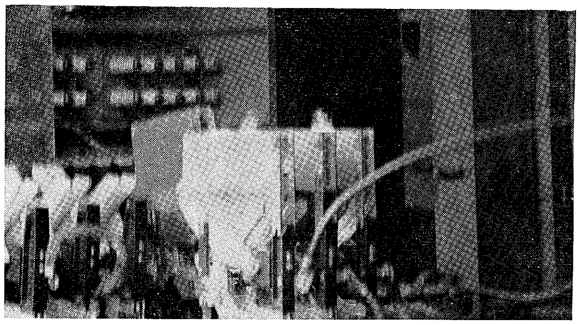


Fig. 9 Scene in interrupting test, 25 Mva at 3.3 kv

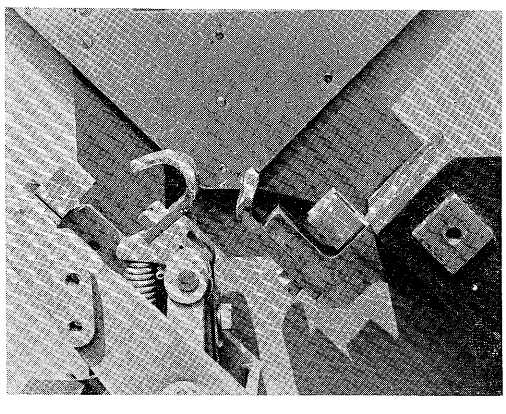


Fig. 10 Contact parts of 3.3 kv 25 Mva contactor after interrupting test

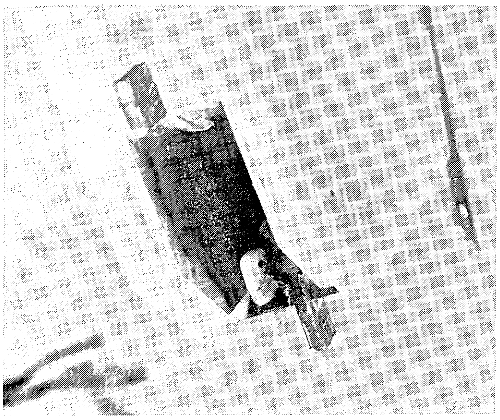


Fig. 11 Arc extinction chamber of 3.3 kv 25 Mva contactor after interrupting test

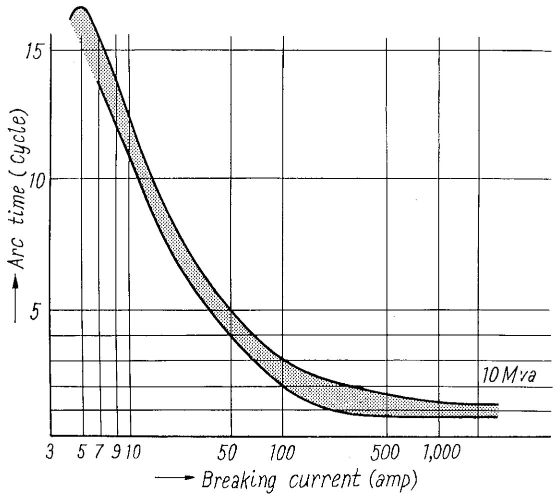


Fig. 12 Interrupting characteristic curves of RHC 13-0.5 contactor

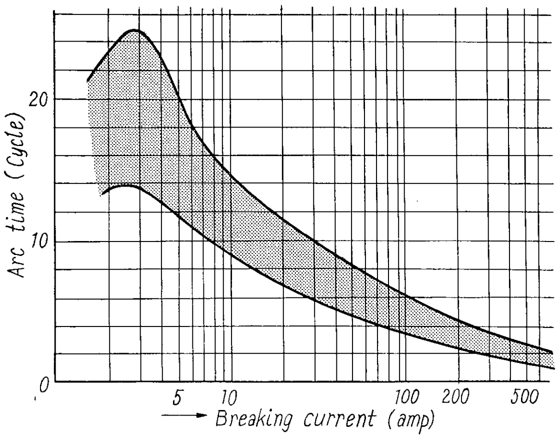


Fig. 13 Interrupting characteristic curves of RHC 23-2 contactor

6. Photographing of the Arc Extinction Chamber by High Speed Camera

As explained in section **IV**, the arc produced between contacts is lead to the arc horn from moving and fixed contacts by magnetic force of the blow out coil, then rapidly moves to the upper portion of the arc extinction chamber, and then divided into series short gap arc by metal arc extinction plates distributed there until it is extinguished. *Fig. 14* shows a photograph depicting movement of electric arc within the model extinction chamber simulating that of RHC 23-2 model contactor in order to analyze this arc extinction process.

Photograph (1) shows the arc produced between contacts moving to the upper portion of the chamber

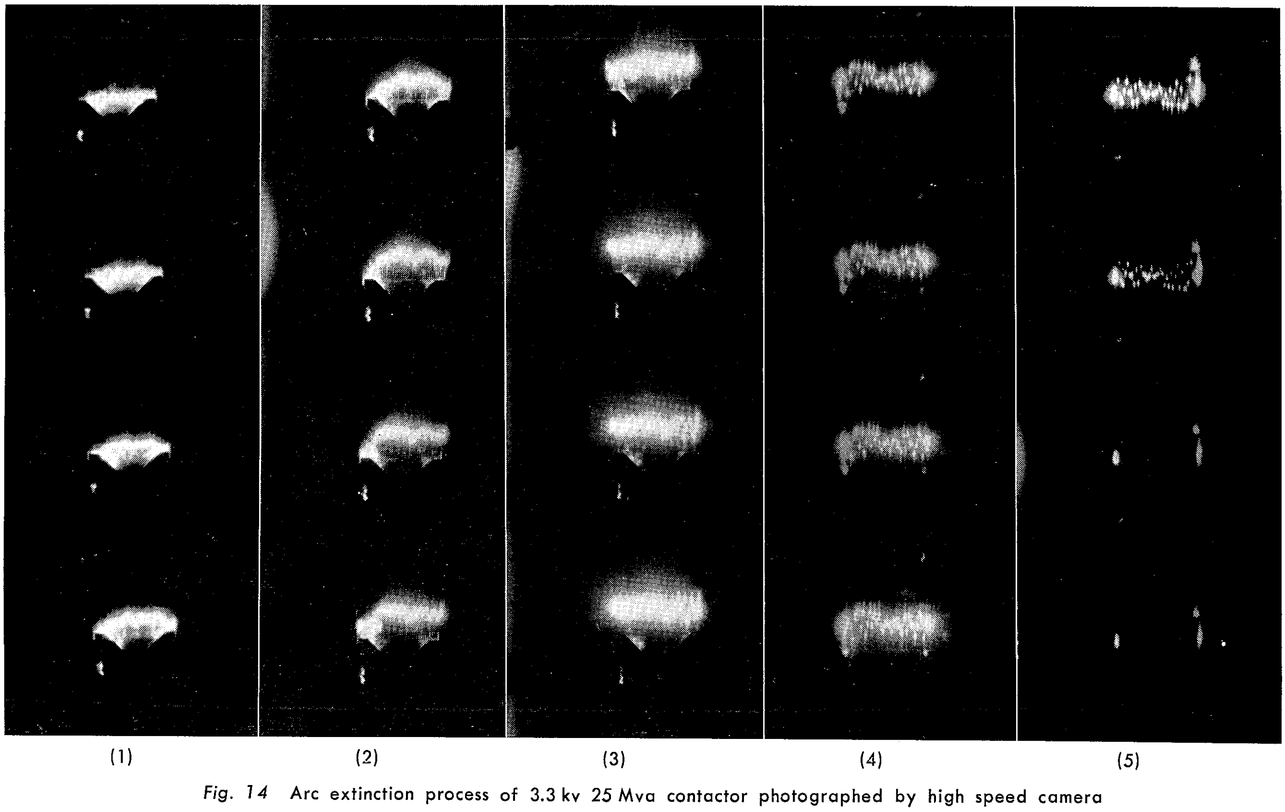


Fig. 14 Arc extinction process of 3.3 kv 25 Mva contactor photographed by high speed camera

as it is lead by the arc horn, (2) shows the condition in which the arc is divided to short gap arc within metal extinction plates, and in (4) and (5) the current reaches zero and extinction is complete. Also electric and mechanical life tests have been conducted in accordance with JEM 1167, with the results proving that contactors sufficiently meet strict requirements of long life and high reliability.

VI. CONCLUSION

The high-voltage air break contactors began to be used widely for control of high-voltage motors because of their capability of withstanding frequent operation and their easy maintenance, and further development is being made in the area of magnetic breakers through combined use of current limiting fuses. In order to meet such demands of customers as easier maintenance, greater economy and higher efficiency, we will exert further efforts for the improvement of these high-voltage air break contactors and development of new products related to them, as well as for their maintenance.