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A-SERIES HIGH-VOLTAGE AIR BREAK CONTACTORS AND DRAW OUT TYPE FUSED CONTACTORS

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I. INTRODUCTION

Fuji's A-series high-voltage air break contactors possess a high breaking stability because of the series short gap arc quenching system and the arc quenching chamber made of special anti arc resin which eliminates the problem of moisture absorption. Insulation has also proven very reliable due to the unique insulation properties of the epoxy resin used as the main constituent. These contactors are selling very well and their performance has proven highly satisfactory.

Since the A-series high-voltage contactor can be operated frequently, it is also suitable for heavy duty (frequent starting, stopping, and similar reversible operations in high-voltage motors). Both electrical and mechanical life are long. The contactor is designed and manufactured mainly for control of high-voltage motors and it performs excellently, as described above, within its duty range. However, short-circuit capacity has increased sharply in large, modern industrial systems mostly using high-voltage motors. The short-circuit breaking capacity of these conventional high-voltage contactors is comparatively small, so small in fact that shortcircuit protection is often impossible with these contactors. The so-called fused contactor containing a current limiting fuse with a large short-circuit breaking capacity is widely employed to cope with this problem.

This article describes the newly developed A-series high-voltage contactor and applied products.

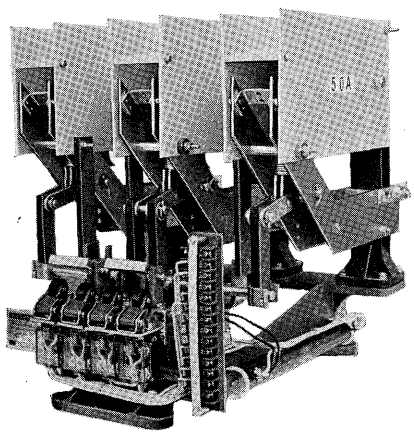
II. STANDARD SPECIFICATIONS AND PERFORMANCE OF THE A-SERIES HIGH-VOLTAGE AIR BREAK CONTACTORS

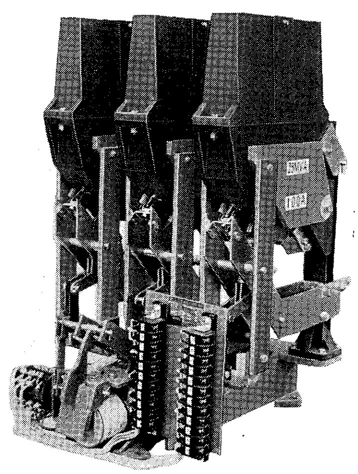
Standard specifications of the 3.3 kv A-series high-voltage air break contactor are shown in *Table 1.*

The various unit types underwent and passed all the tests given in JEM 1167 (high-voltage ac contactor). Other reference tests for respective types were carried out and the results will be reported here. These test results will be a useful reference in the practical application of this contactor.

1. Motor Load Interrupting Test

This test was performed to investigate the differences in recovery voltage and arcing time when the high-voltage motor load and the static reactor load are interrupted with the high-voltage contactor. The motor load interruption oscillograph is shown in *Fig. 3.* As is clear from the diagram, recovery voltage is low directly after interruption but increases steadily with time. The low recovery voltage is due to the fact that the rotor maintains dynamic and magnetic


Model RHC 03A-05 (Reactor short-circuit use) 50 amp)


Model RHC 23AL-1 (Latched type) (25 Mva 100 amp)

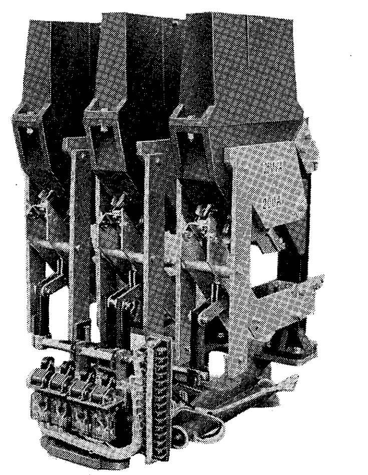

Model RHC 23A-2 (Standard type) (25 Mva 200 amp)

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

Table 1 **Standards of 3.3 kv A-series high-voltage ac air break contactors**

Model	Standard Model (Normal Exciting type)					Lached Type (Mechanical Maintenance Type)					Class D (Reactor Short-Circuit Use)			
	RHC 13A-05	RHC 23A-1	RHC 23A-2	RHC 53A-2	RHC 53A-4	RHC 13AL-05	RHC 23AL-1	RHC 23AL-2	RHC 53AL-2	RHC 53AL-4	RHC 03A-05	RHC 03A-1	RHC 03A-2	RHC 03A-4
Rated Voltage	3.3 kv (3 phase 50/60 cps)													
Rated Current (amp)	50	100	200	200	400	50	100	200	200	400	50	100	200	400
Rated Breaking Capacity (O—2 min—CO) (Mva)	10	25	25	50	50	10	25	25	50	50	—	—	—	—
Service Life: Mechanical (million times)	500	250	250	500	250	10	10	10	10	10	500	250	250	250
Service Life: Electrical (million times)	50	25	25	50	25	25	10	10	25	10	50	25	25	25
Rated Short Time Currrent (0.5 sec) (amp)	1800	4400	4400	8800	8800	1800	4400	4400	8800	8800	1800	4400	4400	8800
Switching Capacity (amp)	500	1000	2000	2000	4000	500	1000	2000	2000	4000	500	1000	2000	4000
	CO 30 sec interval 5 times										100 times (closing only)			
Operation Frequency: Continuous (times/hr)	600	300	300	300	120	600	300	300	300	120	600	300	300	120
Operation Frequency: Intermittent (times/hr)	1200 (5 min)	1200 (2 min)	1200 (2 min)	1200 (5 min)	1200 (2 min)	1200 (5 min)	1200 (2 min)	1200 (2 min)	1200 (5 min)	1200 (2 min)	1200 (5 min)	1200 (2 min)	1200 (2 min)	1200 (2 min)
Closing Time (sec)	0.06	0.06	0.06	0.08	0.08	0.06	0.06	0.06	0.08	0.08	0.06	0.06	0.06	0.08
Opening Time (sec)	0.04	0.04	0.04	0.06	0.06	0.06	0.06	0.06	0.08	0.08	0.04	0.04	0.04	0.06
Control Voltage	Ac 200/220 v 50/60 cps dc 200/220 v Ac 100/110 v 50/60 cps dc 100/110 v													
Tripping Voltage	—					Ac 200/220 v 50/60 cps dc 200/220 v Ac 100/110 v 50/60 cps dc 100/110 v					—			
Applicable Max. Motor Capacity (kw)	200	400	750	750	1500	200	400	750	750	1500	200	400	750	1500
Applicable Max. Transformer Capacity (kva)	250	500	1000	1000	2000	250	500	1000	1000	2000	—	—	—	—

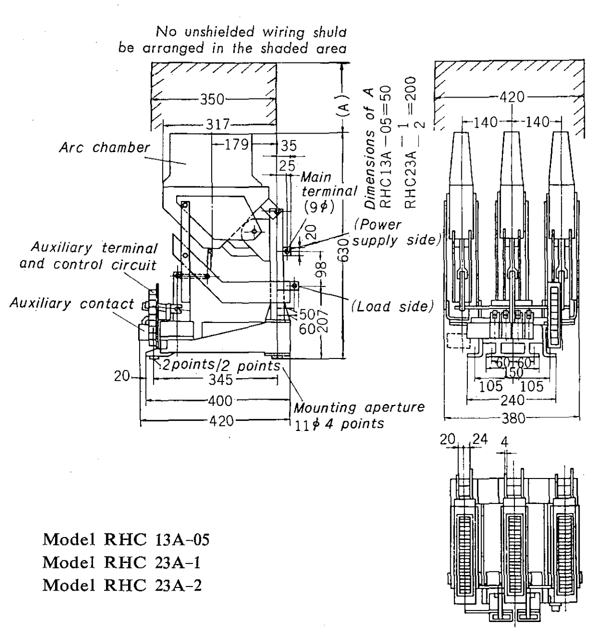


Fig. 2 **Outline dimensions of high-voltage ac air break contactors**

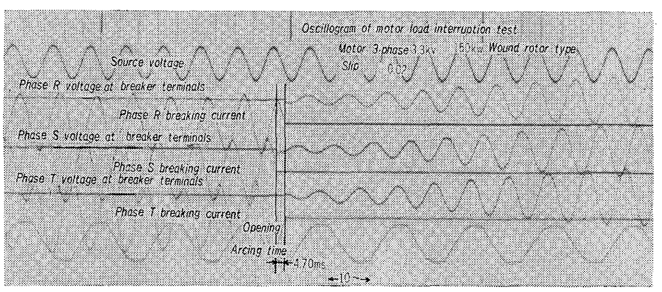


Fig. 3 **Oscillogram of motor load interrupting test**

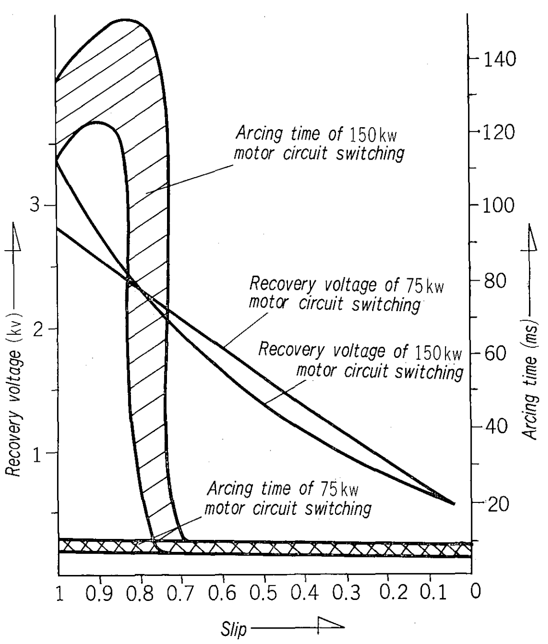


Fig. 4 **Recovery voltage and arc-time versus slip**

energy even after the stator circuit of the motor is open and continues to operate as a generator until these energies are dissipated by friction and current loss. Recovery voltages corresponding to the slip of the high-voltage motor load and to variations in arcing time are shown in *Fig. 4*.

Recovery voltage drops sharply as slip decreases after starting. At full load running, it drops by about 1/6 of that under reactor load. For this reason, arcing time is reduced considerably (n : integer). If the arcing time is expressed as $t=\frac{1}{6}n+\frac{1}{4}$ cycle, that is, $\frac{1}{6}n$ corresponds to preparation time and $\frac{1}{4}$ corresponds to time between the first phase extinction and the final phase extinction, "n" can be considered as zero when the slip is less than 0.6. Therefore, the time taken to prepare for interruption is almost negligible. The arcing time is merely the variation in the interrupting phase and lies between $\frac{1}{4}$ cycle and $(\frac{1}{4}+\frac{1}{6})$ cycle. Therefore, in actual practice, excluding inching and plugging, conditions differ considerably when compared with static induction load interruption. According to JEM Standard, the electrical life test uses static induction load and is very strict. For this reason, in actual application, a sufficient margin is permitted in the guaranteed life value.

2. Dielectric Strength Test

The main high voltage conductor is supported by an independent insulating post at each phase in the RHC-series high-voltage contactor. The insulating post is perpendicular to the frame, employing a unique structure which insures high insulation reliability. Since the lateral surface of the insulator is perpendicular, dust does not tend to collect on the surface and the danger of insulator breakdown is therefore lessened. Dielectric strength tests for moisture absorption were carried out for the RHC 53 A type and results show that dielectric strength above the standard prescribed value can be guaranteed even when moisture is absorbed.

Moisture absorption conditions are relative humidity 95∼100%, temperature 40+30°C, and moisture absorption time 24 hours. For the test, surface flashover voltage and the insulator resistance (by 1000 v megger) were determined both before and directly after moisture absorption (within 3 min after removing it from a constant moisture tank). Chalk powder was sprinkled on the surface of each insulator to reproduce contamination conditions as under

Table 2 **Dielectric Strength Test under Wet Condition**

Material No.	Dielectric Resistance (MΩ)		Surface Flashover Voltage (50 cps kv)	
	Before moisture absorption	Directly after moisture absorption	Before moisture absorption	Directly after moisture absorption
1	More than 2000	100	33.6∼35.4	32.5∼34.0
2	More than 2000	150	33.6∼34.8	31.5∼33.3
3	More than 2000	130	30.0∼34.2	30.0∼33.5
4	More than 2000	100	35.1∼35.4	34.5∼34.8

actual operation.

As shown in *Table 2,* the results confirm that the flashover voltage between the ground and surface does not change before and directly after moisture absorption. The standard values stipulated in JEM 1167 (high-voltage ac interruptor) are an insulation resistance of more than 5 MΩ and a dielectric strength test voltage of 10 kv over a period of one minute.

3. Impulse Test

Although the impulse test is not prescribed in JEM 1167 (high voltage ac interruptor), there are times in actual practice when the breakdown impulse voltage is required. *Table 3* shows the results of the impulse tests performed between the respective phases and between each phase and ground. The waveform is 1×40 μs as stipulated in JIS. The results confirmed that No. 3B can be guaranteed in the standard interruptor for phases-to-ground and across phase.

Table 3 **Impulse Test**

Type	RHC 13 A	RHC 23 A	RHC 53 A
High Voltage Conductor —Ground	40 kv	40 kv	40 kv
Main Conductors Phase-to-phase	43 kv	43 kv	50 kv

4. Special Switching Test

In main contacts, through which the rated current flows, welding can result in the standard contactor during an instantaneous drop in operating voltage or when contact pressure and wiping are reduced by operating voltage fluctuations, due to chattering, etc., in the control switch contacts. Since this may develop into a serious failure of the motor control, the possibility of contact welding phenomena in this contactor was tested as follows by varying the operating voltage.

The operating voltage of each contactor at rated current flow was varied on both the ac and dc sides of the operating circuit by using a pulse waveform with a period of 300 ms, as shown in *Fig. 5.* The zero flow time *"t"* was varied between 10 ms to 60 ms. Operating voltage was maintained at the rated value.

In all the various types, the contacts began chattering when the zero flow time *"t"* was within the 30 ms∼60 ms range. For *"t"* greater than 60 ms, the contacts were completely separated and welding did not occur under any conditions. Theoretically, it is quite possible in the extreme for the main contacts to make contact on application of the operating voltage when the contact pressure is zero. Therefore, some minute welding can be expected. However, in this contactor, contact opening force results from the weight of the movable part and there is sufficient contact surface sliding action. Therefore, the minute welded areas are probably destroyed by the force of the contact spring, and the contacts can separate.

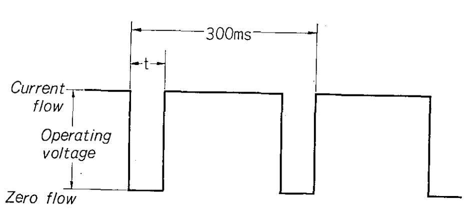


Fig. 5 Waveform of operating voltage

III. SPECIAL HIGH-VOLTAGE AIR BREAK CONTACTORS

1. D Class High-Voltage Air Break Contactor

The D class contactor is employed as a reactor starter, and cannot be used for circuit breaking. A resin cover is fitted in place of the arc quenching chamber. Since this contactor is very low, it combines conveniently with the main switch in a two-deck configuration for accommodation in a cubicle. The standard specifications are shown in *Table 1* and the outer dimensions of the contactor are shown in *Fig. 6.*

Although the D class contactor cannot in practice be used for circuit breaking, when it is employed as a reactor starter circuit breaking might be necessary due to operating coil failure or operating errors. In this case, however, the recovery voltage at breaking becomes the impedance voltage of the reactor (the impedance voltage is about ⅙ of the rating at the 50% reactor tap) and breaking conditions are relaxed. *Fig. 7* shows test results on the D class interruptor in this condition. This test confirmed that no practical

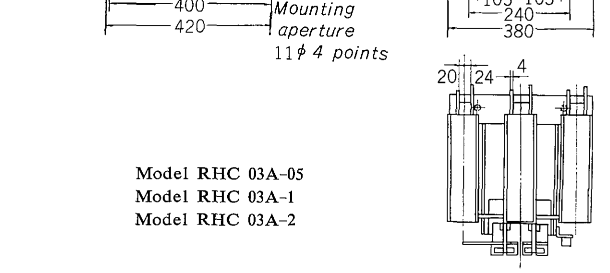


Fig. 6 Outline dimensions of D-class high voltage ac air break contactors

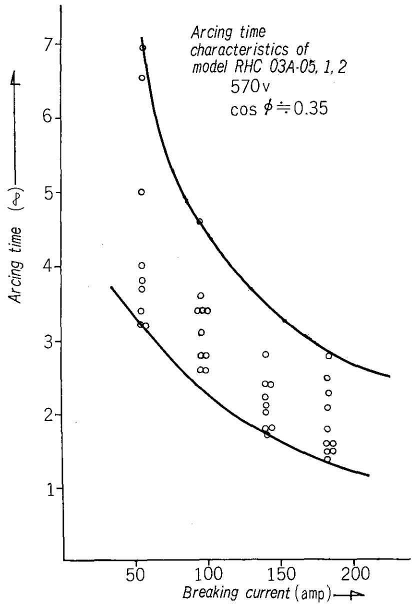


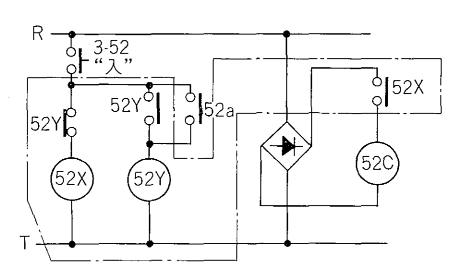
Fig. 7 Arc-time characteristic curves of D-class contactors

problems arise when breaking with this contactor so long as the reactor is inserted in parallel and the current is the rated value.

2. Latched High-Voltage Air Break Contactor

The latched contactor is held in place mechanically after the main contact is made. It does not break unnecessarily during momentary voltage drops and it is practicularly suitable for use as a feeder switch. *Table 1* shows the standard specifications. The latched contactor consists merely of the standard contactor with a latch mechanism attached. Maintenance and inspection of the latch unit present no problem and operation is also highly reliable.

The latched contactor does not have a "free-tripping"device. When a tripping signal is sent out, the operating magnet should not be excited, i.e., the exciter circuit should be open after latching. For this reason, a mechanism is required to prevent continuous excitation, and a pumping prevention device should be incorporated so that the contactor can function as a breaker. A switch control mechanism incorporating a continuous excitation prevention device and the pumping prevention device is available as a separate unit.



52c: Making coil of high voltage air break contactor
52a: Auxiliary "a" contact of high-voltage air break contactor
3-52: Control switch
52X: Delay-release contactor
52Y: Auxiliary relay (pumping prevention)
(The area within the broken line represents the control device)

Fig. 8 Connection diagram of control device

Fig. 8 shows the connection diagram of the control device for ac operation. The switch control device is suitable for all latched contactors. Ratings for ac 200/220 v, 50/60 cps, ac 100/110 v, 50/60 cps, dc 200/220 v, dc 100/110 v are available.

In general, a dry cell battery is utilized as the highly reliable tripping power supply of the latched contactor, but a capacitor tripping device has also been developed for users' convenience. There is no battery or rectifier in this latter device. The rated tripping possible time of this device is more than 30 secs. That is, tripping is possible within 30 secs, even when the capacitor is no longer charging. Although high reliability capacitors are employed in this device, the following measure to prevent failure is adopted. Since the capacitor temperature initially climbs to an abnormally high level of 200°C before breakdown, a temperature sensitive paint with an upper limit of 100°C is coated on the capacitor. Breakdown of the capacitor is therefore easily prevented.

Table 4 Standards of Condenser Tripping Device

Condenser Tripping Power Supply Type	Applied Contactor Type	Applied Rated Input Voltage
HCX-T1	RHC 13AL-05 RHC 23AL-1.2 RHC 53AL-2.4 RHC 26L-1	Ac 100/110 v 50/60 cps
HCX-T2	RHC 13AL-05 RHC 23AL-1.2 RHC 53AL-2.4 RHC 26L-1 RHC 56L-2	Ac 200/220 v 50/60 cps
HCX-T3	RHC 56L-2	Ac 100/110 v 50/60 cps

3. Normal Closing High Voltage Air Break Contactor

This normal closing contactor is completely opposite to the usual contactor. When the operating coil is excited, the main contact breaks and when the excitation field is cut off the main contact makes contact.

This contactor can be employed as a dynamic brake switch in synchronous motors, etc. The contactor is shown in *Fig. 9*.

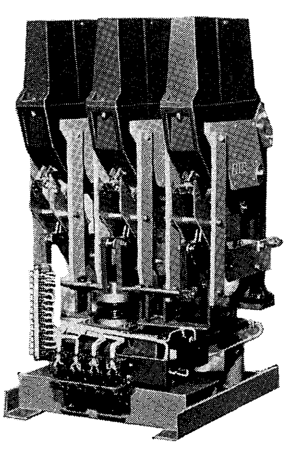
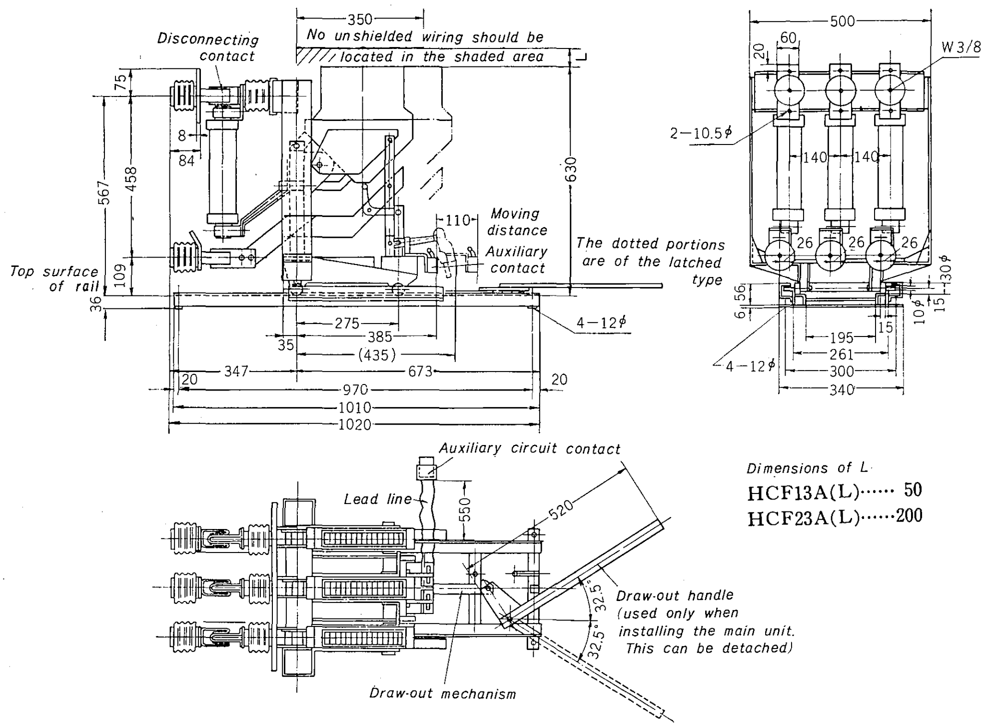


Fig. 9 Normal closing high-voltage ac air break contactor



Model HCFa 13A-05/20~200
Model HCFa 13AL-05/20~200
Model HCFa 23A-1/20~200
Model HCFa 23AL-1/20~200
Model HCFa 23A-2/20~200
Model HCFa 23AL-2/20~200

Fig. 10 Outline dimensions of fused contactor

***Table 5* Types of High-Voltage Fused Contactors**

		Standard Type (Normal Excitation Type)				Latched Type (Mechanical Hold Type)			
Draw Out Type Fused Contactor	Model	HCFa 13A-05	HCFa 23A-1	HCFa 23A-2	HCFa 53A-2	HCFa 13AL-05	HCFa 23AL-1	HCFa 23AL-2	HCFa 53AL-2
	• The rated breaking capacity becomes the value of the standard HH fuse. • The ratings and specifications of the high voltage air break contactor are shown in *Table 1.*								
Type (when the high voltage air break contactor is a single unit)		RHC 13A-05	RHC 23A-1	RHC 23A-2	RHC 53A-2	RHC 13AL-05	RHC 23AL-1	RHC 23AL-2	RHC 53AL-2

Standard HH Fuses in Combination with A-Series Fused Contactors

Ratings				Tubular Fuse	Adopted Standards
Voltage (kv)	Three Phase Breaking Capacity Sym-metry (Mva)	Three Phase Breaking Capacity Asym-metry (Mva)	Current (amp)		
3.6	250	400	5	HF 337C/3/5	JEC-113
			10	HF 337C/3/10	
			20	HF 338C/3/20	
			30	HF 338C/3/30	
			40	HF 338C/3/40	
			50	HF 338C/3/50	
			75	HF 338C/3/75	
			100	HF 338C/3/100	
			150	HF 338C/3/150	
			200	HF 338C/3/200	

IV. DRAW-OUT TYPE FUSED CONTACTORS

Recently, a combination of a current limiting power fuse and a high voltage contactor has been frequently employed as a switch in high voltage motor circuits because of outstanding performance guaranteed by the features of both the current limiting power fuse and the high voltage contactor. The draw-out type fused contactor with a standard HH fuse and an A-series high voltage contactor in a single unit is especially light and compact. It is suited for switchboard installation and the required installation spacehas been decreased considerably since two or three decks are possible. *Fig. 10* shows the external dimensions of the A-series fused contactor. *Table 5* lists the different types of contactor suitable for motors or transformers with small and large capacities. Special features are as follows:

1. Special Features

1) Large breaking capacities

The standard HH fuse with superior breaking performance is incorporated. 250 Mva symmetrical and 400 Mva unsymmetrical are guaranteed.

2) Both the individual unit and the switchboard is also more economical when compared with circuit breaker utilization. Mechanical and thermal stress on series connected machines during short-circuits is also reduced due to the current limiting effect of the fuse.

Fig. 11 shows the reduction as compared with the case when a circuit breaker is employed.

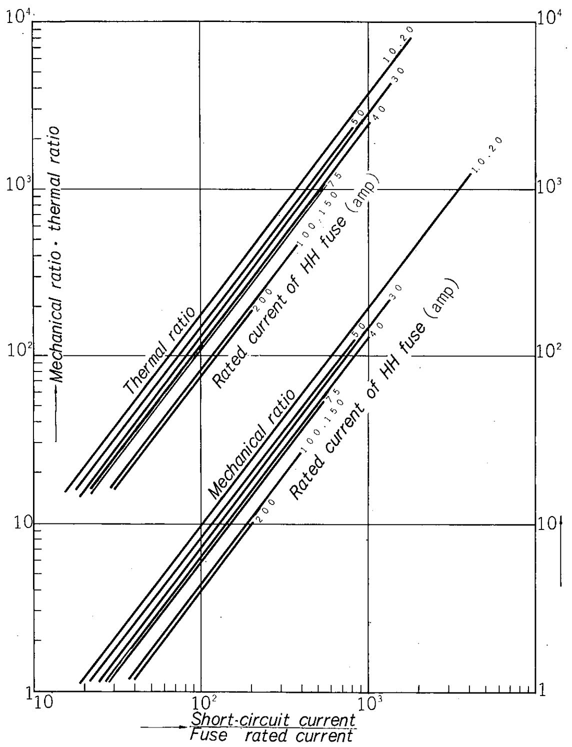


Fig. 11 Thermal stress and mechanical stress ratio

The respective stress ratios in the diagram are obtained from the formula below.

Mechanical stress ratio

$$=\frac{(\text{Short circuit current peak value})^2}{(\text{HH fuse current limiting value})^2} \cdots\cdots(1)$$

Short circuit current peak value:

(short circuit current ac effective value) $\times 2.5$

HH fuse current limiting value:

determined from the current limiting characteristic curves

Thermal stress ratio

$$=\frac{\int i^2dt \text{ of the ac circuit breaker}}{\int i^2dt \text{ of the HH fuse}} \cdots\cdots\cdots(2)$$

$\int i^2dt$ of the ac circuit breaker:

(short circuit current ac effective value)^2
$\times$(relay time + breaking time, assuming 10 cycles)

$\int i^2dt$ of the HH fuse:

$$\left(\frac{\text{limiting current peak value}}{\sqrt{3}}\right)^2$$

$\times$(breaking time, assuming 5 ms)

3) Easy maintenance and inspection

Since the contactor is of the draw-out type, it can be safely and easily separated from the high voltage circuit so that replacement of fuse and inspection of contacts and arc quenching chamber can be carried out properly. Operation, therefore, is very reliable. The contactor, as shown in *Fig. 10*, consists of a main circuit disconnection unit, an auxiliary circuit plug-in mechanism and a guide rail draw-out mechanism.

4) Single-phasing protection

The fused contactor can be opened by the operating indicator contact of the fuse. Since the fuse is a single phase interruptor, single-phasing protection is a very important problem. For example, when the primary side of the load center transformer is protected with a fuse, the following points should be considered. The respective current versus time characteristic curves of the fuse on the primary side and the low-voltage circuit breaker of the secondary bus bar are generally either very close or difficult to coordinate.

Consequently, during an arcing short-circuit of the secondary bus bar, the single-phase component of the fuse on the primary side is interrupted. Breakdowns cannot be entirely eliminated since the breakdown current appears at the single phase in a suppressed form, especially in the case of an intermittent arc. The overcurrent protector then fails to operate and the arc is maintained resulting in damage to the machine. This type of failure can be avoided by operating the bus bar circuit breaker with a ground relay. When the failure point is above the circuit breaker, the fuse operation indicator and the circuit breaker on the primary side should be ganged together. It is therefore dangerous to use only a fuse: A fused contactor combined with the switch is preferable.

2. Protective Coordination

For correct application of the fused contactor, the values of short-circuit current which are generated in the respective parts of the system, the fuse characteristics, characteristic of the contactor which is used in the combination, etc., are very important.

If an excessively large rated current fuse is selected, the protective device will fail to operate and if the rated current of fuse is excessively small breaking is repeated unnecessarily due to the starting current of the motor in the protected circuit, the rush current when the transformer is switched on, or the making transient current of the capacitor. Consequently, when selecting the fuse rated current, it is necessary to determine whether the protected circuit load consists of a high voltage motor, a capacitor, or the sum load of each type through a transformer. Examine the shape of the load curve, the operation characteristics of the overload relay and short circuit relay, and the permissible fuse current versus the time characteristic; at this time the appropriate fuse may be selected.

In the overload range, detection takes place with the overload relay and breaking is made by the high voltage contactor. In the short-circuit range, interruption is made by the current limiting power fuse. Coordination measures for each type of load are described below.

1) High voltage motor circuit

The high voltage motor generally used is a special cage induction motor or a wound induction motor. Starting current and starting time differ according to the rated output, rotation speed, applied load, type and starting method. In any case, the fuse should not blow because of the starting current, and the fuse element should not deteriorate and blow due to errors in the high temperatures used. For this reason, the rated current of the fuse should be greater than the rated current of the motor. *Fig. 11* illustrates the protective co-ordination of the motor.

This co-ordination curve should be examined in connection with the following points.

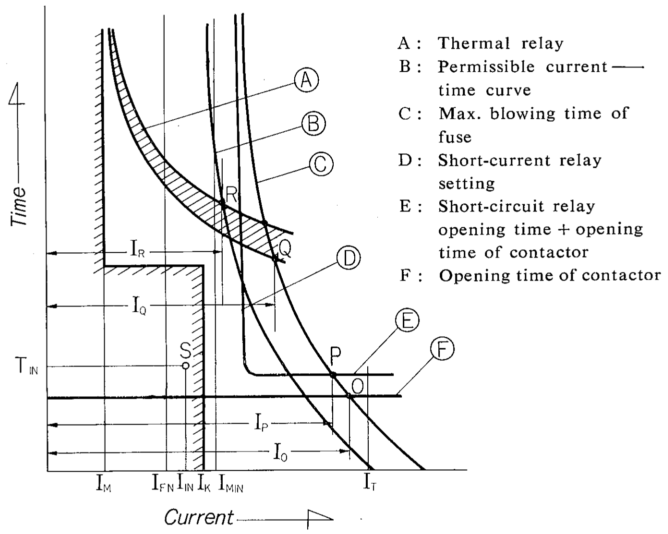


Fig. 12 Coordination graph

(1) The relation between the current value I_Q, at the intersection point Q of the minimum operating time characteristic of the overload relay and the maximum blowing time characteristic (C) of the power fuse, and the rated breaking current I_T of the high voltage contactor is $I_T > I_Q$.

(2) The relation between the motor starting current I_K and the current value I_R at the intersection point R of the maximum operating time characteristic of the overload relay and the permissible power fuse current versus time characteristic (B) is $I_R > I_K$.

(3) The relation between the current value at the intersection point R in (2) and the minimum breaking current I_{MIN} of the power fuse is $I_R > I_{MIN}$. (Where (E) is not used.)

(4) The relation between the rated current I_{FN} of the power fuse and the full load current I_M is $I_{FN} > I_M$.

(5) The relation between the intersection point P of the operating time characteristic for the short-circuit protective relay + the breaking time characteristic (E) of the contactor and the maximum breaking time characteristic of the power fuse, and the rated breaking current I_T of the contactor is $I_T > I_P$.

However, in this case, the operating power supply of the contactor is considered as separate from the main circuit power supply. When a transformer is used with the same power supply, a short-circuit occurs and at the same time the operating voltage decreases. Since the contactor then breaks, only the breaking time characteristics should be considered. In other worlds, the relation between the intersection point 0 of the breaking time characteristic for the contactor and the maximum blowing time characteristic for the power fuse and the rated breaking current I_T of the contactor is $I_T > I_0$.

If the above five relations are satisfied, the motor circuit is completely coordinated. A short-circuit protective relay is installed in addition to the overload relay in order to protect the overload relay for currents which exceed the overcurrent tolerance of the overload relay and also in order to prevent the fuse from operating as far as possible within the rated breaking capacity of the contactor. The relation between the starting current I_K of the motor and the minimum breaking current I_{MIN} of the power fuse should be $I_K > I_{MIN}$ so that the power fuse can provide protection after the overload relay is installed. The full range breaking type power fuse manufactured by Fuji is suitable for this purpose.

When there are two or more motors, motors protection by means of a set of power fuses should be definitely avoided since the starting current and starting time differ in the respective motors; several starting sequences are possible and complete protection is therefore difficult.

2) Transformer circuit

When the transformer in the no-load condition is switched on in the circuit, excitation rush current will appear. Although the surge current time is short, the maximum value is large. This point should be considered when selecting the rated current for the power fuse.

(1) To avoid unnecessary power fuse operations by the excitation rush current of the transformer, the intersection point S of the excitation rush current I_{IN} and the decline time I_{IN} should be lower than the permissible power fuse current versus time characteristic curve as shown in *Fig. 11*.

(2) If a power fuse is employed for protection of the primary side of the transformer and the rated current is excessive, the fuse will not blow within the short-circuit permissible time (2 secs. in JIS C4304) of the transformer during a short-circuit fault on the secondary side and the transformer cannot be protected. For this reason, a power fuse is selected for which the break is completed within 2 secs during a short-circuit on the transformer secondary side.

(3) In addition to coordination between the power fuse and the contactor, protective coordination should be used so that the fuse on the secondary side or the circuit breaker opens before the short circuit current blows the power fuse during a short-circuit on the secondary side of the transformer.

3) Capacitor circuit

When the capacitor is switched on in the circuit, a rush current from 3 to 10 times the normal value will flow. The values of the rush current and its flow time should not exceed the permissible current versus time characteristics curve values.

3. Coordination Test

The A-series high voltage contactor and the standard HH fuses were combined and coordination tests were performed under conditions similar to actual operation. From the results, it was shown that the rated breaking capacity (250 Mva symmetrical, 400 Mva asymmetrical) can be guaranteed for all types tested.

1) Test method

Voltage: 3.6 kv
Short-circuit current: 40 ka (effective value)
Operating circuit:

I. The contactor is held in the make position and a short-circuit current flows.

*II. 3 ms~5 ms before the short-circuit current flows, operating coil of the contactor is de-energized and the main contact is opened.

* Since, in actual practice, the operating power supply is fed from the main circuit through the operating transformer, conditions are as in operating circuit II.

2) Test results

All the various types can be applied for circuits with a short circuit capacity of 250 Mva symmetrical, 400 Mva asymmetrical. *Fig. 12* and *Fig. 13* show the representative oscillograms. In *Fig. 12*, the contactor is held in the make position and in *Fig. 13* operating circuit excitation is cut off 5 ms before the short-circuit current flows. *Fig. 14* and *Fig. 15* are photographs of the main contact point and the arc quenching chamber after tests as in *Fig, 13.* It is evident that wear is negligible.

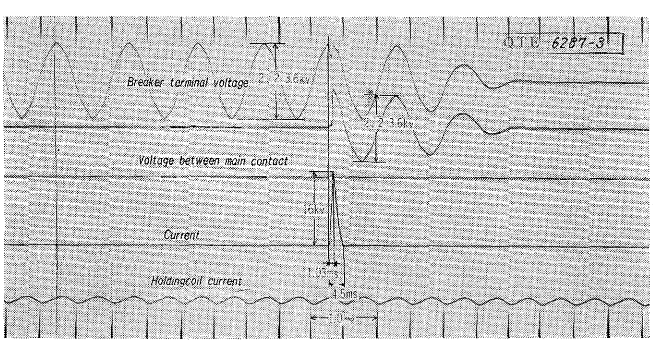


Fig. 13 Oscillogram of current limiting interruption

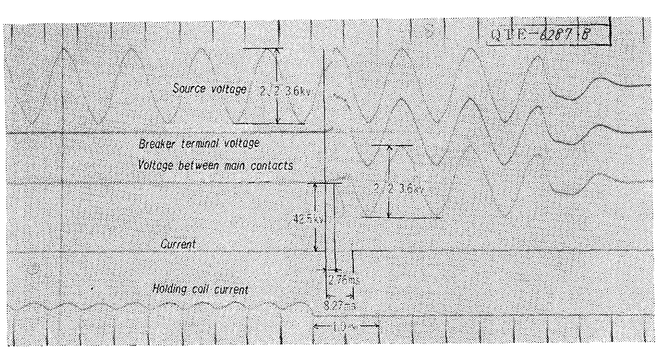


Fig. 14 Oscillogram of current limiting interruption

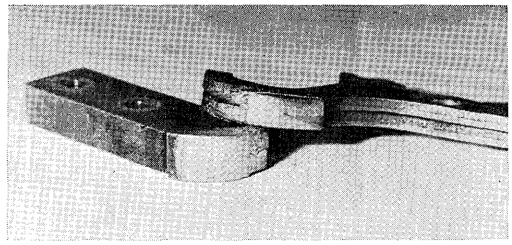


Fig. 15 Contacts of fused contactor after interruption tests

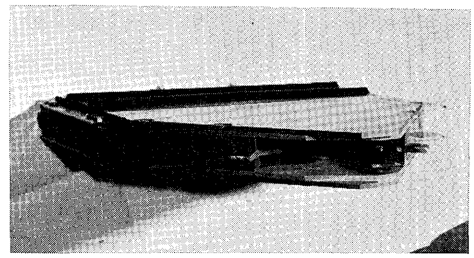


Fig. 16 Arcing chamber after interruption test by fuse

3) Considerations

It has been proven that all types can be used in 250 Mva circuits. Thermal capacity can be investigated from the test shown in *Fig. 13.*

The rated short-time current of 4.4 ka and flow time of 0.5 sec. are guaranteed for RHC 23 A high voltage contactor which was used in the test. In this case $\int i^2 dt$ is:

$$(4.4\times10^3)^2\times0.5=9.7\times10^6\ [\mathrm{A^2\,sec}]$$

On the other hand, if the current in *Fig. 13* is considered to have triangular waveforms, the effective value of the current is $42.5/\sqrt{3}$ ka and here, $\int i^2\,dt$ is

$$[(42.5\times10^3)/\sqrt{3}\,]^2\times0.00827=5\times10^6\ [\mathrm{A^2\,sec}]$$

Therefore, sufficient allowance is made from the thermal point of view.

V. CONCLUSION

This paper describes the standard specifications and performance, special tests and special applications of A-series high voltage air break contactors, and the standard specifications and protective coordination of draw-out type fused high voltage air break contactors. Every effort has been made to develop and refine the high voltage air break contactor and new products for application with this contactor. The special tests and the special applications in this paper have been developed in consideration of the many suggestions received from customers. These units have so far exhibited a high level of operating performance. In all cases, Fuji constantly endeavors to meet the requests and requirements of customers.