

# LOW SURGE VOLTAGE VACUUM CIRCUIT BREAKERS

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## 1 INTRODUCTION

It's been about twenty years since vacuum circuit breakers have come to be commercialized in the market, meanwhile various problems such as those concerning opening and closing surge voltage have been studied and researched in each sector of the industry, and now, we can safely say that measures for these problems have been more or less established, and many virtues inherent to vacuum circuit breakers as compactness in size, lightness in weight, long useful life and incombustibility are rightly appreciated now, and as the result, it is a well known fact that they enjoy a wide diffusion in everywhere.

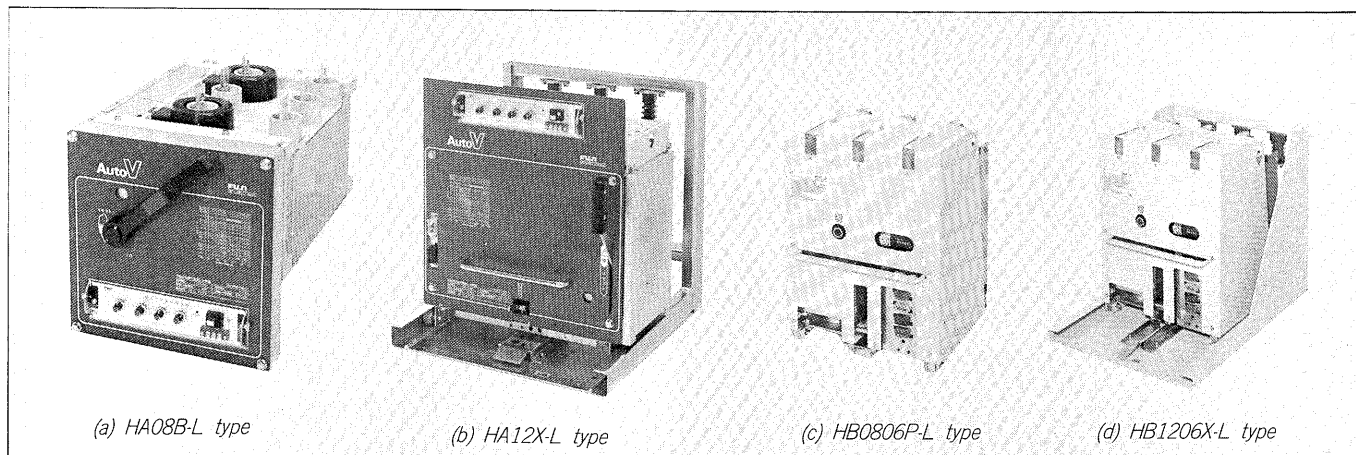
Fuji Electric has started first manufactured and commercialized the vacuum breakers in 1968, and ever since it has kept on studying the fundamental technology particular to the vacuum circuit breakers and, at the same time, accumulated knowhows in practical operation of these machines, as well as investigated and studied on the measures for surge voltage at the time of closing and opening of the circuit, and tried to elucidate the mechanism of surge generation. We had a knowledge of abnormal voltage in the early phase of appearance of vacuum circuit breaker in the market, which was mainly the voltage peak value due to the

current chopping, then, generated voltage peak value based on analysis on the phenomenon of voltage escalation due to high-frequency multiple reignition and at present, the voltage steepness in particular came to be focussed from the point of view of electric motor protection. Also, as the protective devices, lightning arrester aiming at cutting peaks as measures to be taken against chopping surging, and, though rarely, as measures against surging due to high-frequency multiple reignition, C-R surge absorber or peak cut type absorber for mitigating generated voltage steepness, are generally adopted. These protective devices suppress surges generated at the time of opening and closing circuits to a low value and, at the same time, as they eliminate the generating factors themselves, through studies and development of materials and shapes of vacuum interrupter contact, they have come to contribute greatly to reducing of surges at the time of closing and opening circuits. Now as we have developed and commercialized low surge voltage vacuum circuit breakers, we disclose their ratings, features and test results.

## 2 FEATURES

Vacuum circuit breakers are provided with many outstanding features as intermediate voltage breakers, not only as their superiority in interrupting capability, but also

Fig. 1 Low surge voltage vacuum circuit breakers



(a) SH-700, (b) SH-699, (c) SF-873, (d) SF-874

compactness, lightness in weight, less effort for maintenance, high reliability and high operational safety.

The low surge voltage vacuum circuit breakers introduced in this report are provided with, besides, the fundamental features mentioned above, the following ones:

- (1) Chopping current value is about 1/10 of that of conventional standard type circuit breakers.  
Standard HA and HB types vacuum circuit breakers using Cr Cu special alloy as contactor material, has the chopping current value as small as less than about 1/3 of the standard value generally accepted, that is 3.5A. In particular, for devices of smaller capacity, as their operational requirement demands, they are required to have still smaller chopping current value, consequently we have adopted a value as extremely small as 0.4A in-average for that purpose.
- (2) Outer view, outer dimensions and mounting dimensions are the same as those of standard type vacuum circuit breakers. As their outer dimensions are the identical to that of standard type, their mounting design is easily be made and they can be used easily with different manners depending on the load.
- (3) Requires no protective measures against surging  
Since they require basically no protective device against surging when opening and closing the circuits, the whole installation space can be reduced with ease.

3 RATINGS AND SPECIFICATIONS

A list of ratings of the low surge voltage vacuum circuit breaker developed this time is given in Table 1.

4 LOW SURGE VOLTAGE VACUUM INTERRUPTER, ITS STRUCTURE AND PRINCIPLE OF OPERATION

Properties required for the contacts of vacuum interrupter for vacuum circuit breakers are as follows:

- (1) Small chopping current value
- (2) High resistance to wears
- (3) Large interrupting capacity
- (4) High short-time performance
- (5) Freedom from abnormality due to generation of protrusion and/or crack on the contact surface during the interruption
- (6) That they do not cause any damage to insulator walls during the interruption
- (7) Small contact resistance between contactors
- (8) High mechanical strength

These properties partially contradicts one another, so that for development, the investigators should determine the optimum value through design techniques on contact material, shape and stroke, and composition and dimensions of insulating cylinders and shield, and in case of low-surge voltage vacuum interrupter, points (1) and (3) above present a big problem. That is to say that, it was necessary to secure contradicting properties for the vacuum interrupter, the characteristic of low chopping current for interrupting small current and, at the same time, large-current breaking functioning for short-circuit current.

The current chopping phenomena generated at the time of cutting out small current is explained as it is due to the lack of supplies of metal vapor from cathode point for maintaining interpolar arc by the arc scattering phenomena. Therefore, in order to make the chopping current value smaller, it is necessary to provide metal vapor sufficient for forming stable arc, and this demand is determined by the contact material.

On the other hand, what is the most important in interrupting the large current, is to eliminate the local heat due to the concentrated arc on the contact surface.

The low surge voltage vacuum interrupter developed this time secures the low-surge voltage characteristics by using special contact material made from Cr-Cu alloy base added with high vapor pressure material in order to supply metal vapor necessary for interrupting small current, and on the other hand, the valve is made with contactor structure having cylindrical contact base with a slit included so as to present an excellent effect for interrupting large current that is adopted in the standard series. By adopting these two contradicting features in one device dexterously, the problem have been resolved.

In case of interruption of small current, by the contact plate in material added with high vapor-pressure metal vapor will be supplied in sufficient quantity thus no current chopping phenomenon will be produced, and arc will be maintained almost to the current natural zero point. Consequently, the surge voltage due to the chopping current can be suppressed to an extremely small value.

In case of interruption, on the other hand, of large current, by the large current flowing on the inclined slit provided on the cylindrical contact base connected to the contact plate, generating a magnetic field acting to the right angle to the axis of that current, the arc will move turning to the direction of circumference on the contact plate without stopping until the current is completely inter-

Table 1 List of ratings for low surge voltage vacuum circuit breaker

Type		HA08□-□□-L	HA12□-□□-L	HB0806□-04Hf-L	HB1206□-06Hf-L
Ratings	Voltage (kV)	7.2/3.6	7.2/3.6	7.2/3.6	7.2/3.6
	Current (A)	400	600	400	600
	Interrupting current (kA)	8	12.5	8	12.5
	Closing current (kA)	20	31.5	20	31.5
	Interrupting time (cycle)	3	3	3	3
Withstand- ing voltage	Commercial frequency 1 minute (kV)	22	22	22	22
	Lightning impulse (kV)	60	60	60	60
No load closing time (s)		5: electric spring system	5: electric spring system	0.15	0.15
Closing operating system		Manual spring system Electric spring system	Manual spring system Electric spring system	Electro-magnetic system	Electro-magnetic system

Fig. 2 Structure of vacuum Interrupter

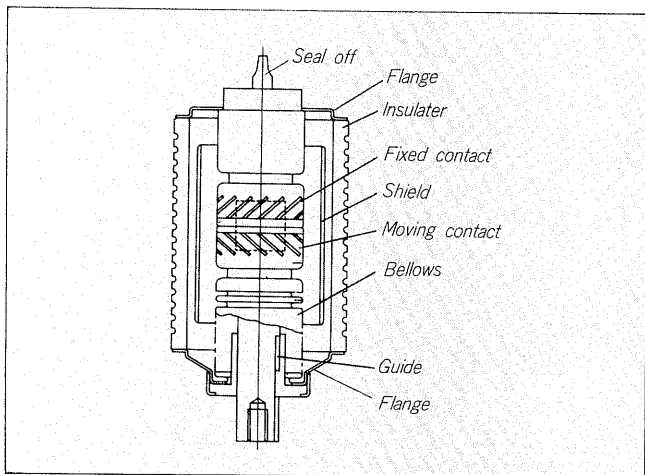


Fig. 3 Contact structure of vacuum interrupter

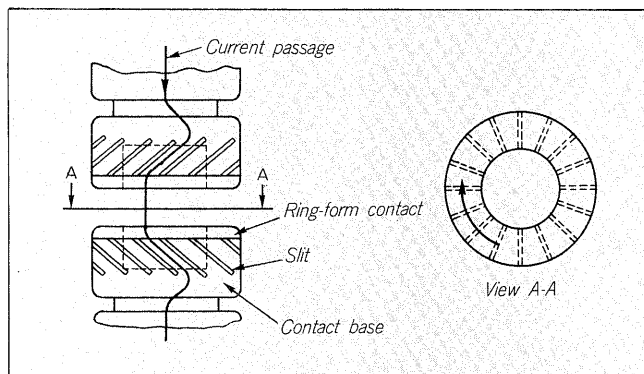
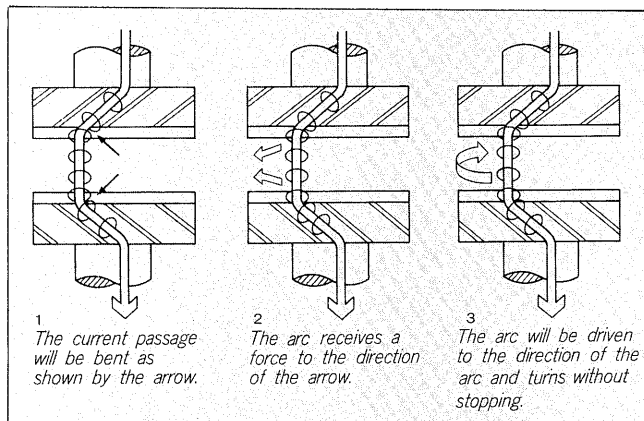


Fig. 4 Effect by contact structure



rupted. Consequently, no local heating of the contact will take place and an excellent interrupting performance can be obtained. That is, as shown in Fig. 4, by the cylindrical contact having a fine inclined slit, the current passage will be bent in a direction shown by an arrow in 1, and the arc generated by opening of the contact will receive a force in the direction of an arrow of 2, and rotated to the direction of an arrow in 3. As the contact plate is of ring form,

the arc will not repose at one place but will turn until it is extinguished, and it will be extinguished within a very short time. Consequently, no local heat will be produced on the contact surface, and the contact surface will show even wears. And as the result, the contact surface will always maintain an uniform state showing an excellent voltage withstanding characteristics. By this the contact gap will be smaller, then, the arc will always be generated perpendicularly to the contact surface. So that the arc length could be short and the arc energy, small. And it is by this reason that contact can be small but can be of long life.

By the principle of arc extinction, we could obtain with an extremely simple structure, circuit breakers of an excellent low surge voltage characteristic, superior large-current interrupting performance and of a long useful life. Summarizing the above and with further complementary features, we can describe the circuit breakers in the following way:

- (1) Low surge voltage characteristic, provided with fine large current interrupting efficiency and compactness in size.
- (2) Thanks to the unique contact structure, no protrusion or cracks will be produced on the contact surface during the current interruption, so that its characteristic is very stable.
- (3) As the contact material, a chrome alloy having an extremely strong getter action, so that no lowering of vacuum degree will take place due to the current interruption. Its reliability is high.
- (4) As the contact stroke is small, arc voltage is low and the contact wears are small. That is, its electric life is long.
- (5) A ribbed insulator having an excellent resisting contamination characteristic is adopted.
- (6) An insulator made of high purity alumina ceramic having an excellent heat resisting characteristic and mechanical resistance is adopted.
- (7) Bellows materials is special stainless steel having an excellent anti corrosive property and no lowering of softening degree due to high temperature heating as well as mechanical life, so that it is highly resistant to ambient conditions.

## 5 TEST RESULTS

By conducting tests according to JEC 181 (1975) and JIS C 4603 (1975) to confirm that all performance required by these standard and, at the same time, by defining other various critical values not defined in these standards as well as by conducting tests during actual operations, a high reliability was obtained. The following reports the outline of the test results.

### 5.1 Chopping current

The value of chopping current depends much on the value of the overvoltage. And for this low surge voltage circuit breaker has, as shown in Fig. 5, extremely small

Fig. 5 Vacuum circuit breaker chopping current (Tests results obtained by us)

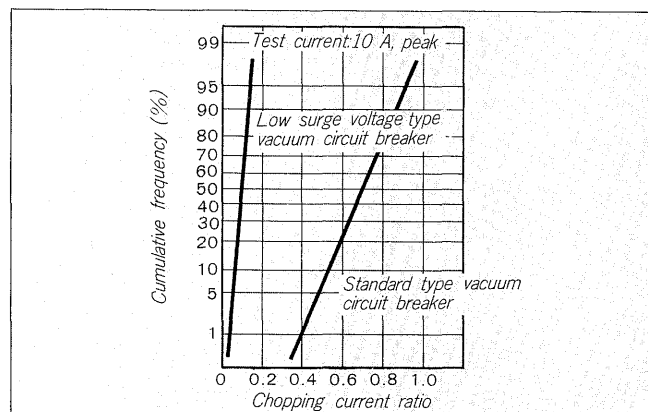


Fig. 6 Example of arc observation

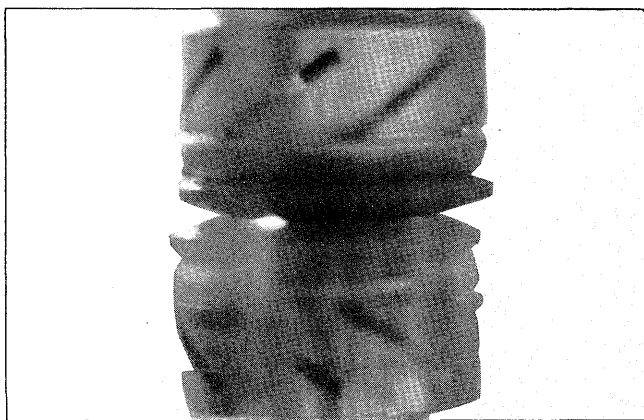
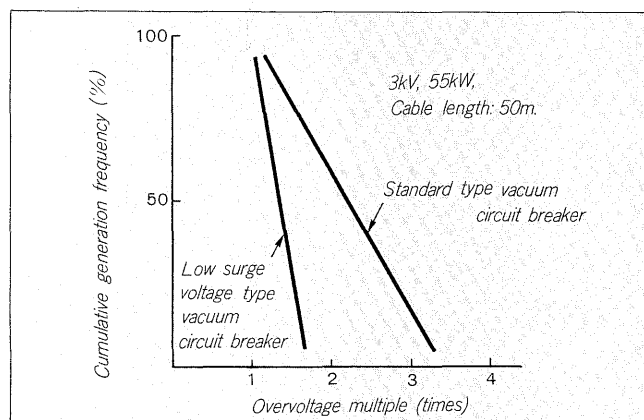


Fig. 7 Induction motor make and break overvoltage test results



interruption current as compared with those of conventional type breakers. The fact has been proved by the tests. Also, it was proven by the tests that there is little change in the value of chopping current before and after various sorts of load opening and closing tests through unique design techniques on the shapes and materials of the contact. Further, from the results of the analysis on arc behavior by photograph during the small current interruption, it was confirmed that each component element has

fully attained the design objective. The example is shown in Fig. 6.

## 5.2 Actual loading test

### 5.2.1 Induction motor load make and break test

By conducting making and breaking tests under various conditions as starting, rated speed running, etc. with an induction motor as a load, it was confirmed that the generated overvoltage is negligible for actual application of electric motor. Fig. 7 shows make and break overvoltage in case of 3 kV and 55 kW induction motor, compared with that of conventional type.

### 5.2.2 Transformer load make and break test

In case a 6 kV mould transformer is taken as a load, sometimes, making and breaking of exciting current and rush current as well as light load current constitute a problem for making and breaking surge. But in either case, the overvoltage generated is so low that there constitutes little problem for the practical operation. The fact is confirmed by the series of tests.

### 5.2.3 Condenser load make and break test

From the result of make and break test using a condenser as the load, from about 1 A to several hundreds A, in no case generation of re-arcing was observed and no abnormality in contact produced, and a good result was obtained. So that it was proved that the circuit breaker has an excellent characteristics for being applied to phase advance condenser circuit.

### 5.2.4 Electrical life test

For a load of delayed power factor of 7.2 kV and more than several hundred A, an electrical endurance test of more than 10,000 times has been conducted. As the result, no abnormal contact wears or alteration in contact resistance have been observed and no change in the chopping current after the test as mentioned above have neither observed. So that it was proved that there registered no abnormal deterioration in the performance including that of continuity.

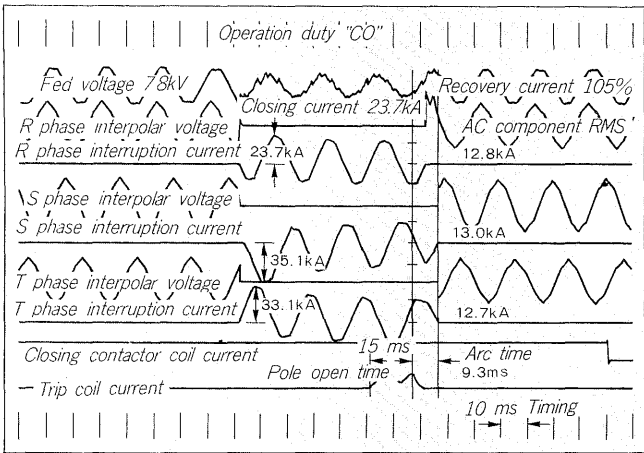
### 5.2.5 Short circuit interruption test

After conducting the electrical life test, by 10 to 100% short circuit interruption current test, it was confirmed that the circuit breaker had an excellent arc time characteristic all through the interruption range and that it can carry out good operational duties. Also, the contact wears after the short circuit test is negligibly small and there is little change in contact resistance and interruption current. Of course, the dielectric rigidity of 1.5 times more of rated voltage (10.4 kV) for 10 minutes after the short circuit interruption test is secured with an ample margin. Fig. 8 shows an example of the oscillogram for 100% short circuit current interruption test.

### 5.2.6 Others

In addition to all the tests according to standards,

Fig. 8 Example of interruption test oscillogram



many tests as those of temperature, humidity, vibrations and shocks as well as other weathering tests have been conducted. Furthermore, by conducting mechanical resistance test against the making and breaking shocks produced within the vacuum circuit breaker, it was proved that the breaker can be used in the adverse conditions without causing problems.

6 APPLICATION OF SURGE PROTECTING DEVICE

The low surge voltage vacuum circuit breaker, as it is known by various test results, requires no application of surge protecting device in almost all circuits.

The summary of examples of standard of surge protection for standard type vacuum circuit breakers and low surge voltage type vacuum circuit breakers is as shown in Table 2.

Table 2 Examples of surge protection standard

Load equipment	Rotary machine	Mould transformer (BIL ≥ 60 kV)	Oil immersed transformer	Dry type transformer (BIL ≥ 35 kV)
Standard type vacuum circuit breaker	C-R	Not required (Note 1) (Note 2)	Not required (Note 1) (Note 2)	C-R
Low surge voltage vacuum circuit breaker	Not required (Note 3)	Not required	Not required	Not required

- (Note 1) In case there is a semiconductor equipment on the secondary side of the transformer, a protective device as filter condenser should be mounted.
- (Note 2) In case of interrupting exciting rush current and light load current, provide an arrester.
- (Note 3) In case inching operation is expected to be done often, provide a C-R.

7 SUMMARY

We believe that the vacuum circuit breakers will be diffused more and more as a central equipment in the power circuit breakers from now on. With this situation, the low surge voltage vacuum circuit breakers developed this time, as they require no make and break surge protection in almost all circuits, they are extremely for their application and easier to handle. By this, replacement of obsolete circuit breakers is made easier. We sincerely wish this newly developed circuit breakers of ours will contribute to updating of the installations and facilities of our customers.