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DEVELOPMENT OF A HIGH-VOLTAGE CURRENT-LIMITING FUSE WITH FULL-RANGE CLEARING ABILITY

By Toyoaki Omori
Kawasaki Factory

I. INTRODUCTION

There are presently two types of high voltage fuses, namely, the current-limiting type (enclosed type) and the non-current-limiting type (expulsion type). Each of these two types of fuses have their own respective advantages and disadvantages.

In recent years, the advantages of current-limiting fuses have come to be well acknowledged and they have been widely used in the 3 to 70 kv range.

Because the advantageous features of current-limiting fuses have already been introduced in a previous volume of the *Fuji Electric Journal*(1) they will not be repeated here. The major disadvantages of these fuses are:

(1) In the ordinary type of current-limiting fuse, the minimum current that will cause the fuse element to melt in a specified period of time differs from the minimum breaking current. In the existing JEC–113 (High Voltage Fuse Specifications), the minimum breaking current is three times the rated fuse current.

(2) In general, the overvoltage when breaking short-circuit currents is high.
Fuji current-limiting fuses, as specified in JEC–113 (High Voltage Fuse Specifications), guarantee a minimum breaking current capacity of three times rated current. Recently Fuji developed a high-voltage current-limiting fuse with full-range clearing ability (fuses of this type are rarely found in foreign countries), and has introduced some of these fuses.

A high-voltage current-limiting fuse was announced in 1965 by Line Material Corp. of USA.(2) According to this announcement, M-spot effect and gas blowing were employed for the arc extinguishing system. Under such construction, however, the gas pressure, as was pointed out by R. E. Koch of General Electric, would rise to an abnormal value when breaking a large current.(3)

Fuji recently developed high-voltage current-limiting fuses which have sufficient breaking capacities for minimum melting currents and which have the maximum breaking capacity in this country. Outlines of these fuses will now be introduced.

In these current-limiting fuses, the overvoltage in breaking short circuit-currents is within the limit of overvoltage of the Draft Recommendation of IEC Standards (International Electrical Standards) for high-voltage current-limiting fuses.

The dimensions of these fuse links have been made the same as those of existing fuses to facilitate interchanging of the two.

II. TYPES AND USES OF HIGH-VOLTAGE CURRENT-LIMITING FUSES

High-voltage current-limiting fuses are classified, according to Draft Recommendation of IEC Standards, into the following two types:(4)

(1) General purpose fuse

This type of fuse can break the current of the melting on the current-time curve which correspondes to one hour.

(2) Back-up fuse

This type of fuse enables the current to be broken from the minimum current specified in the melting on the current-time curve to the rated break current.

The general purpose fuse of item (1) can break, by a single high-voltage fuse alone, all currents ranging from overload currents to short-circuit currents and therefore, if no routine switching operation is necessary, does not require a load break switch.

The back-up fuse of item (2) must be used in combination with a load break switch which will automatically break the current in the overload range.

Applications of general purpose and back-up fuses are shown in *Table 1*.

III. RATINGS OF HIGH-VOLTAGE CURRENT-LIMITING FUSES WITH FULL-RANGE CLEARING ABILITY

Types and ratings of the recently developed high-voltage current-limiting fuses with full range clearing ability are shown in *Table 2*.

As has previously been mentioned, the dimensions of the fuse links are identical with those of existing fuses.

Fuses with rated breaking capacity of 250 Mva

Table 1 **Applications of General Purpose and Back-up Fuses**

Fuse Type	General Purpose Fuse	Buck-up Fuse
Uses	• Protection of all kinds of equipment • No automatic breaking device is required. • For example, can be used in series with an oil filled switch housed in a simplified cubicle. • Rated fuse current: $\leqq \frac{\text{Rated on-off current of oil filled switch}}{1.8}$ • Larger rated circuit current is available. • The fuse does not blow even when the switch has failed.	• Can be used only for motor protection • To protect a transformer, as in the case of motor circuits, an expensive automatic circuit breaking device is required. • Rated fuse current: $\leqq \frac{\text{Rated on-off current of oil filled switch}}{3^{*}}$ *When differences of individual fuses are taken into consideration, the figure would be 5 to 7. • An automatic circuit breaking device is required. • Available rated circuit current is smaller. • The fuse may blow unless a positively operating automatic breaking device in the overload range is used.

at 3.6 kv or 350 Mva at 7.2 kv are called general purpose HH fuses and those with breaking capacity of 400 Mva or 500 Mva at 3.6 kv are called HH fuses.

IV. CHARACTERISTICS OF HIGH-VOLTAGE CURRENT-LIMITING FUSES WITH FULL-RANGE CLEARING ABILITY

Fig. 1 shows the current breaking characteristics

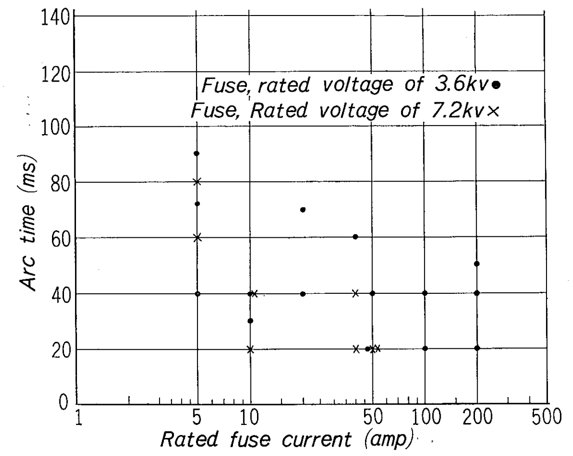


Fig. 1 Relation between rated fuse current and arc time at 3 times rated fuse current

Table 2 **Ratings of high-voltage current-limiting fuse with full-range clearing ability**

Nomenclature	Ratings				Type			
	Voltage (kv)	Three-phase breaking capacity		Current (Mva)	Cylindrical fuse	Fuse holder (connection: F-F)		
		Sym (Mva)	Asym (Mva)			Outdoor use (Breaker type)	Indoor use (Breaker type)	Indoor use (Permanent)
HH fuse for general use	3.6	250	400	5, 10	HF337C/3/5, 10	—	• HF323/3a	• HF323A/3a
				20~100	HF338C/3/20~100		• HF323/3a	
				150, 200	HF338C/3/150, 200		HF323C/6b • HF323/3b	• HF323A/3b
				300, 400	2×HF338C/3/150, 200		HF323 II/3b	• HF323A II/3b
	7.2	350	560	5, 10	HF337C/6/5, 10	—	HF323C/6a	• HF323A/6a
				20, 30	HF338C/6/20, 30		• HF323/6a	
				40~150	HF338C/6/40~150		HF323C/6b • HF323/6b	• HF323A/6b
				200~300	2×HF338C/6/200, 300		• HF323 II/6b	• HF323A II/6b
HH fuse	3.6	400	640	5, 10	HF337D/3/5, 10	HF326/6a	HF323/3a	HF323A/3a
				20~100	HF337D/3/20~100		• HF323C/6a	
				150, 200	HF338D/3/150, 200	HF326/6b	HF323/3b • HF323C/6b	HF323A/3b
				300, 400	HF338D/3/300, 500	HF326 II/6b	HF323 II/6b	HF323A II/3b
	7.2	500	800	5, 10	HF337D/6/5, 10	HF326/6a	HF323/6a	HF323A/6a
				20, 30	HF338D/6/20, 30		• HF323C/6a	
				40~150	HF338D/6/40~150	HF326/6b	HF323/6b • HF323C/6b	HF323A/6b
				200, 30 0	HF338D/6/200, 300	HF326 II/6b	HF323 II/6b	HF323A II/6b

Note: (1) Newly developed high-voltage current-limiting cylindrical fuses with full range clearing ability are marked "F.R" which distinguishes them from regular cylindrical fuses.
(2) Fuse holder is identical to that of conventional fuses, and they are interchangeable.

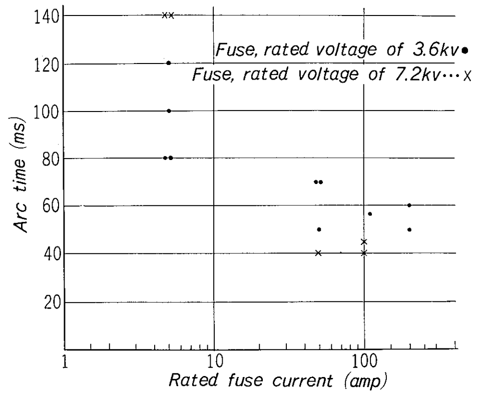


Fig. 2 **Relation between rated fuse current and arc time at 2 times rated fuse current**

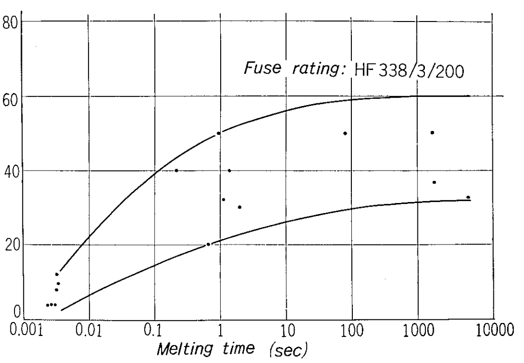


Fig. 3 **Melting time-arc time characteristic curves**

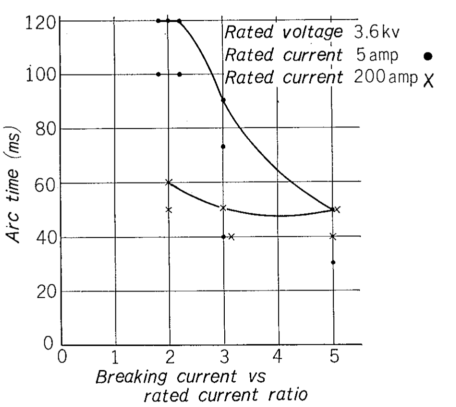


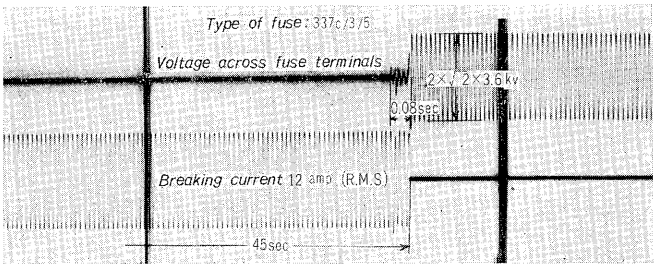
Fig. 4 **Breaking current-arc time characteristic curves**

at three times rate fuse current. *Fig. 2* shows the current breaking characteristics at two times rated fuse current.

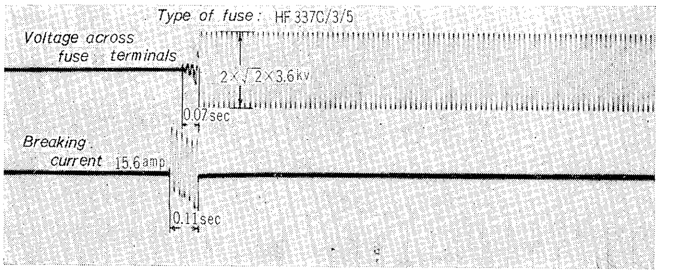
As can be seen from *Figs. 1* and *2,* the larger the rated currents, the smaller the arc times. The cause of this is that, when one element melts and an arc is produced, the arc is transferred sequentially to the remaining elements for breaking action and, therefore, the arc time becomes shorter.

Fig. 3 shows the characteristic curves between breaking current and arc time of a fuse with a rated voltage of 3.6 kv and a rated current of 5 amp and 200 amp.

From *Fig. 4,* it is seen that the arc time is almost

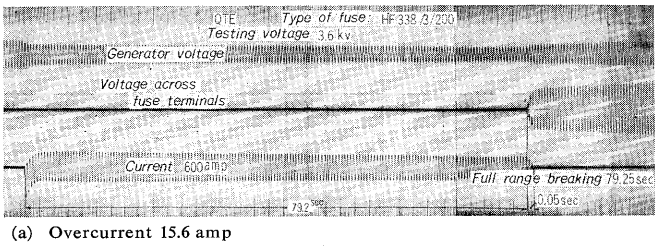


(a) Overload 12.0 amp

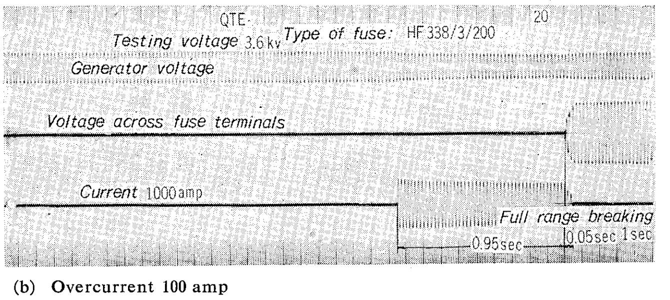


(b) Overcurrent 15.6 amp

Fig. 5 **Small current interruption of fuse with rated voltage of 3.6 kv, rated current of 5 amp**



(a) Overcurrent 15.6 amp



(b) Overcurrent 100 amp

Fig. 6 **Small current interruption of fuse with rated voltage of 3.6 kv, rated current of 200 amp**

saturated even when the breaking current is small.

Fig. 5 (*a*) and (*b*) depict oscillograms of small current interruption of a fuse with a rated voltage of 3.6 kv and a rated current of 5 amp.

Fig. 6 (*a*) and (*b*) show oscillograms of small current interruption of a fuse with a rated voltage of 3.6 kv and a rated current of 200 amp.

As can be seen from *Fig. 5* and *6,* the arc time is stable irrespective of the magnitude of the melting current or the melting period. While the arc voltage of fuses with large rated currents increases linearly, those of fuses with small rated currents increase stepwise. This is because the arc characteristics differ depending on the numbers of parallel elements.

Fig. 7 shows the fuse breaking time characteristics of fuses with ratings of 3.6 kv and 7.2 kv.

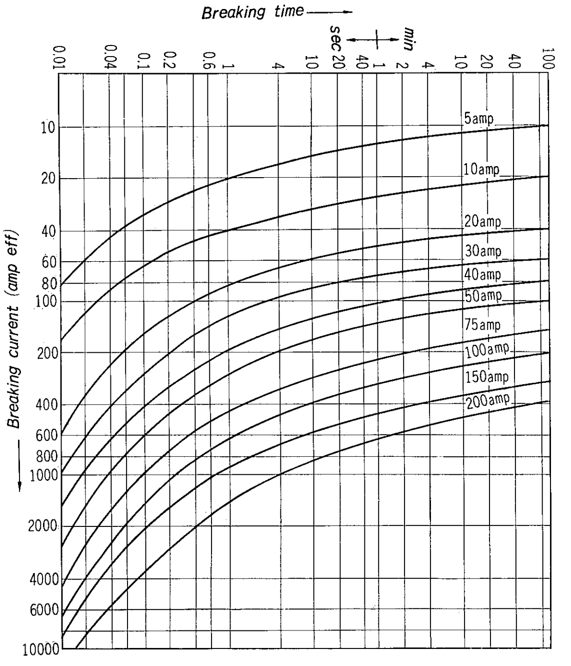


Fig. 7 **Breaking time-breaking current characteristic curves**

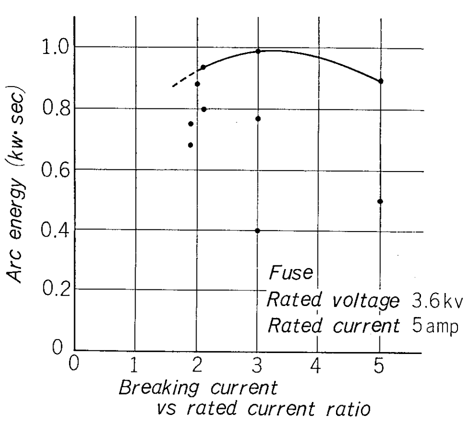


Fig. 8 **Breaking current-arc energy characteristic curve**

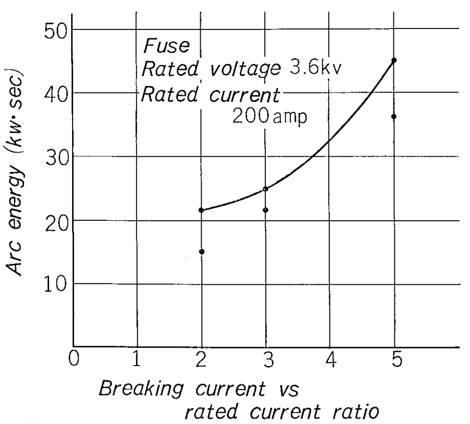


Fig. 9 **Breaking current-arc energy characteristic curve**

Fig. 8 shows a characteristic curve between breaking current and arc energy of a fuse with a rated voltage of 3.6 kv and a rated current of 5 amp. *Fig. 9* shows a characteristic curve between breaking current and arc energy of a fuse with a rated voltage of 3.6 kv and a rated current of 200 amp.

It is reported that,[5] [6] in general, the maximum

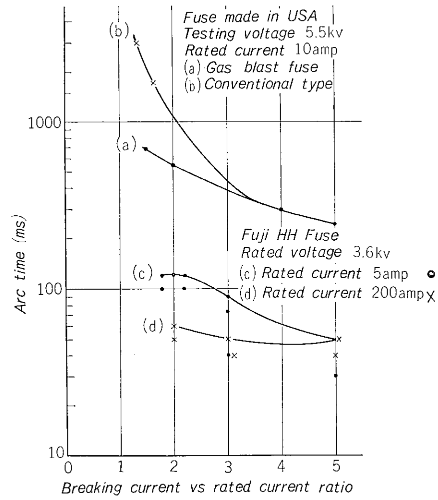


Fig 10 **Breaking current-arc energy characteristic curves**

arc energy of the high-voltage current-limiting fuse is produced at a current of 3 to 10 times the half-wave melting current of the fuse. In this case, the phenomenon is mainly within the medium to large current range.

As can be seen from this experiment, there are fuses (of small rated currents) which show maximum arc energies at small current ranges. Therefore, the maximum arc energies of existing high-voltage current-limiting fuses would be required to be studied on the basis of arc energy peaks or maximums.

Fig. 10 shows characteristic curves between breaking currents and arc energies of existing type fuses made by the Line Material Co. of USA and of Fuji's newly developed high-voltage current-limiting fuses with full range clearing ability. As is shown in *Fig. 10,* the arc time of new Fuji fuses, as compared with that of the Line Material Co., is approximately 1/4 to 1/8 for breaking current of approximately two times rated current, indicating the superior performance of fuses manufactured by Fuji.

V. CONCLUSION

The characteristics and applications of high-voltage current-limiting fuses with full-range clearing ability have been introduced in this report. We expect the demand for this type of fuse to increase rapidly as current-limiting fuses for high-voltages and simplified cubicles become more generally used in the future.

Thus, as a worldwide trend, more fuses of this high-voltage current-limiting type will be developed.

References

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