

Highly Modular TWIN BREAKER Series

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1. Introduction

The importance of the stable supply of electricity that plays a fundamental role in our contemporary, information oriented society is ever increasing. Electric facilities which supply electric energy must not only be reliable but easy to use, maintainable and flexible to permit specification changes. Manufacturers are developing new technologies for with miniaturization, standardization and automation of electric facilities. With consideration of technical trends and overall cost reduction for electric facilities, we have revolutionalized major component devices such as the molded case circuit breaker and earth leakage breaker. Based on new concepts, Fuji Electric has developed a series of TWIN BREAKERS, the Fuji Auto Breaker (FAB) and Fuji Earth Leakage Breaker (ELB), ranging from 30A to 225A Frames, which have been well received in the market. We have recently developed a series of SUPER TWIN BREAKERS, medium and large-capacity FAB and ELB which range from 400A to 800A Frames. Fuji Electric's TWIN BREAKER series of 30A to 800A Frames is now complete.

2. Features of the SUPER TWIN BREAKER

Figure 1 and **Figure 2** show an ON/OFF indicator, a TRIP button, a TEST/LEAK indicator button, etc. functionally arranged within window frame on the front cover of the breaker.

Features of the SUPER TWIN BREAKER are described below.

(1) FAB and ELB have the same dimensions

Figure 3 shows how we reduced and standardized the number of different frame sizes of our FAB and ELB, 6 different frame sizes for the 400AF to 800AF FAB and ELB have been reduced to 2. The full line of TWIN BREAKERS, ranging from 30A to 800A, has been reduced from 21 frame sizes to only 9. In addition, we developed ELBs which have higher interrupting capacities (**Fig. 4**), and expanded functions (**Fig. 5**). As a result, the user can select a breaker with a wider range of ratings, reducing management costs incurred in designing and producing a switch-board.

Fig. 1 400AF SUPER TWIN BREAKER

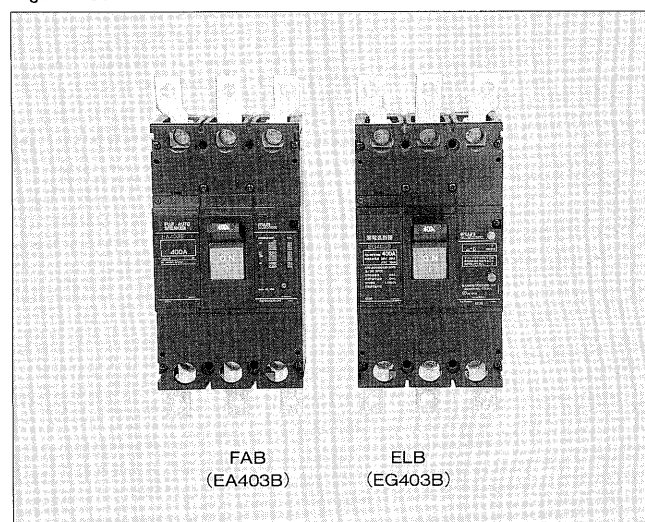
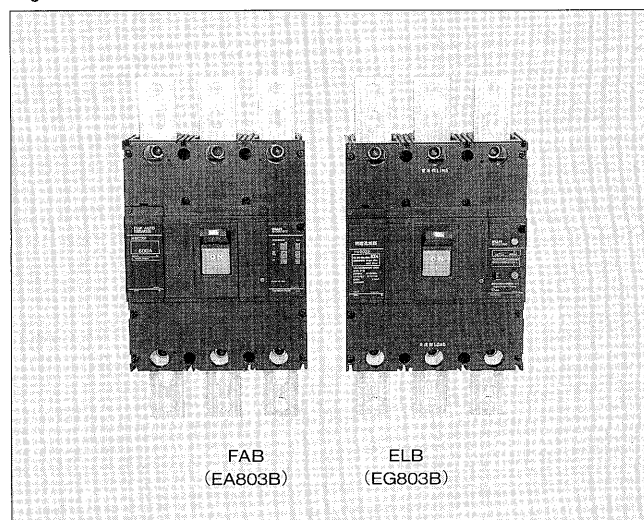


Fig. 2 800AF SUPER TWIN BREAKER



(2) Internal accessories in detachable cassette

An internal accessory cassette was constructed to contain such items as an auxiliary switch which outputs the ON/OFF status of a breaker, an alarm switch which outputs the TRIP status, a shunt trip device which trip a breaker

Fig. 3 Reduction of the number of basic frame sizes to nine

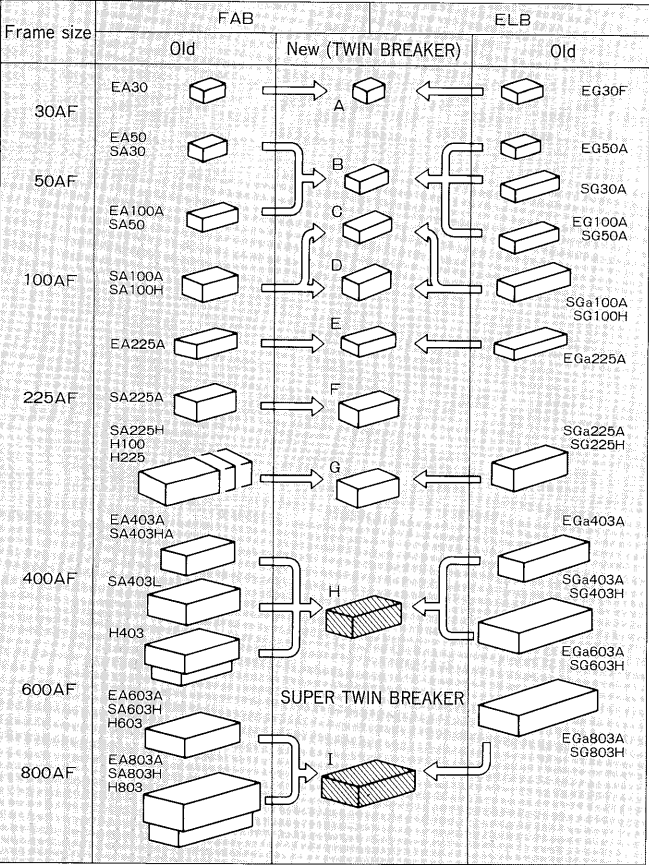
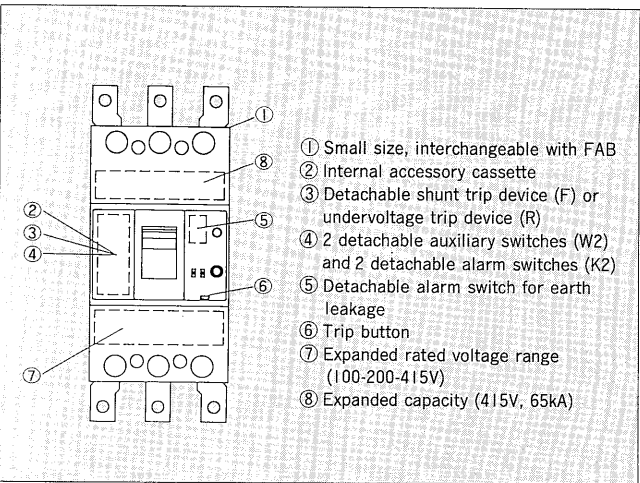


Fig. 5 Enhanced ELB functions



changes which may occur in the course of designing or manufacturing a switchboard, or even after operation has begun.

(3) Breaker is compact and has a high interrupting capacity

Based on Fuji's Active-Arc Driving Technique (AD technology) which was developed for the TWIN BREAKER, a new compact dual-latch current limiting mechanism was developed to achieve high current limiting interruption with large capacity breakers. This has resulted in much smaller external dimensions, with a maximum 30% volume reduction for FAB, and about 70% reduction for ELB. In addition, high-performance ELB models (415V, 65kA) have been recently developed and added to our product line.

(4) Conformance with new international standard, IEC 947-2

The TWIN BREAKER (FAB) meets the new international standard for low voltage circuit breakers, IEC 947-2. In the IEC 947-2, the rated service short-breaking (interrupting) capacity (I_{cs}), specified for assumed operating conditions, is added to the interrupting capacity (I_{cu}) which is specified for an assumed fault just beneath the power source transformer. The IEC standard requires an interrupting duty of "O"-"CO"-"CO" for I_{cs} . The I_{cs} for the TWIN BREAKER (FAB) is 25% I_{cu} or 50% I_{cu} .

3. Ratings and Specifications of the SUPER TWIN BREAKER

SUPER TWIN BREAKERS have a wide range of different interrupting capacities, enabling economical selection of the main circuit breaker for low voltage utilities. Both the FAB and ELB have economical models (Series E), general purpose models (Series S), and high performance models (Series H). Table 1 and Table 2 show the ratings and specifications of the basic types of SUPER TWIN BREAKERS.

Fig. 4 Expansion of high interrupting capacity ELBs

415V AC		Expanded application range of TWIN BREAKER		Expanded application range of SUPER TWIN BREAKER			
Transformer capacity (kVA)	Short-circuit current (kA)	30AF	50AF 60AF	100 AF	225 AF	400 AF	600 AF 800 AF
2,000	60			HG100B	HG225B	HG400B	HG600B HG800B
1,500	42			SG100R	SG225R	SG400R	SG600R SG800R
500	25			SG100B	SG225B	SG400B	
200	10						
7.5				SG50R SG60R			
5				SG50B SG60B			
100	5			EG100B	EG225B	EG400B	EG600B EG800B
50	2.5						
1.5				EG30B			
				EG50B EG60B			

remotely, and an undervoltage trip device. The user can attach this internal accessory cassette to the front of an already mounted breaker without having to open the cover of that breaker. This internal accessory cassette provides a quick and flexible means to respond to specification

Table 1 Ratings and specifications of SUPER TWIN BREAKERS (FAB)

E series	Frame (A)			400				600		800							
	Type	Instantaneous tripping current fixed		EA402B		EA403B		EA603B		EA803B							
		Instantaneous tripping current adjustable		EA402BN		EA403BN		EA603BN		EA803BN							
	Rated current (A)			250, 300, 350, 400				500, 600		700, 800							
	Poles			2		3		3		3							
	Rated insulation voltage	AC		660				660		660							
		DC		250				250		250							
	Rated interrupting capacity (kA) IEC947-2 I_{cu} (sym)	AC	500V	18				22		22							
			415V	25				35		35							
			240V	35				50		50							
DC		250V	20				20		20								
Dimensions (mm)		Width	140				210		210								
		Length	257				275		275								
		Height	103				103		103								
Frame (A)			400				600		800								
S series	Type	Instantaneous tripping current fixed		SA402B	SA403B	SA402R	SA403R	SA603R		SA803R							
		Instantaneous tripping current adjustable		SA402BN	SA403BN	SA402RN	SA403RN	SA603RN		SA803RN							
	Rated current (A)			250, 300, 350, 400		250, 300, 350, 400		500, 600		700, 800							
	Poles			2	3	2	3	3		3							
	Rated insulation voltage	AC		660		660		660		660							
		DC		250		250		250		250							
	Rated interrupting capacity (kA) IEC947-2 I_{cu} (sym)	AC	500V	22		35		35		35							
			415V	35		50		50		50							
			240V	50		85		85		85							
		DC	250V	20		40		40		40							
	Dimensions (mm)		Width	140		140		210		210							
			Length	257		257		275		275							
			Height	103		103		103		103							
H series	Frame (A)			400				600		800							
	Type	Instantaneous tripping current fixed		H402B		H403B		H403R		H603B		H603R		H803B		H803R	
		Instantaneous tripping current adjustable		H402BN		H403BN		H403RN		H603BN		H603RN		H803BN		H803RN	
	Rated current (A)			250, 300, 350, 400		250,300,350,400		500, 600		500, 600		700, 800		700, 800			
	Poles			2		3		3		3		3		3			
	Rated insulation voltage	AC		660		660		660		660		660		660			
		DC		250		250		250		250		250		250			
	Rated interrupting capacity (kA) IEC947-2 I_{cu} (sym)	AC	500V	42		85		42		85		42		85			
			415V	65		125		65		125		65		125			
			240V	125		125		125		125		125		125			
		DC	250V	40		40		40		40		40		40			
	Dimensions (mm)		Width	140		140		210		210		210		210			
			Length	257		257		275		275		275		275			
Height			103		103		103		103		103		103				

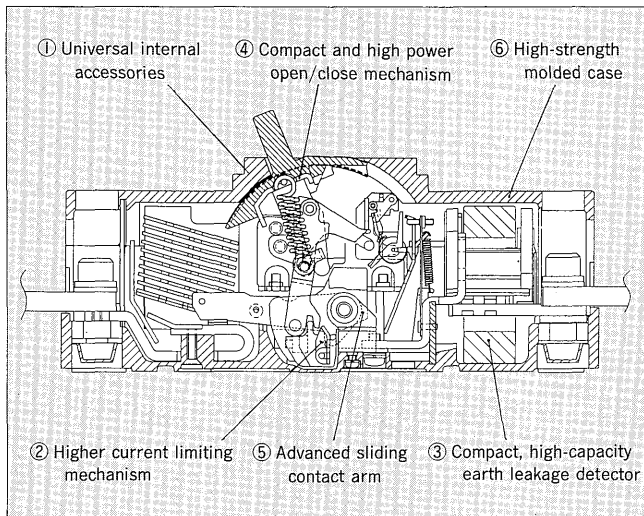
Table 2 Ratings and specifications of SUPER TWIN BREAKERS (FLB)

E series	Frame (A)		400		600	800
	Type	High speed type	EG403B		EG603B	EG803B
		Time delay type	EG403BD		EG603BD	EG803BD
	Poles		3		3	3
	Rated voltage AC (V)	High speed type	100–200–415 common		100–200–415 common	100–200–415 common
		Time delay type	200–415 common		200–415 common	200–415 common
	Rated current (A)		250, 300, 350, 400		500, 600	700, 800
	High speed type	Rated sensitive current (mA)	30, 100/200/500 switchable		100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	within 0.1		within 0.1	within 0.1
	Time delay type	Rated sensitive current (mA)	100/200/500 switchable		100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	0.3/0.8/2 switchable		0.3/0.8/2 switchable	0.3/0.8/2 switchable
		non-tripping time (s)	0.15/0.4/1 or greater		0.15/0.4/1 or greater	0.15/0.4/1 or greater
	Rated interrupting capacity (sym)	AC415V	25		35	35
		AC200V	35		50	50
		AC100V	35		50	50
Dimensions (mm)	Width		140		210	210
	Length		257		275	275
	Height		103		103	103

S series	Frame (A)		400		600	800
	Type	High speed type	SG403B	SG403R	SG603R	SG803R
		Time delay type	SG403BD	SG403RD	SG603RD	SG803RD
	Poles		3	3	3	3
	Rated voltage AC (V)	High speed type	100–200–415 common	100–200–415 common	100–200–415 common	100–200–415 common
		Time delay type	200–415 common	200–415 common	200–415 common	200–415 common
	Rated current (A)		250, 300, 350, 400	250, 300, 350, 400	500, 600	700, 800
	High speed type	Rated sensitive current (mA)	30 30, 100/200/500 switchable	30, 100/200/500 switchable	100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	within 0.1	within 0.1	within 0.1	within 0.1
	Time delay type	Rated sensitive current (mA)	100/200/599 switchable	100/200/500 switchable	100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	0.3/0.8/2 switchable	0.3/0.8/2 switchable	0.3/0.8/2 switchable	0.3/0.8/2 switchable
		non-tripping time (s)	0.15/0.4/1 or greater	0.15/0.4/1 or greater	0.15/0.4/1 or greater	0.15/0.4/1 or greater
	Rated interrupting capacity (sym)	AC415V	30	50	50	50
		AC200V	42	85	85	85
		AC100V	42	85	85	85
Dimensions (mm)	Width		140	140	210	210
	Length		257	257	275	275
	Height		103	103	103	103

H series	Frame (A)		400		600	800
	Type	High speed type	HG403B		HG603B	HG803B
		Time delay type	HG403BD		HG603BD	HG803BD
	Poles		3		3	3
	Rated voltage AC (V)	High speed type	100–200–415 common		100–200–415 common	100–200–415 common
		Time delay type	200–415 common		200–415 common	200–415 common
	Rated current (A)		250, 300, 350, 400		500, 600	700, 800
	High speed type	Rated sensitive current (mA)	30, 100/200/500 switchable		100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	within 0.1		within 0.1	within 0.1
	Time delay type	Rated sensitive current (mA)	100/200/500 switchable		100/200/500 switchable	100/200/500 switchable
		Tripping time (s)	0.3/0.8/2 switchable		0.3/0.8/2 switchable	0.3/0.8/2 switchable
		non-tripping time (s)	0.15/0.4/1 or greater		0.15/0.4/1 or greater	0.15/0.4/1 or greater
	Rated interrupting capacity (sym)	AC415V	65		65	65
		AC200V	125		125	125
		AC100V	125		125	125
Dimensions (mm)	Width		140		210	210
	Length		257		275	275
	Height		103		103	103

Fig. 6 Major technical issues



4. Structure and Performance of the SUPER TWIN BREAKER

Figure 6 shows major technical issues which had to be solved to realize the new SUPER TWIN BREAKER. These major issues were (1) to develop an internal accessory cassette which can be mounted after breaker installation, (2) to develop a large capacity and high speed current limiting mechanism, (3) to develop a large capacity and compact earth-leakage-detection unit. In addition, to achieve compact size, it was necessary (4) to develop a compact switching element with large output capacity, (5) to develop a sliding contact arm without a lead wire, and (6) to develop a high strength mold material. All the above were achieved with development based upon Fuji's technology and the use of computer-aided design and simulation.

4.1 Internal accessory cassette attachable to an installed breaker

(1) Need for the internal accessory cassette

More than 30 percent of main circuit breakers are equipped with an auxiliary switch, an alarm switch and internal accessories to send signals such as ON/OFF and TRIP status to, and to receive BREAK signals from a central supervisory facility. This figure, 30%, is almost two times greater than that for branch circuit breakers. The large number of circuit breakers which require internal accessories has led to many variations and combinations of circuit breakers. Previously, as it was necessary to open the circuit breaker cover to mount an internal accessory, the place where this could be performed and the people who could do it were limited. Therefore, it was difficult to respond quickly to specification changes after a switchboard was assembled or operation had begun. The newly developed internal accessory cassette completely solved the above difficulties, enabling any person to mount the accessories easily on any occasion. Even if internal accessories easily on any occasion. Even if internal accessory

Fig. 7 Structure of universal internal accessories

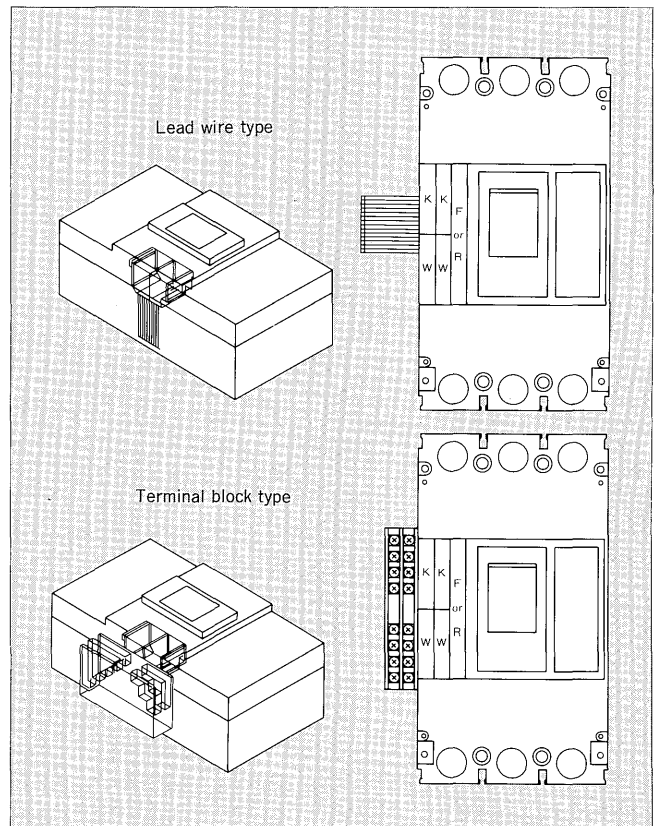
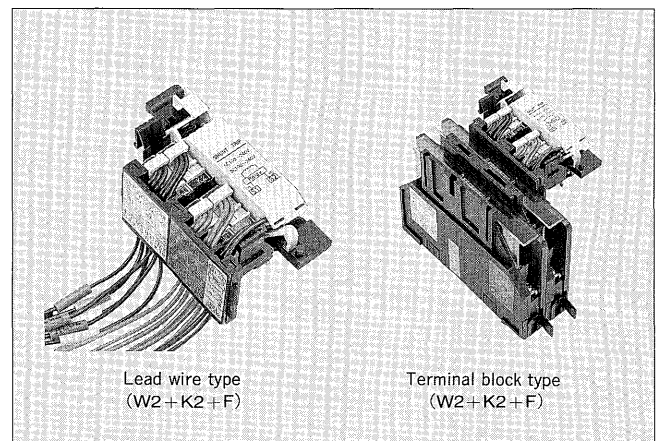


Fig. 8 Internal accessory unit



specifications are not fixed, the user may order a basic breaker unit and proceed to produce a switchboard. When the specification is determined, he has only to attach the specified internal accessory to the breaker. If a facility is in operation, a maintenance person can mount or replace internal accessories whenever electric power is briefly off.

(2) Structure of the internal accessory cassette

Figure 7 shows the internal accessory cassette; in Fig. 8, three accessory elements make up one internal accessory unit; and in Fig. 9, this unit is mounted on a breaker with an auxiliary cover, over the left pole, opened.

(3) Internal accessories are common to all frames

Table 3 shows the available internal accessory units

Fig. 9 Breakers with the same internal accessory unit mounted

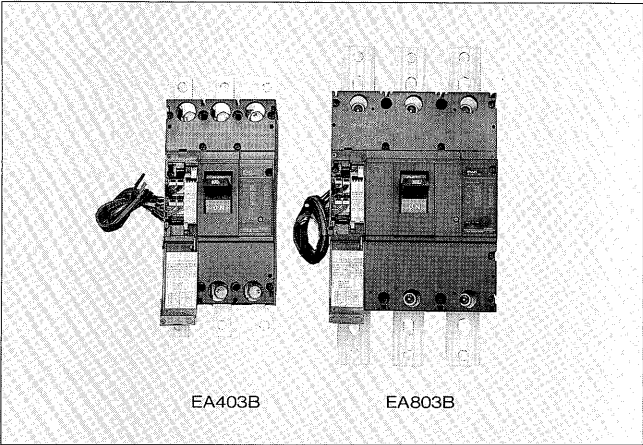


Table 3 Internal accessory combinations for the SUPER TWIN BREAKER

Accessory	Mounting location	Accessory	Mounting location
Auxiliary switch : W		W2 + R	
Alarm switch : K		K + F	
Shunt trip device : F		K2 + F	
Undervoltage trip : R device		K + R	
W2		K2 + R	
W + K		W + K + F	
W2 + K		W + K + R	
K2		W2 + K + F	
W + K2		W2 + K + R	
W2 + K2		W + K2 + F	
W + F		W + K2 + R	
W2 + F		W2 + K2 + F	
W + R		W2 + K2 + R	

※ : newly available for FAB
○ : newly available for ELB

with different combinations of accessory elements. These units are common to FAB and ELB of 400A to 800A Frames. **Table 3** also shows a shunt trip device and an undervoltage trip device, which were not previously available for ELB. Possible internal accessory variations have increased dramatically.

4.2 Realizing high current limiting with a large capacity breaker

(1) Current limiting interruption

The current limiting capability of a low voltage circuit

Fig. 10 Current limiting interruption

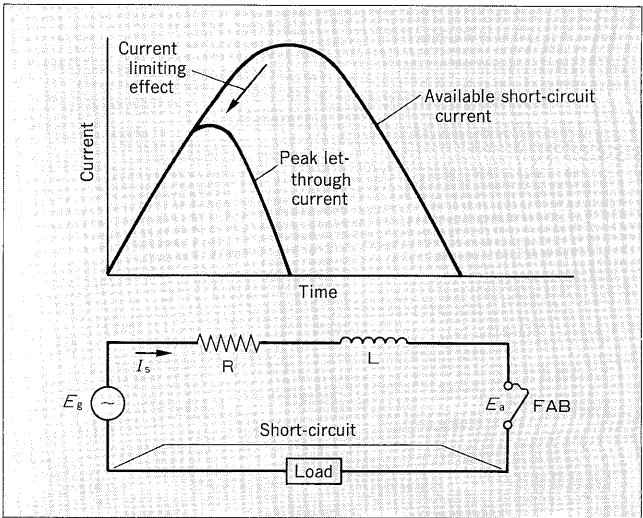
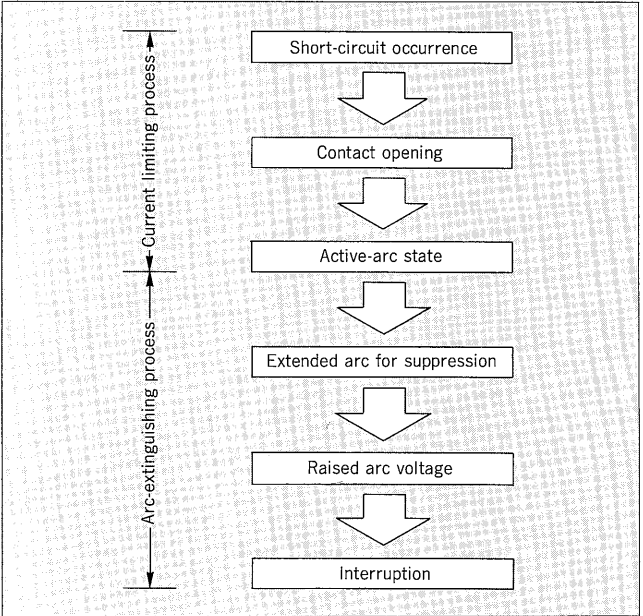


Fig. 11 Interruption process



breaker is determined by how it lowers stress due to arc energy generated during an interruption. **Figure 10** shows the principle of current limiting interruption. In this interruption, the electric arc generated between contacts is cooled, arc resistance increased, short circuit current reduced, and then interrupted. **Figure 11** shows the interrupting process. To increase the current limiting effect, contacts must open earlier, and move with as high an opening speed as possible, to make the arc change from agglutinative to active states in a very short period of time.

(2) AD technology for current-limiting interruption

Fuji Electric has already established for TWIN BREAKERS of up to 225A Frames, an AD technology that extremely lowers arc energy. This technology offers the latest contact-opening method in which the magnetic repulsion force between contacts is concentrated on a current limit-

Fig. 12 Rise-time of arc voltage

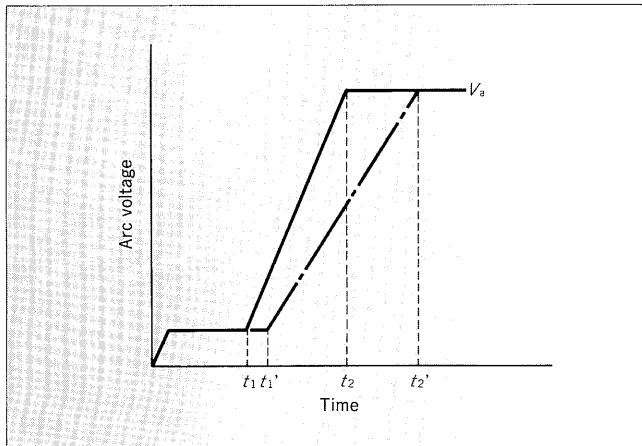


Fig. 13 Sketch of dual-latch current limiting mechanism

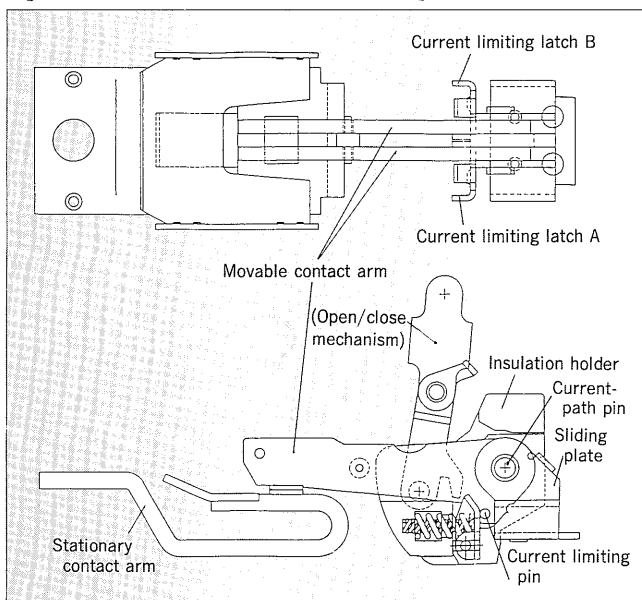


Fig. 14 Appearance of the dual-latch current limiting mechanism

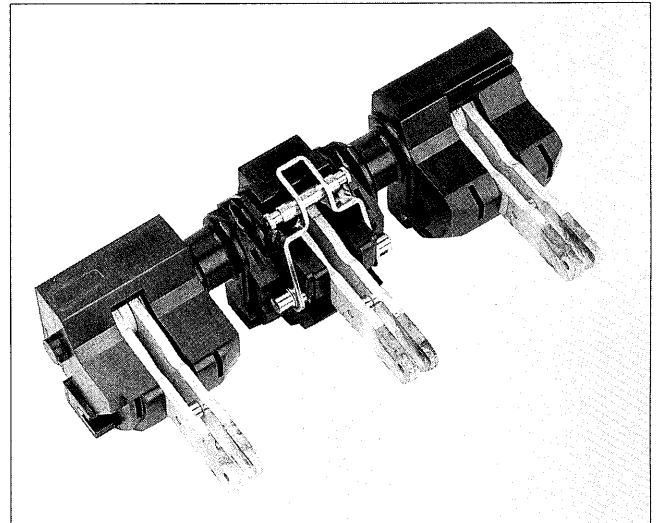
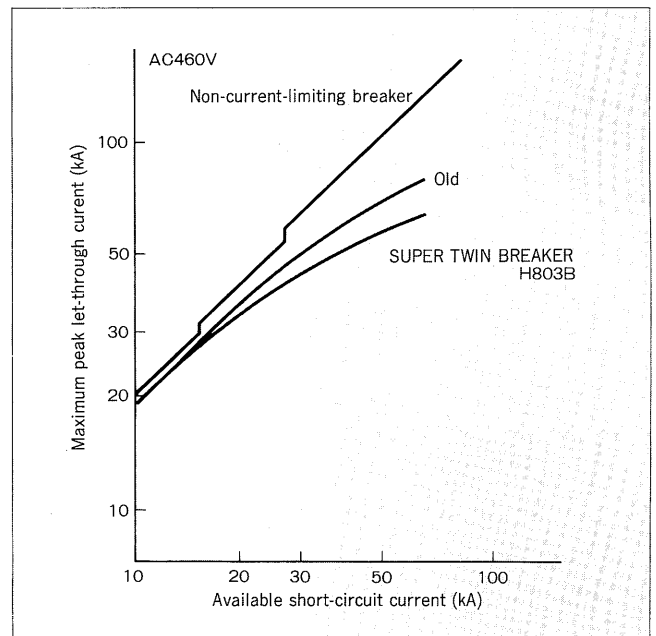


Fig. 15 Maximum peak let-through current comparison



ing latch. When the magnetic force exceeds a certain limit this latch is triggered, and the contacts will open quickly. (3) Applying AD technology to a large capacity circuit breaker

In developing the SUPER TWIN BREAKER, let-through current and arc power were lowered as much as possible to achieve a compact and high interrupting capacity breaker. Based upon arc voltage data of the TWIN BREAKER (up to 225AF) interrupting a current, a computer was used to simulate the arc voltage when 800A-rated contacts interrupt a current. There were a few problems with the above data, shown in Fig. 12.

- (a) Arc agglutination time t_1' is longer than t_1 of the small TWIN BREAKER
- (b) Arc rise-time t_2' is longer than t_2 .

It was feared that, due to the above, let-through current and arc power might increase so that the internal pressure would exceed the strength of the breaker housing. However, it was found that the contact mass increased to have a larger current capacity. Then, due to an increase in

the moment of inertia, the opening speed of the contact decreased.

Figure 13 shows a new device for current-limiting, the dual-latch current limiting mechanism, developed for the SUPER TWIN BREAKER. This mechanism has two movable contact arms, arranged in parallel, each of which has a relatively small mass. The contact arms move independently during early stages of the opening motion, then move jointly until open completely. Figure 14 shows the dual-latch current limiting mechanism. In the past, it has been difficult to obtain current limiting effects with large circuit breakers. The SUPER TWIN BREAKER of 600A and 800A Frames, due to its dual-latch current limiting mechanism, has an arc agglutination time (t_1 in Fig. 12) and an arc rise time (t_2 in Fig. 12) which are as short as those of small circuit breakers. Figure 15 and Figure 16 show current

Fig. 16 Let-through I^2t comparison

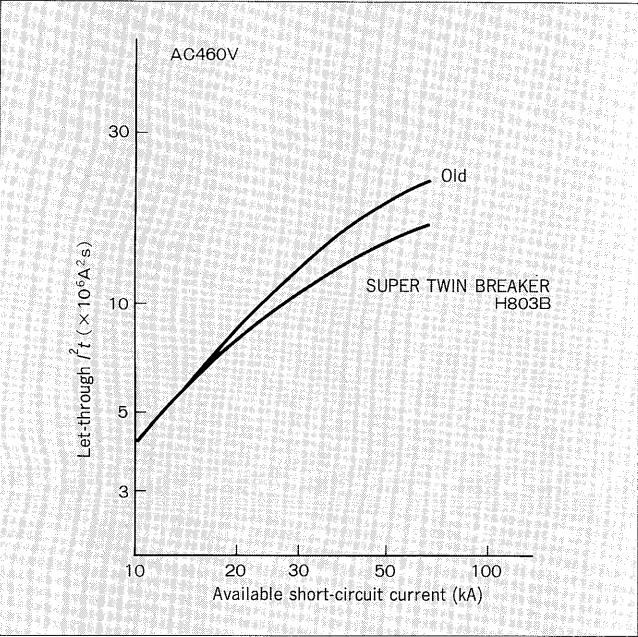


Fig. 18 Comparison of old and new ZCT structures for 800A Frame ELB

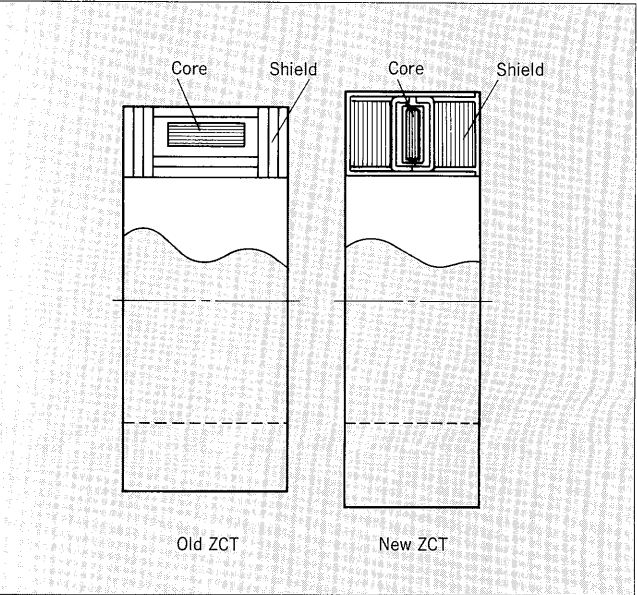


Fig. 17 Miniaturizing of the ELB

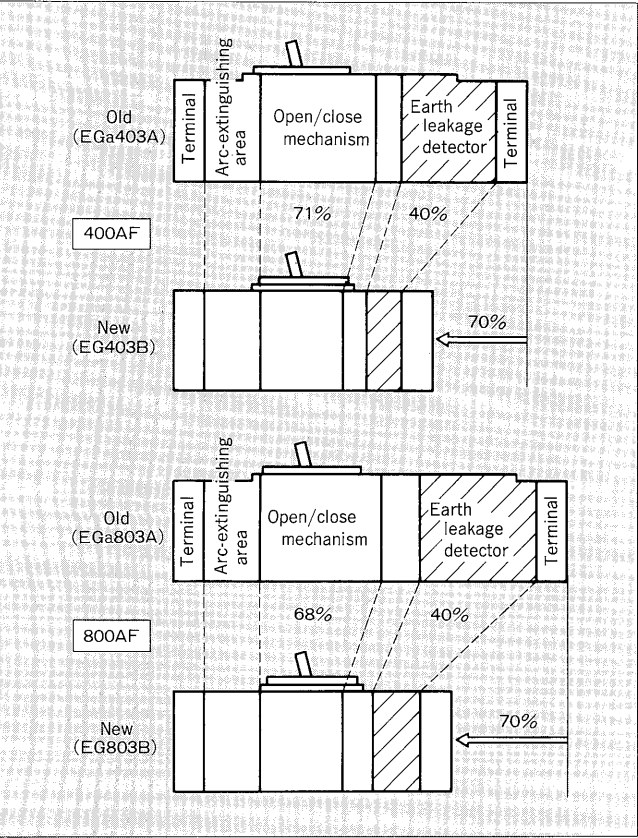


Fig. 19 Equilibrium characteristics of the 800A Frame ZCT

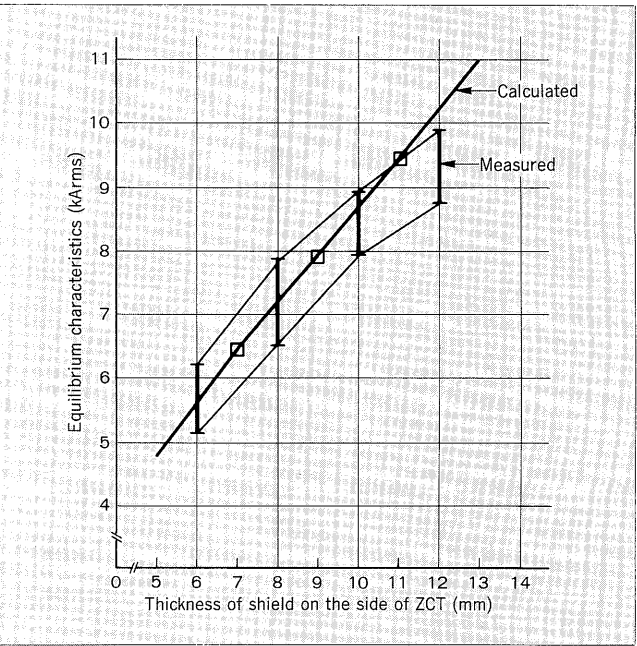


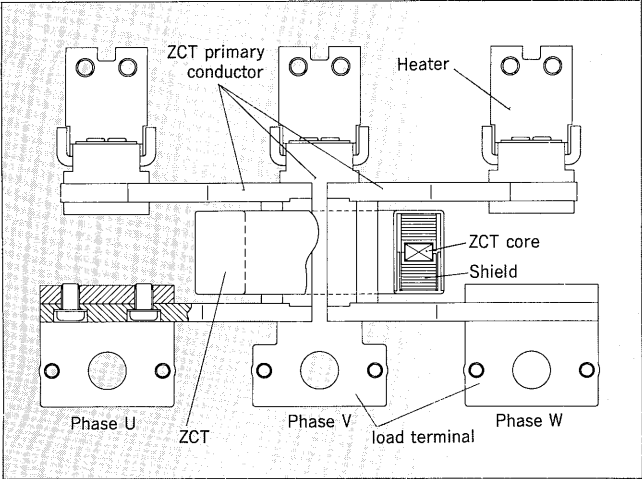
Figure 17 compares the size of the SUPER TWIN BREAKER (ELB) and the old ELB. Both 400A and 800A Frame models decreased to 70% of their previous length. The miniaturization of the compact switching mechanism and earth leakage detection unit was difficult because these parts included terminals and current-breaking parts which were difficult to make compact. It was necessary to reduce the earth leakage detection unit to 40% of its previous size. This was achieved through the optimum construction of a zero-phase current transformer (ZCT) and its primary conductor which usually occupy most of the space in an earth leakage detection unit.

limiting characteristics of SUPER TWIN BREAKER H803B at 460V. Both the maximum peak let-through current and let-through I^2t are extremely low.

4.3 Miniaturization of the large capacity earth leakage detection unit

(1) Miniaturization of the ELB

Fig. 20 Structure of the new 800A Frame ZCT and primary conductor



(2) Flattening the ZCT's core

Basic ZCT characteristics include zero-phase current detection and equilibrium characteristics. The former is explicitly determined by the ELB sensing current and ZCT core volume. The latter characteristic relates to the level of load current which does not cause the ZCT to output. This characteristic is expressed in multiples of the rated current. Optimum core shielding determines ZCT dimensions for large capacity ELB. This is because the ZCT

primary conductor generates a leakage flux which passes through core, and causes the ZCT to output. **Figure 18** compares the construction of ZCT for old and new ELB of 800A Frames. The thickness of the ZCT laminated core for new ELB's has been minimized, and a shield has been placed on both sides of the core. As a result, the effect of leakage flux from the primary conductor, which is placed in a hole on the ZCT, is reduced leakage flux from a part of the primary conductor positioned on the side of the ZCT is effectively shielded.

The magnetic field was analyzed, and equilibrium characteristic measured. As **Fig. 19** shows, both the calculated and measured characteristics were in agreement. From the above, an optimum thickness for the ZCT core was determined. **Figure 20** shows the new 800A Frame ZCT and primary conductor.

5. Conclusion

In addition to 30A to 225A Frame TWIN BREAKERS, Fuji Electric is marketing the SUPER TWIN BREAKER introduced in this article. Dimensions have been standardized for FAB and ELB of identical frames (ranging from 30A to 800A Frames). Fuji Electric's TWIN BREAKER product line is now complete. We are confident that this TWIN BREAKER product line with its compact size, high performance and high flexibility is sufficient for the needs of advanced and complex electric facilities.