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SERIES OF MINIMUM SIZE DC HIGH SPEED AIR CIRCUIT BREAKERS

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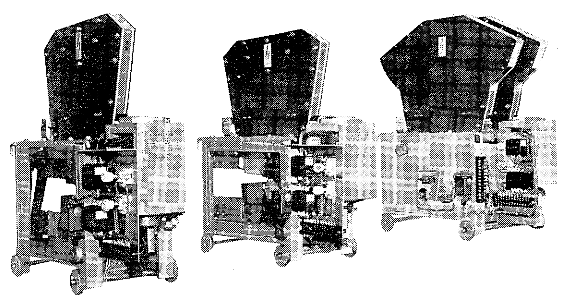
I. INTRODUCTION

The previously announced Type BWV (750 V and 1,500 V, 2,000 A) minimum size high speed air circuit breakers (1/4 th the volume and 1/5 th the weight of conventional circuit breakers) has gained the attention of the world as ideally matched to plans for small, rational DC substations. A large number of these breakers have already been delivered and are continuing to operate satisfactorily, and their superb performance and easy maintenance have been acknowledged.

We have now added 3,000 A, 4,000 A, and 6,000 A breakers to this 2,000 A breaker and have both completed the BWV Series minimum size high speed air circuit breakers (refer to *Fig. 1* and *Table 1* and formed a system which can uniformly use this BWV Series in DC substation plan spanning a wide 2,000~6,000 A rated current range. Special considerations were given in the development of these new 3,000~6,000 A breakers to improve reliability by making their parts common with those of the 2,000 A breaker. That is, the parts used in the 3,000 A breaker are the same as those of the 2,000 A breaker except that the capacity of the current carrying parts has been increased, the 4,000 A breaker and 6,000 A breaker have been unitized by using in parallel with the current carrying parts of the 2,000 A and 3,000 A breaker respectively. An outline of this BWV Series is introduced in this article.



BWV 82 750 V, 2,000 A — BWV 83 750 V, 3,000 A — BWV 156 1,500 V, 6,000 A

Fig. 1 Series of minimum size DC high speed air circuit breaker

II. FEATURES

1. Compact and Lightweight

The weight and volume are only 25~45% and 20~25% those of the Fuji Electric standard breakers respectively. (Refer to *Fig. 2* for size comparison.)

Table 1 List of Ratings and Specifications

Type		BWV82	BWV83	BWV84	BWV86	BWV152	BWV153	BWV154	BWV156
Rated voltage	(V)	DC 750				DC 1,500			
Rated current	(A)	2,000	3,000	4,000	6,000	2,000	3,000	4,000	6,000
Breaking capacity (Short circuit current)	kA	50 (at $di/dt=3\times10^6$ A/S)							
Short circuit trip range	(kA)	2~4 3~6	3~6 5~8	5~8 6~10	8~12	2~4 3~6	3~6 5~8	5~8 6~10	8~12
Short circuit trip direction		Non-polarity							
Operating control voltage	(V)	DC 100/110							
Closing time	(s)	0.5							
Weight	(kg)	90	100	170	190	100	110	190	210
Aux. switch		1a+1b							
Installation		Fixed type, draw-out type							

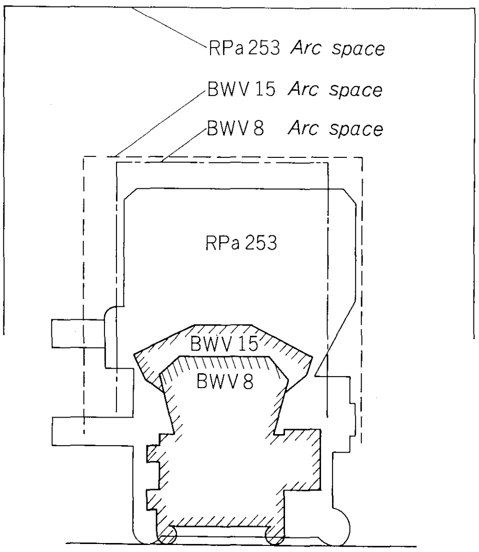


Fig. 2 Comparison of BWV and RPa 253

2. Stable Circuit Breaking Capability Because of Unique Arc Quenching Method

The arc is controlled by a U-shaped arc horn in the 750 V arc quenching chamber and a rationally arranged grid in the 1,500 V arc quenching chamber. In this way, a stable circuit breaking capacity is achieved, the arc quenching chamber is more compact and the arc space is minimized.

3. Ingenious Operating Mechanism and Minimum Number of "Live" Parts

The heat generated is limited since the circuit through which the current passes is very short. In addition, an ingenious system of a pair of springs serve the three functions of closing, contacting, and breaking is employed.

4. Mechanical Holding System

Since a mechanical holding system is employed there is no need for a holding power supply. Moreover, variations in the operating current are small because tripping detection is unrelated to changes in the operating voltage.

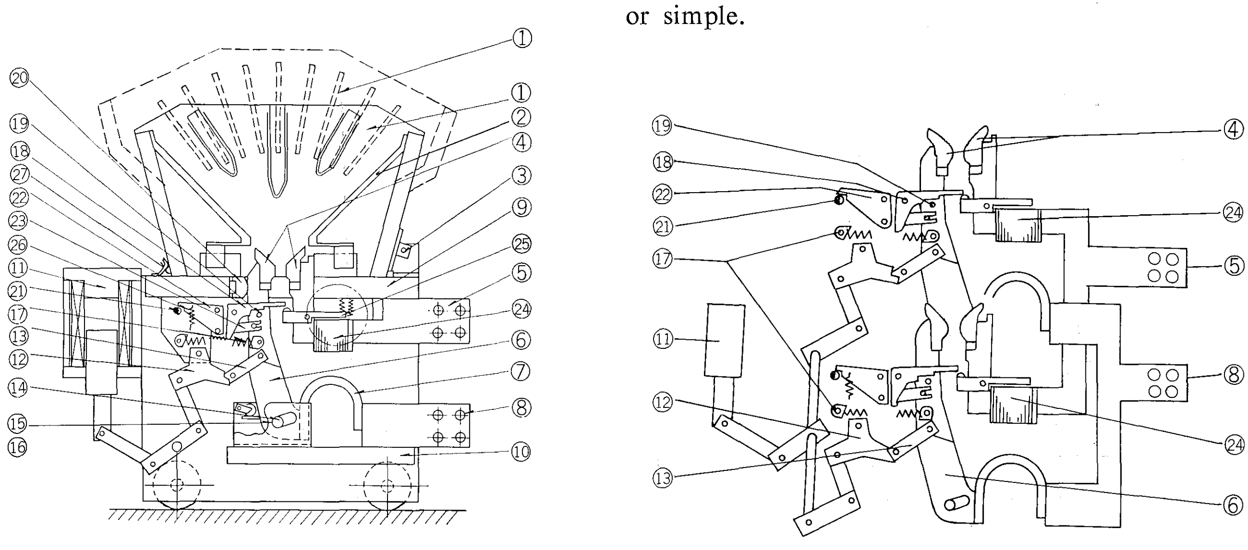
5. Non-directional Current Breaking Possible

Since breaking is performed by the force of attraction of a magnet installed in the circuit through which the current passes, the same breaking operation is performed for currents in either the positive or negative directions.

6. Various Types of Tripping Such as Overcurrent Tripping Possible

7. Control Devices Built-in

Since the contactor, relays, and fuses required for operation are built-in, a control panel is unnecessary or simple.



(a) BWV 82, 83 / BWV 152, 153 (750/1,500 V, 2,000/3,000 A)

(b) BWV 84, 86 / BWV 154, 156 (750/1,500 V, 4,000/6,000 A)

① Arc quenching chamber
② Arc horn
③ Hinge
④ Contact
⑤ Upper conductor
⑥ Moving contact arm
⑦ Flexible lead
⑧ Lower conductor
⑨ Insulating base
⑩ Insulating base
⑪ Operating device
⑫ Joint lever
⑬ Joint lever
⑭ Hinge bolt
⑮ Long hole
⑯ Long hole
⑰ Spring
⑱ Latch lever
⑲ Latch roller
⑳ Stopper
㉑ Semicircle pin
㉒ Trip lever
㉓ Span lever
㉔ Yoke
㉕ Anchor
㉖ Spring

Fig. 3 Construction of BWV

8. Eays Maintenance and Inspection

Since the construction has been simplified, there are few inspection points, and the arc quenching chamber and contacts can be changed in about 5 minutes.

III. RATING AND SPECIFICATIONS

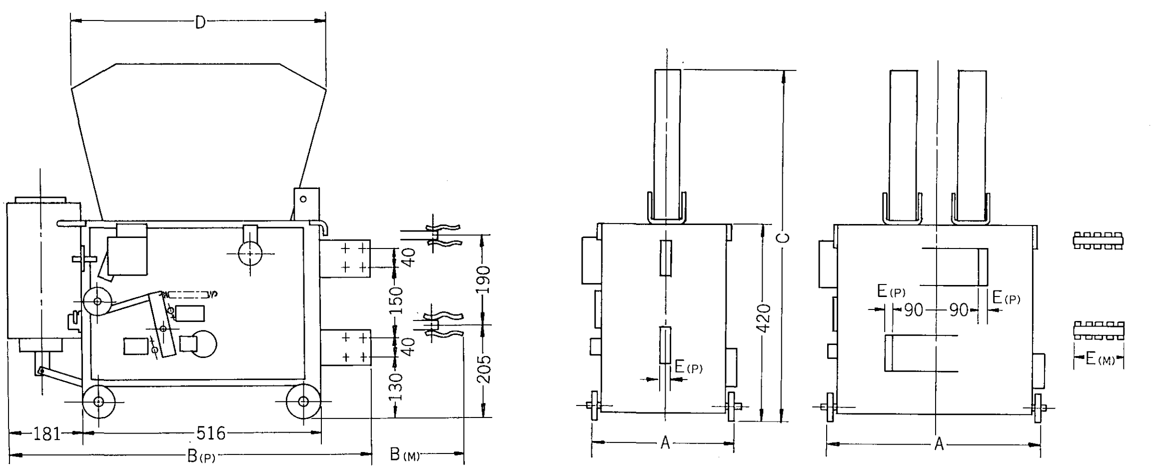
The ratings and specifications of the type BWV circuit breaker are listed in *Table 1.*

IV. CONSTRUCTION AND OPERATION

External views of the BWV82, 83 and BWV156 are given in *Fig. 1*, the construction drawing is given in *Fig. 3*, the external dimensions drawing is given in *Fig. 4*, and the external dimensions table is given in *Table 2*. The 2,000 A and 3,000 A breakers have a single current carrying part and the 4,000 A and 6,000 A breakers have two current carrying parts arranged on a suitable spaced insulated base. Switching is performed by a single operating device and tripping mechanism housed in this one frame. The newly developed 3,000 A breaker has a large cross sectional area so that the current carrying part of the 2,000 A breaker has ample current carrying capacity. Moreover, the 4,000 A and 6.000 A breakers have common unitized parts. The 4,000 A breaker is in parallel with the current carrying part of the 2,000 A breaker and the 6,000 A breaker is in parallel with the current carring part of the 3,000 A breaker as shown in *Fig. 3* (b). The contacts are common for all ratings. There are two types of arc quenching chambers, 750 V and 1,500 V and converting of the BWV8 (750 V) and BWV1 (1,500 V) is possible by merely changing the arc quenching chamber.

1. Arc Extinguishing Method

As already described for the 2,000 A breaker high speed current limiting breaking of fault currents is possible by means of the rational arc extinguishing system. Arc extinguishing principle is shown in *Fig. 5*. In other words, the magnetic force of the arc produced immediately after opening of the contacts is utilized to the maximum extent by a U-shape arc



(a) Fixed type (b) Draw-out type (c) 2,000/3,000 A (d) 4,000/6,000 A (e) Draw-out type

Fig. 4 Outline dimensions

***Table 2* Outline Dimensions**

Type	A Breadth	B Depth P (Fixed type)	B Depth M (Draw-out type)	C Height	D Arc quenching chamber	E Terminal P (Fixed type)	E Terminal M (Draw-out type)
BWV 82	317	785	890	770	560	20	85
BWV 83	317	865	970	770	560	50	130
BWV 84	487	907	847	770	560	25	170
BWV 86	487	987	847	770	560	50	260
BWV 152	317	785	890	895	756	20	85
BWV 153	317	865	970	895	756	50	130
BWV 154	487	907	847	895	756	25	170
BWV 156	487	987	847	895	756	50	260

horn (750 V use) or grid (1,500 V use) separated by a heat resistant arc extinguishing wall and by making the contact horn shape. For this reason, superb current limiting performance and stable small current breaking performance are obtained and also a small arc quenching chamber is possible while eliminating the current limiting performance improvement blow-out coil and air blast device to contribute to small current breaking performance installed in conventional high speed circuit breakers. In the case of the 4,000 A and 6,000 A breakers, since two contacts and arc quenching chambers having ample breaking performance are arranged in parallel, breaking is performed in parallel or in the arc quenching chamber of the unit which is tripped last. In the latter case, since the contacts of the side which breaks the current wear, the tripping error becomes small at the next breaking and operation shifts to parallel breaking. Since breaking is performed in this manner so that the tripping error is always small, wear of the contacts and arc quenching chambers arranged in parallel is averaged and the life is almost double that of the 1 contact 1 arc 2,000 A and 3,000 A breakers.

2. Operation

As shown in *Fig. 3* (b), execpt for the operating device, the link mechanism and moving parts of the

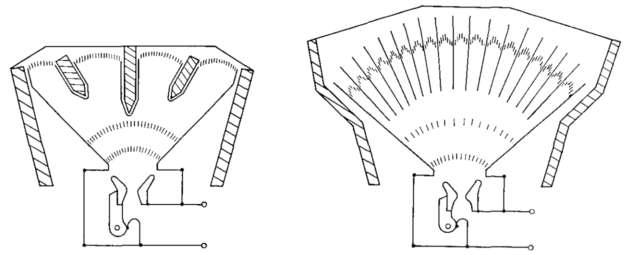
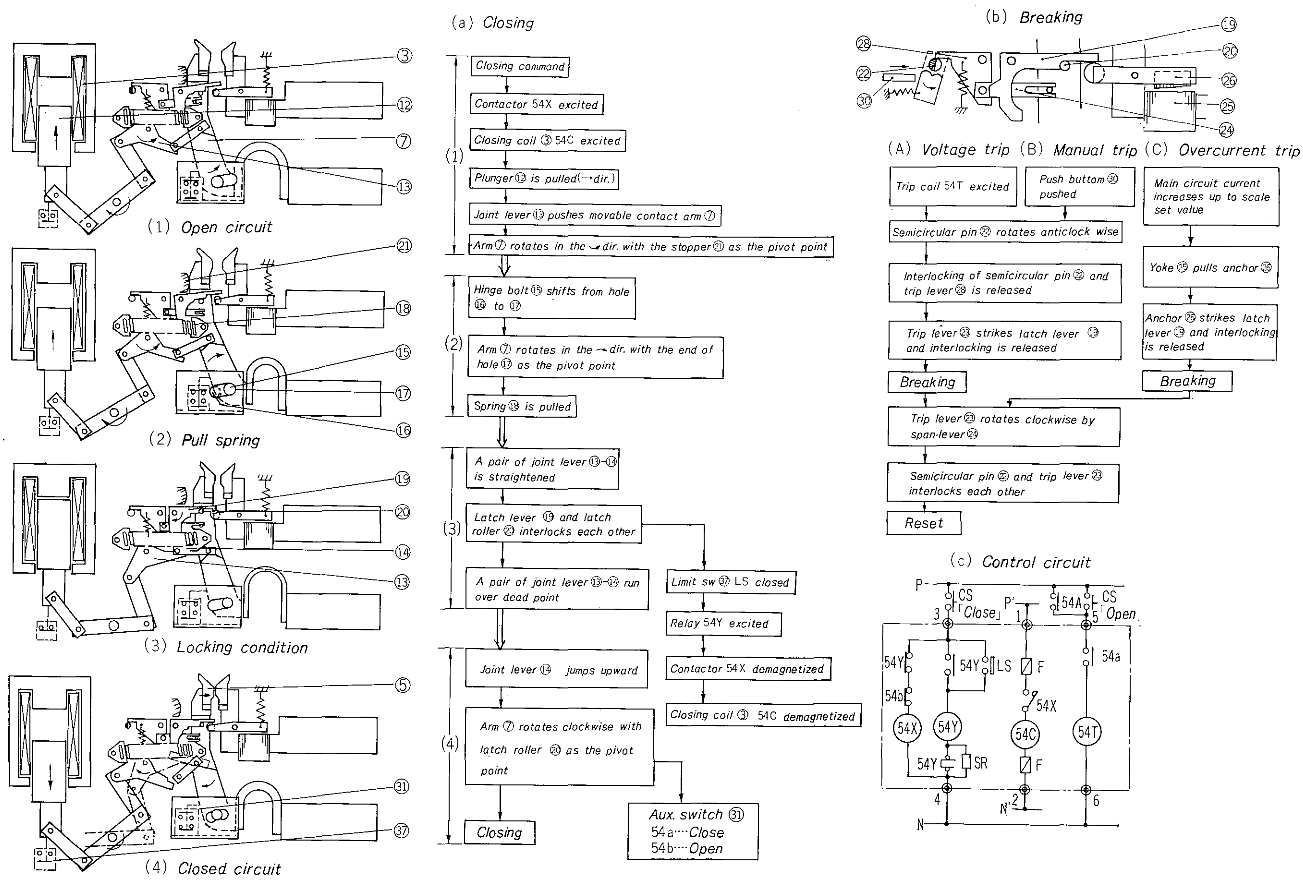


Fig. 5 **Arc extinguishing principle**



54X: Closing contactor
54Y: Relay
54C: Closing coil
54T: Trip coil
54 a} 54 b} ···Aux. switch
LS: Limit switch
F: Fuse
SR: 54Y Series resistor
CS: Control switch
◎: Terminal
54A: Relay

Fig. 6 **Operating mechanism**

4,000 A～6,000 A breakers are in parallel, but their principle of operation is identical to that of the 2,000～6,000 A breaker and the closing and breaking operations are performed in accordance with the flow chart shown in *Fig. 6*.

V. TESTS

Stringent tests such as short circuit breaking, manual breaking, small current breaking tests and continuous switching test, etc. assuming troubles which can be considered to be produced in an actual system were performed on each rated unit based on JEC–152 and JRS (JNR Standard). Their superb actual performance was confirmed. The results of the major tests are given here.

1. Short Circuit Test

In the case of short circuit faults, DC high speed circuit breakers are used for high speed current limiting breaking of the fault current, minimize circuit damage and protect the circuit devices. This BWV Series is guaranteed to maintain the high speed current limiting breaking performance required in high speed circuit breakers by means of our short circuit test facilities. As one example, the 750 V and 1,500 V AC equivalent test results on the 4,000 A breaker are given in *Table 3* and typical oscillograms are given in *Fig. 7*.

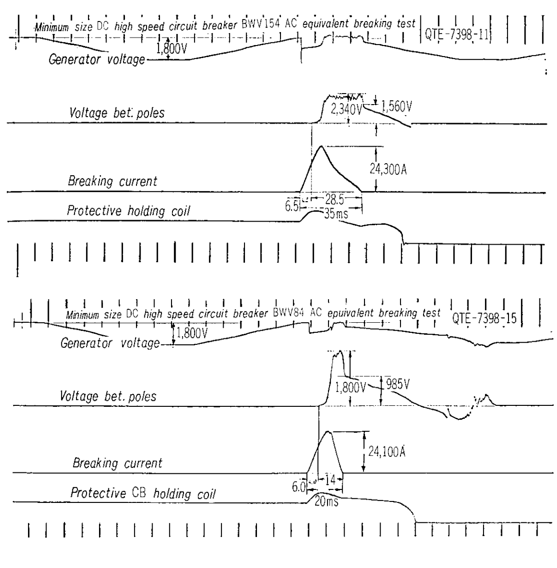


Fig. 7 Oscillogram of AC equivalent breaking test

Table 3 Results of AC Equivalent Breaking Test

Short circuit 50,000 A $di/dt=3\times10^6$ A/S Setting current 8,000 A

Type	OSC No. QTE-	Test frequency (Hz)	Generator voltage Peak value (V)	Working voltage (V)	Recovery voltage (V)	Breaking current (A)	Opening time (ms)	Breaking time (ms)	Arc voltage (V)	Duty cycle
BWV 154	7398-11	5.8	1,800	1,800	1,560	24,300	6.5	35	2,350	0
	7398-12	5.8	1,800	1,800	1,580	24,300	6.7	34	2,500	0
BWV 84	7398-15	5.8	1,800	1,800	985	24,100	6.0	20	1,800	0
	7398-16	5.8	1,800	1,800	970	24,200	6.0	20	1,760	0

2. L Circuit Breaking Test

Positive breaking of a large inductance current which are not tripped by overloads or faults, but by operating conditions or manually was tested and guaranteed. The results are given in *Table 4* and typical oscillograms are shown in *Fig. 8*.

3. Small Current Breaking Test

Automatic arc quenching circuit breakers are generally equipped with a air blowout device having small magnetic blowout force. This accessory device has been eliminated and stable small current breaking characteristics have been obtained in this series by effectively utilizing the electromagnetic force of the arc itself. A large number of breaking tests were performed especially in 10～200 A range of the critical current, and all the arc times were confirmed to be under 0.5 seconds.

4. Temperature Rise Tests

The test results are given in *Table 5*.

Table 4 Results of L Circuit Breaking Test

Working voltage (V)	Breaking current (A)	Circuit inductance (mH)	Arc time (ms)	Arc voltage (V)
1,650	4,020	16	50～62	3,100～3,200
	8,150	8	51～60	3,050～3,160
800	4,150	16	79～96	1,600～1,800
	7,570	8	60～75	1,500～1,800

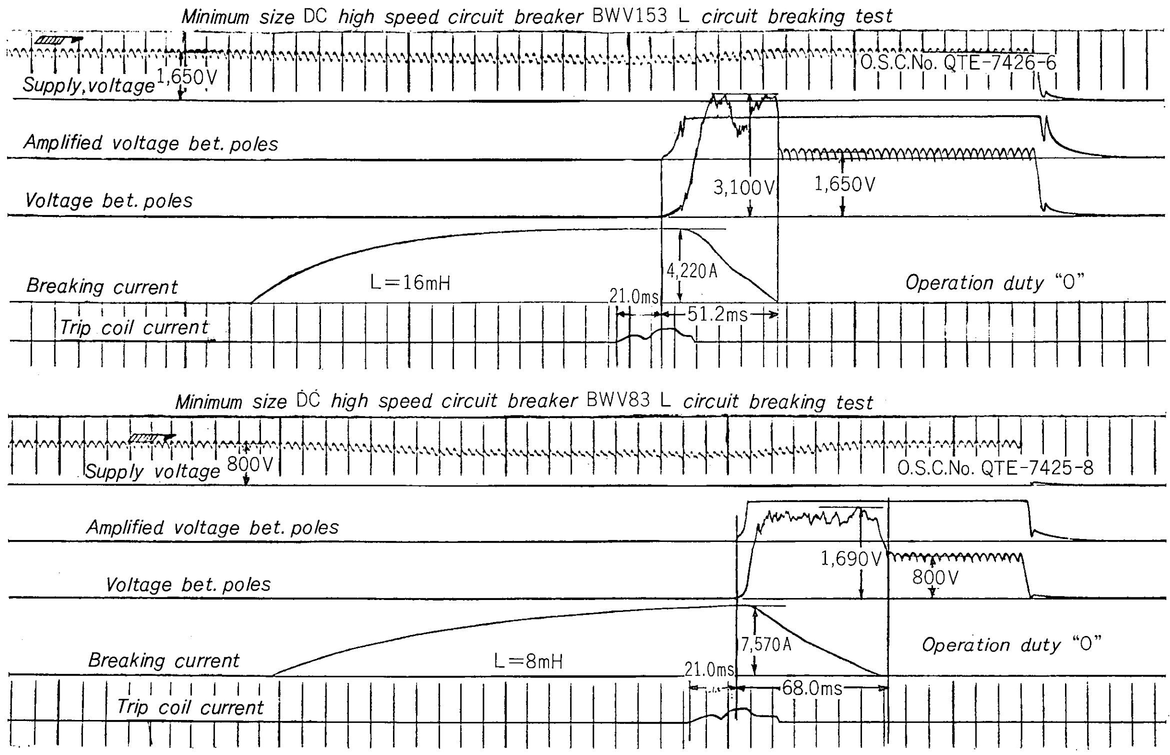


Fig. 8 Oscillogram of L circuit breaking test

Table 5 **Results of Heatrun Test**

Type	Through current (A)	Temperature rise (°C)			
		Upper terminal	Contact	Flexible lead	Lower terminal
BWV 82, 152	2,000	36	64	41	34
BWV 83, 153	3,000	37	68.5	47	36
BWV 84, 154	4,000	33	60	39	30
BWV 86, 156	6,000	37.5	69	48	37
Standard		40	75	60	40

VI. CONCLUSION

3,000 A, 4,000 A, and 6,000 A breakers in addition to the 2,000 A breaker already reported has been completed and the minimum size DC high speed circuit breaker type BWV Series has been completed.

This circuit breakers meet todays demands for small size, light weight and easy maintenance and inspection, and will contribute to the rationalization and reduction in size of DC substation facilities over a wide range.