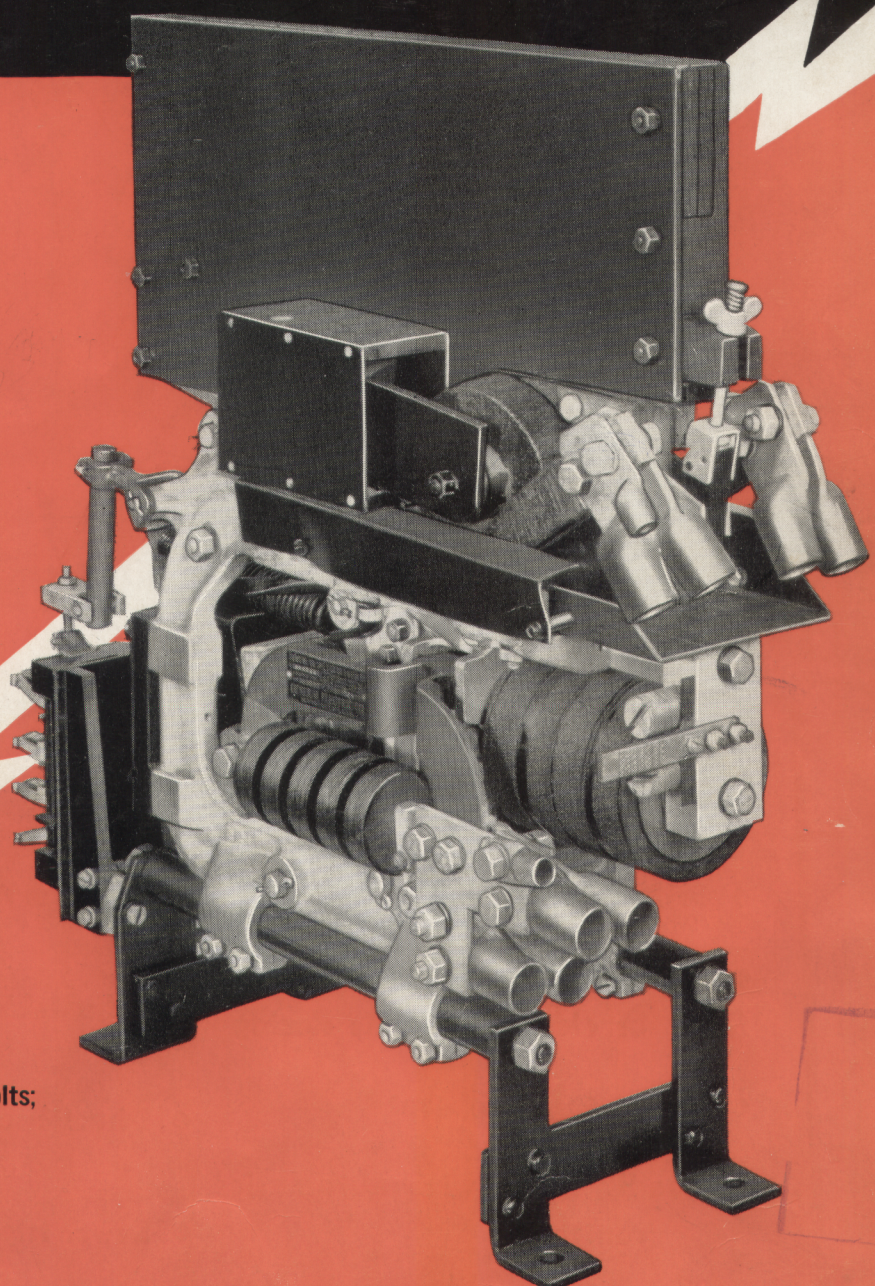
GEA-7208

HIGH SPEED D-C CIRCUIT BREAKERS

For
PROTECTING
and
SWITCHING

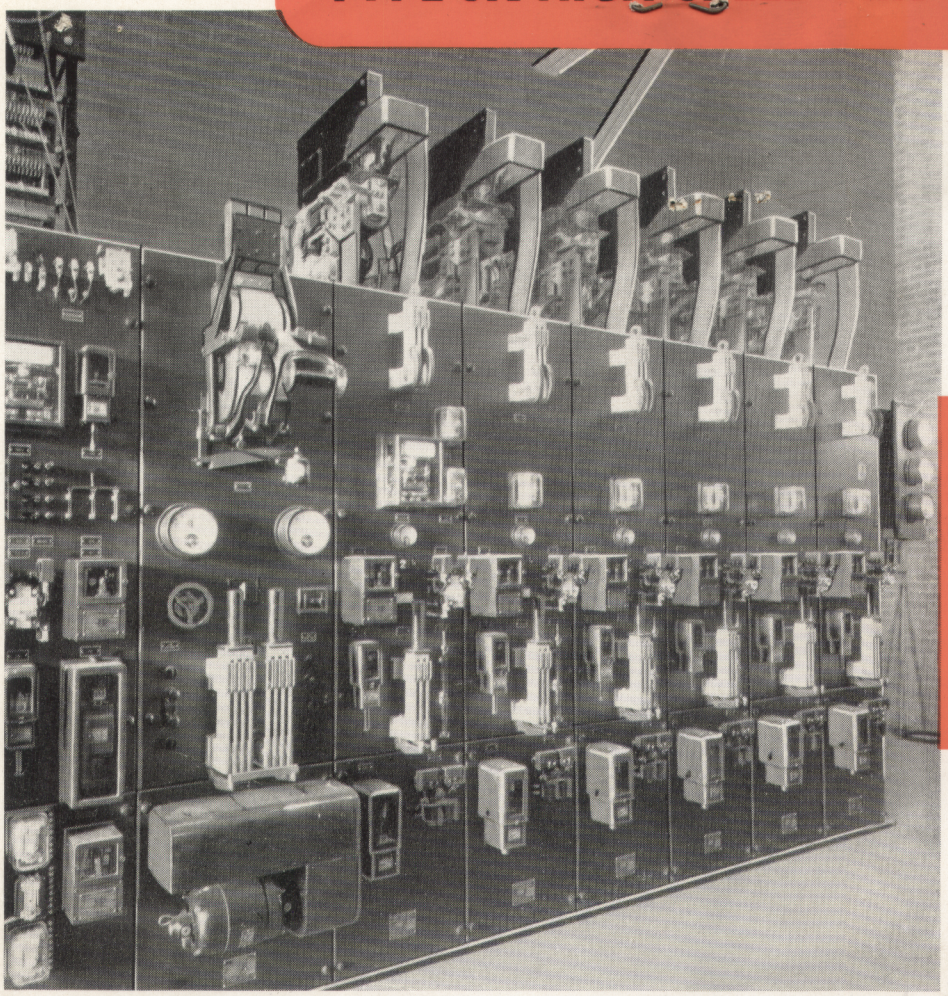
Synchronous Converters
•
Generators
•
Rectifiers
•
Locomotives
•
Feeder Circuits



Type JR
For 600, 1500, or 3000 volts;
625 to 10,000 amperes

GENERAL ELECTRIC

TYPE JR HIGH-SPEED AIR CIRCUIT BREAKERS



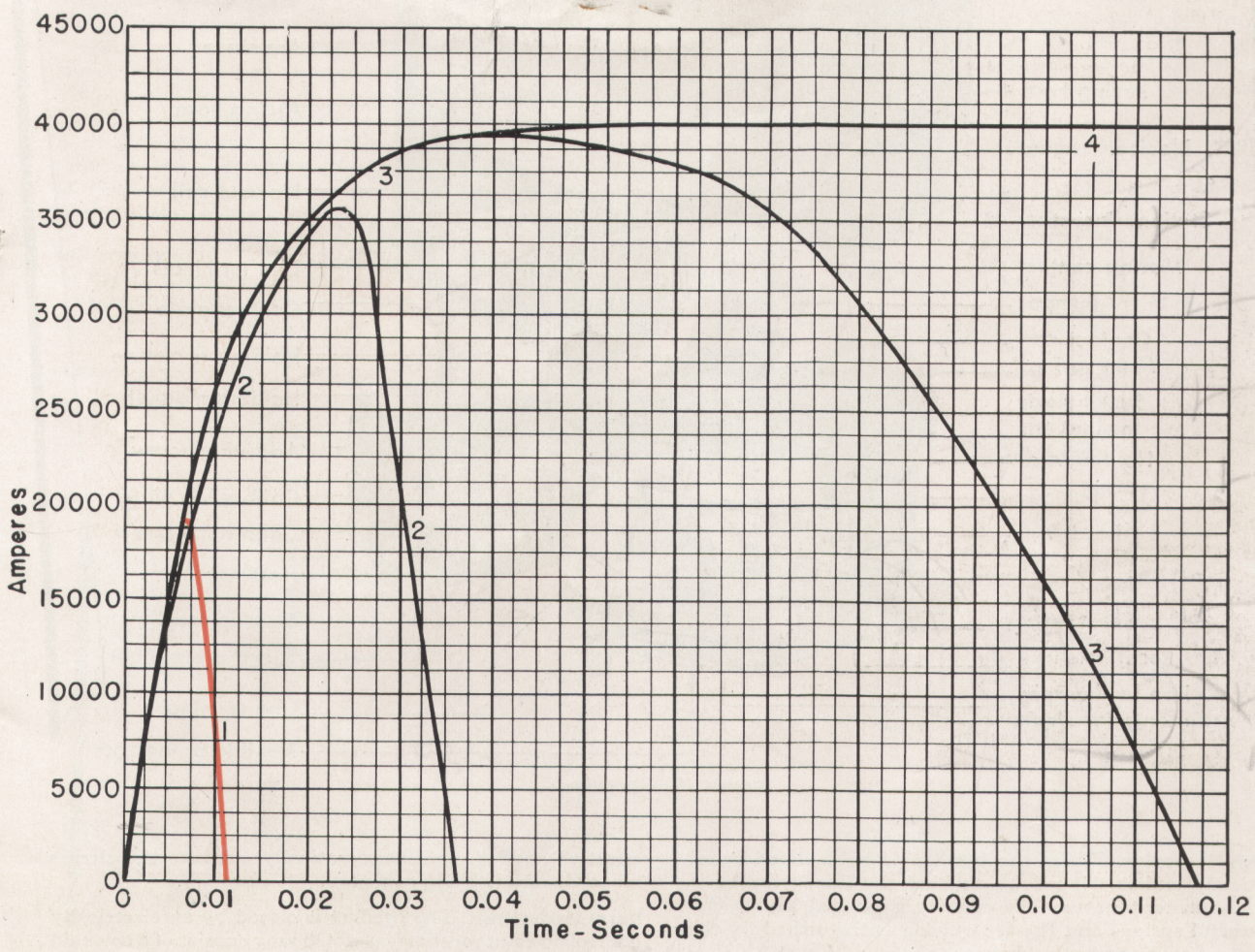
High-speed circuit breakers installed for feeder protection in Ashmont Substation, Boston Elevated Railway.

OUTSTANDING FEATURES

- Self-contained unit
- Electric, electro-pneumatic, or electro-hydraulic closing
- Low-voltage drop-out
- Readily used with automatic control
- Low recovery voltages
- Adjustable calibration
- Directional tripping
- Lower trip point on short circuit

Clear the Circuit Faster and at LOWER FAULT CURRENT

The high speed with which the Type JR breaker trips, as compared with two types of mechanically latched breakers, is illustrated below.



Comparative tripping characteristics of air circuit breakers

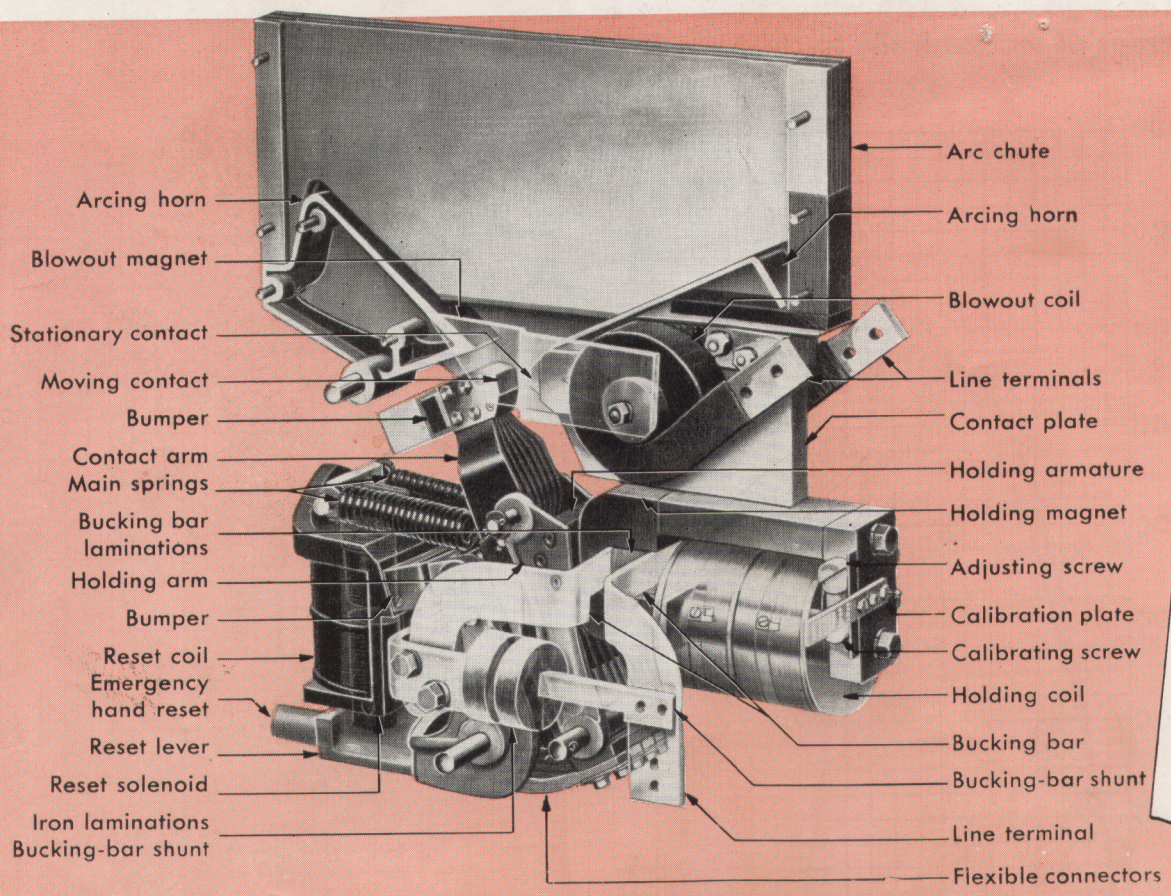
Curve 1 shows that the JR breaker limited the current to less than 20,000 amperes. The mechanically latched circuit breaker with fast moving parts and magnetic blowout on the arcing contacts limited the current to 35,400 amperes (curve 2). The mechanically latched current breaker with carbon arcing contacts did not limit the current, which reached almost 40,000 amperes (curve 3). Curve 4 shows an uninterrupted short circuit. Tests were made with the same external circuit conditions and with the same amount of connected power.

PROVIDES UNUSUAL SELECTIVITY

In addition to minimizing system and substation disturbances and damage from short circuits, the high-speed and current-response characteristics of the Type JR provide many operating benefits not obtainable with lower-speed breakers.

For example, such features as the direct-operating directional trip, the automatic lowering of the breaker trip point with rapid rates of current increase, and the lowering of the trip point with a lowering of line voltage, permit selective operation of breakers when clearing a fault. The JR breaker is, therefore, admirably suited for d-c switching. It is used widely on 600-volt circuits and almost exclusively on 1500- and 3000-volt circuits.

HOW THE TYPE JR HIGH-SPEED BREAKER OPERATES



Details of construction

Latch Mechanism ● Since the breaker is held closed magnetically and is tripped by shifting the flux, tripping is almost instantaneous. The contact is opened rapidly by powerful springs and the arc quickly extinguished by the blowout coils and heavy-duty arc chute.

When the breaker closes, a small laminated armature on the moving-contact arms bridges the gap between the poles of the holding magnet and holds the breaker closed. A bucking bar, connected in series with the contacts, is located in the gap between the magnet poles, near the armature; thus any change in the current flowing through the bucking bar varies the holding flux in the armature on the contact arm.

When a short circuit or overload occurs in a direction to trip the breaker, the current through the bucking bar shifts the flux from the holding armature to release the contact arm and open the breaker.

Interrupting System ● The contacts of the breaker are between the poles of the blowout magnet and directly below the arc-chute opening. The blowout magnet, excited by coils in series with the contacts, gives an intense magnetic field that forces the arc into the long, narrow slots of the arc chute, where it is quickly interrupted. The arc chute is hinged at one end so that it can be swung back to inspect the contact tips.

The 1500- and 3000-volt breakers have an additional blowout coil in the arc chute, which divides the arc into two parts to provide additional blowout effect and more effective cooling. It is automatically cut into the circuit when the arc is being ruptured.

Reset Mechanism ● The breaker is closed by an electrically controlled reset mechanism which may consist of a solenoid coil and air-operated piston, or an oil-operated mechanism obtaining pressure from a motor-driven pump mounted on the breaker.

Control Voltage ● The breaker-holding coil and reset mechanism can be energized from any constant potential d-c source. In substations the control battery, exciter, or main-machine potential can be used. The use of main-machine potential prevents the connection of that machine to the bus until it has built up potential. In cross-tie and sectionalizing stations, the holding coils of the breaker are normally supplied from the bus or line. A reduction in holding-coil voltage by a short circuit lowers the trip point, and results in faster operation of the breaker nearest the short circuit. This assists in obtaining selective operation.

Setting the Trip Point ● Calibrating screws in the holding magnet vary the flux through the holding armature by changing the reluctance of the circuit. The position of the screws determines the tripping point of the breaker.

To facilitate maintenance, the breaker has a calibrating coil in the bucking-bar assembly which permits the calibration to be checked on location. Simply disconnect the breaker from the line and pass current from a separate source through the coil. A conveniently located engraved

plate, mounted on the bucking bar, provides data for making this calibration check.

Discrimination ● The Type JR breaker is built with an inductive shunt in parallel with the bucking bar. On a slow rise of current, such as is caused by load, the breaker will not trip until the current has reached the normal overload trip value, for the current in the parallel paths divides inversely as the resistance of the two paths.

However, on short circuits a greater portion of the current goes through the bucking bar because the surge current divides inversely as the inductance; thus, the breaker is tripped on a lower value of line current than on a normal overload. This "discrimination" feature improves speed and reduces the peak current. The amount of discrimination can be varied by changing the number of iron disks on the bucking-bar shunt.

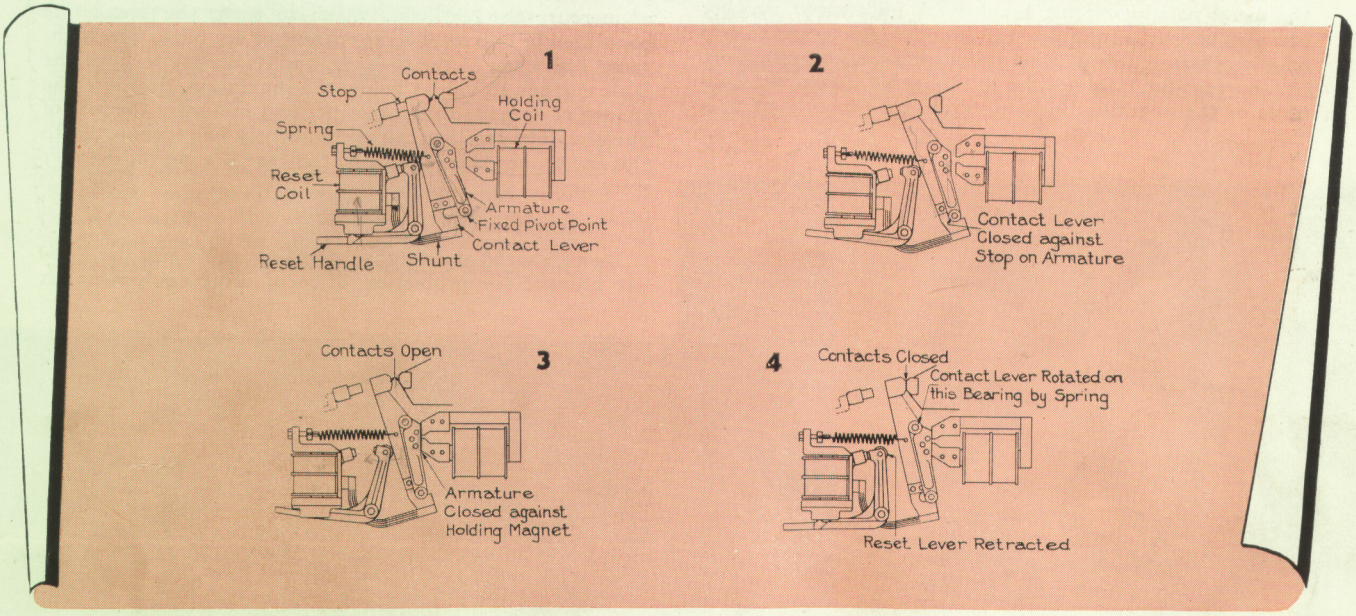
Trip-free Feature ● The Type JR high-speed breaker with its trip-free feature can be closed on load or short circuit without impairing the high-speed protective features. The trip-free action is shown below.

A. On the solenoid-operated breaker, the moving contact arm consists of two parts—the contact lever and the holding armature. The holding armature is pivoted at the bottom to the main breaker frame and at the top to the contact lever.

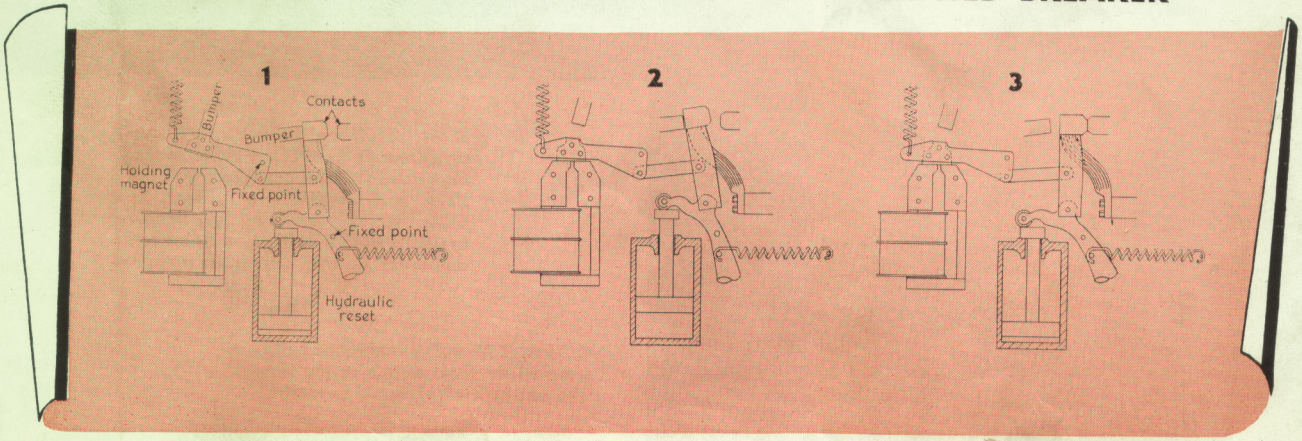
When the reset lever operates, the holding armature revolves forward around its lower pivot until it comes in contact with the holding magnet. During the same motion the contact lever pivots around the upper end of the holding armature so that the contact remains open. As the reset lever drops back, the spring tension rotates the contact lever back about its pivot, and the main contacts snap together. Thus the breaker is in complete readiness to trip when the main contact is made.

B. Although the arrangements of parts are slightly different, the reclosing action of the hydraulically operated breaker is quite similar to that of the solenoid-operated breaker. The lift of the hydraulic piston rotates the moving contact arm in a clockwise direction about the bumper "A" (as a fulcrum) until the holding armature contacts the holding magnet and extends the main springs. The retraction of the piston then allows the contact arm to rotate counterclockwise about its middle pivot and close the circuit. The mechanism at any point in the sequence is completely trip-free.

TRIP-FREE ACTION OF SOLENOID-OPERATED BREAKER



TRIP-FREE ACTION OF HYDRAULICALLY OPERATED BREAKER



THE Type JR high-speed breaker is a self-contained unit which can be located independently of the control point and the protected apparatus. In stations, control switches for both the reset and holding coils, with their respective signal lights, are usually located on the switchboard. An auxiliary contactor is used to handle closing current on all solenoid-reset breakers. This auxiliary contactor is furnished as a separate device to mount on the switchboard. Because it is electrically operated, and because the holding-coil principle provides an undervoltage release or safe failure if the control does not operate, the breaker is well-suited for use with automatic control.

Collapsible and readily removed covers are available for use with breakers, particularly those mounted on a machine floor or another location where accidental contact with live circuits would be possible. These covers surround all parts of the breakers except the arc chute.

Synchronous Converters and Motor-generator Sets

When used with synchronous converters or motor-generator sets, a Type JR breaker is usually connected in the negative or grounded side, preferably between the armature and series windings, and is used in addition to the usual positive-circuit breaker. A high-speed breaker can also be used as the positive breaker, connected to trip on the reverse current. This affords maximum protection.

A current-limiting resistor is connected across the contacts of the negative breaker, to reduce the current to a value well within the commutating capacity of the machine. The positive breaker is electrically interlocked with the negative breaker to follow it in opening, thus reducing the short circuit to zero in two steps.

The above method of short-circuit switching is particularly advantageous with synchronous converters. These machines are more liable to flashover during the time the short-circuit current is being decreased than they are while it is increasing. This is due to the large out-of-phase synchronizing current taken to restore the converter armature to the no-load position. By reducing the current in two steps, the probability of flashover is materially reduced.

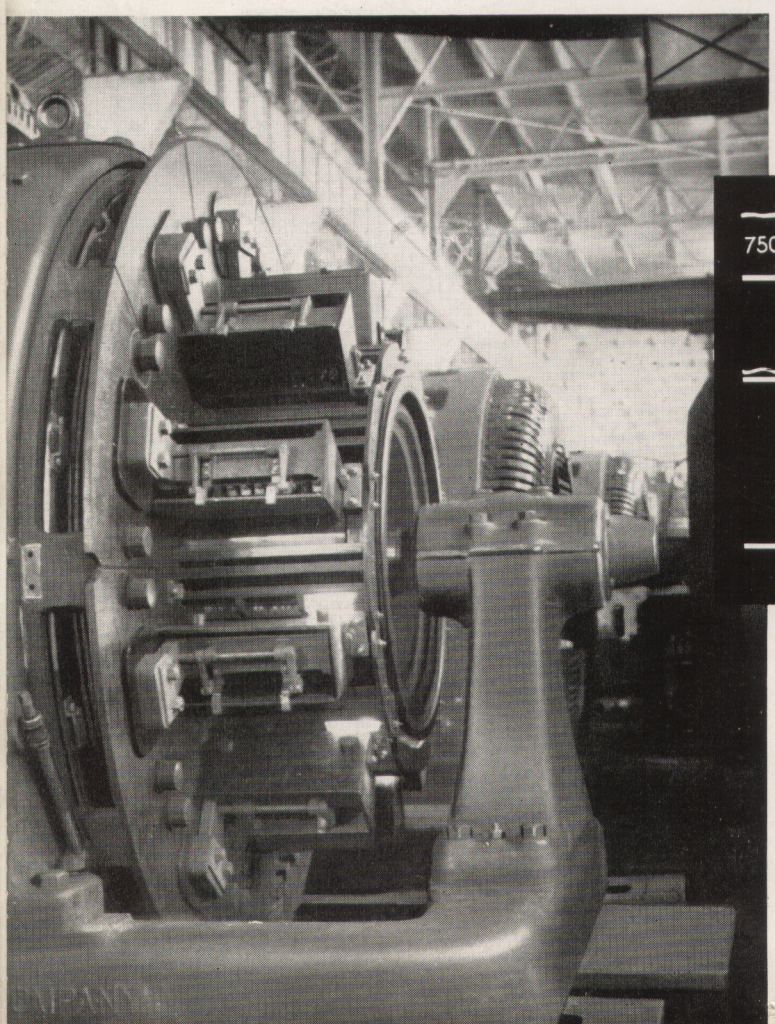
When used with synchronous converters or generators, the negative breaker is usually installed near the commutator end of the machine, either on the same floor or in the basement directly beneath. The positive machine and feeder breakers in high-voltage stations are usually located on a gallery. In low-voltage stations these breakers are often located on the switchboard tie rods above and behind the panels.

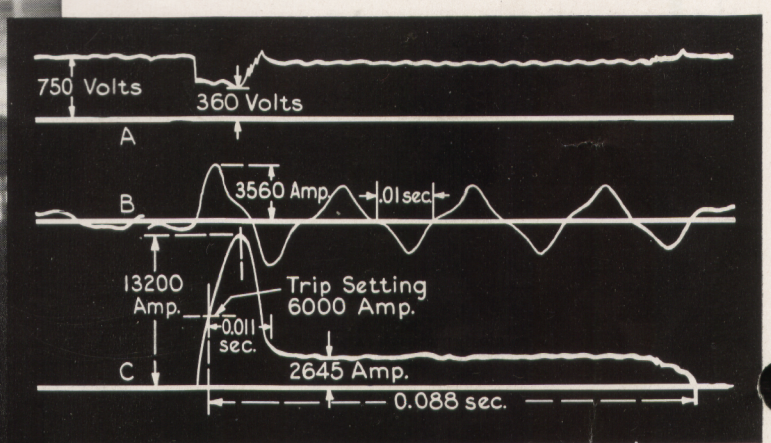
Mercury-arc Rectifiers

The Type JR high-speed breaker is commonly used for switching and protection of the cathode, or positive, circuit of mercury-arc rectifiers. When so used, the breaker is connected to trip on reverse current or arc back. The high-speed operation of the breaker, and its ability to limit the fault current to values below the maximum, decrease the chance of damage to the rectifier and minimize the loss of vacuum. The rectifier can consequently be reconnected to the line sooner than would be the case if a slower breaker were used.

Locomotives

Its high speed and compactness admirably suit the Type JR breaker for protection of locomotive equipment. It





Short circuit on 1000-kw, 750-volt synchronous converter protected by high-speed circuit breaker, flash barriers, and load-limiting resistor. Resistor circuit opened by positive breaker. A, line volts; B, a-c converter amperes; C, d-c converter amperes

1000-kw, 750-volt synchronous converter under short circuit at the time the above oscillogram was made

occupies much less space than any other available switching device which might be used for this service. Its fast operation prevents damage to locomotive apparatus in the event of a motor flashover or short circuit, and thus decreases chances of road failures.

The closing mechanism of the breaker is air-operated on locomotive installations, so that it can be co-ordinated with the electro-pneumatic system controlling the other devices.

Feeder Circuits

The advantages of the Type JR high-speed breaker on feeder circuits are threefold: greater protection against apparatus damage; less possibility of disturbance to both the system and the conversion apparatus; and breaker selectivity, because it inherently discriminates between short circuits and overloads.

The Type JR breaker is also used in automatic-reclosing feeder equipment where both the discriminating and trip-free features are very advantageous. The breaker in conjunction with relays will operate automatically, remaining open as long as the short circuit persists or for a definite time after the short circuit has been removed.

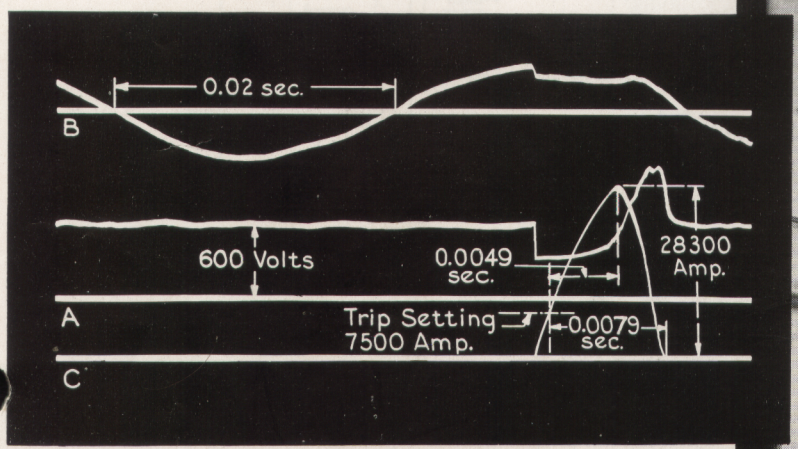
Co-ordinated Distribution Systems

The combination of fast operation, ability to limit currents on short circuits, directional tripping, adjustable trip setting, discriminating feature, and a lowering of the trip point with a reduction in holding-coil voltage—all provided in the Type JR breaker—make it ideal for selective operation on co-ordinated distribution systems. Selective operation can readily be obtained between the breakers used in the cross-tie and sectionalizing station and those used in the substation. Therefore, a fault can be completely isolated quickly, with little disturbance to the system. The breaker adjustments to obtain selective operation are as follows:

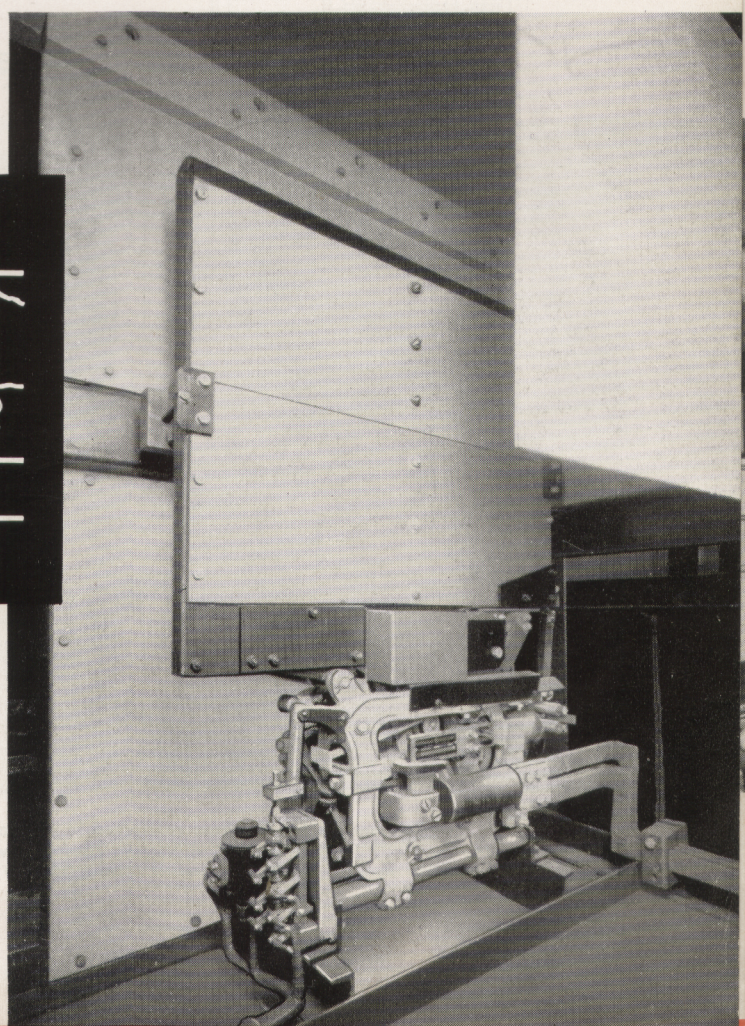
A. The breaker trip settings may be adjusted in proportion to the load currents carried by the breakers. That is, the cross-tie and sectionalizing-station breakers may have the lowest setting, the substation-feeder breakers may be somewhat higher, and the conversion-apparatus breakers may be given the highest setting.

B. The adjustment of the discrimination feature of the breakers depends on the application. The breakers protecting the conversion apparatus may be adjusted to trip at a definite current regardless of the rate of current increase. The substation feeder breakers may be adjusted with some discrimination or lowering of the trip point with a rapid rate of current increase. In the cross-tie and sectionalizing stations, the breakers may be adjusted with the maximum amount of discrimination.

C. The breakers in the substations should have their holding coils supplied from a constant-voltage source. The holding coils of the cross-tie and sectionalizing-station breakers should be supplied from the system voltage. On a remote short circuit the substation voltage remains normal, while the system voltage at the short circuit will be zero. Thus, there will be a gradual change in system voltage from zero at the short circuit to normal at the substation. In this way, the breaker nearest the short circuit will have the greatest reduction in voltage with a corresponding lowering in its trip point.



Short circuit on 600-volt feeder of 12,000-kw substation protected by high-speed circuit breaker. Short circuit made at station. A, line volts; B, incoming station volts, 25 cycles; C, d-c feeder amperes

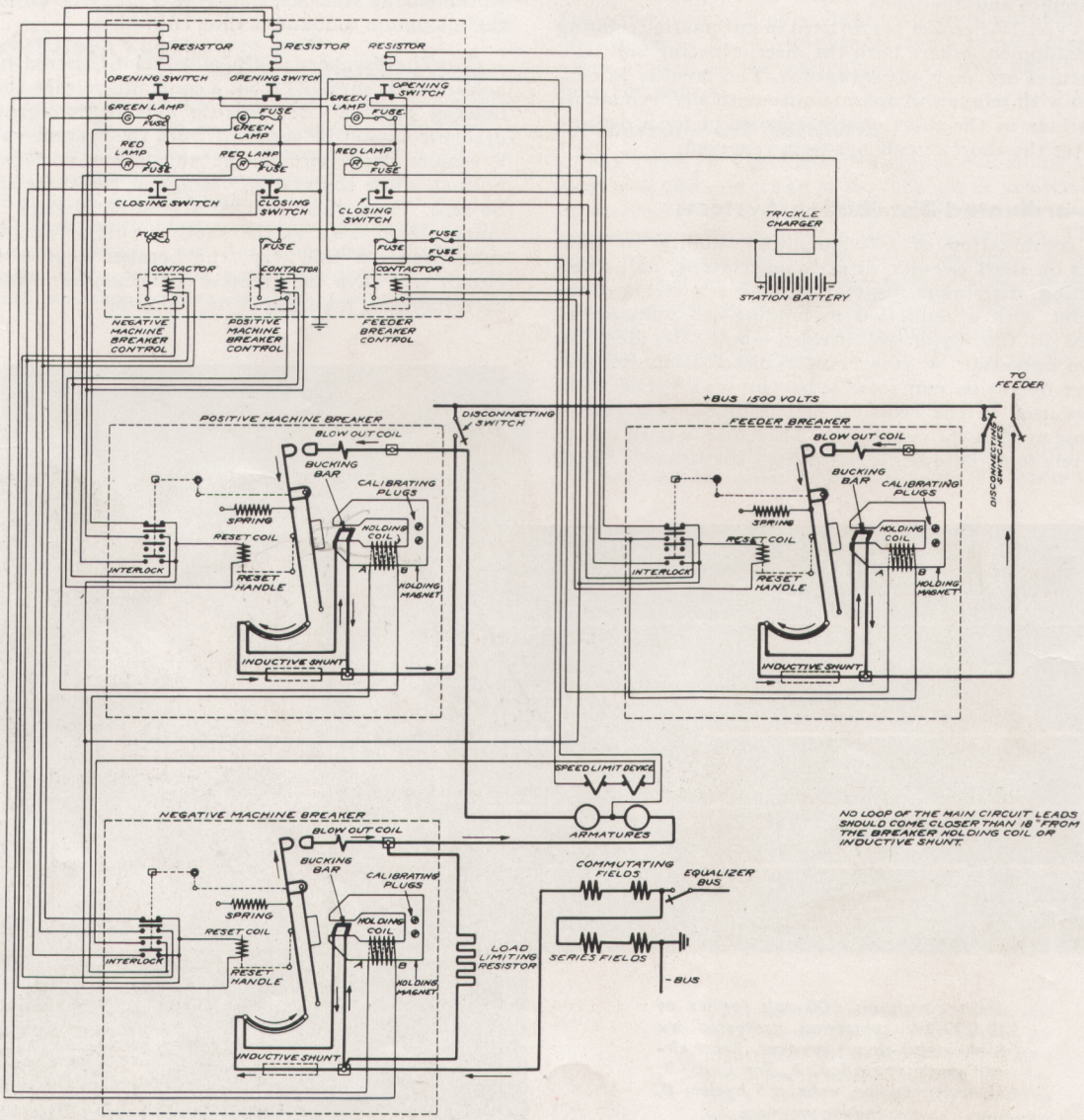


A 3000-volt Type JR breaker installed in a locomotive

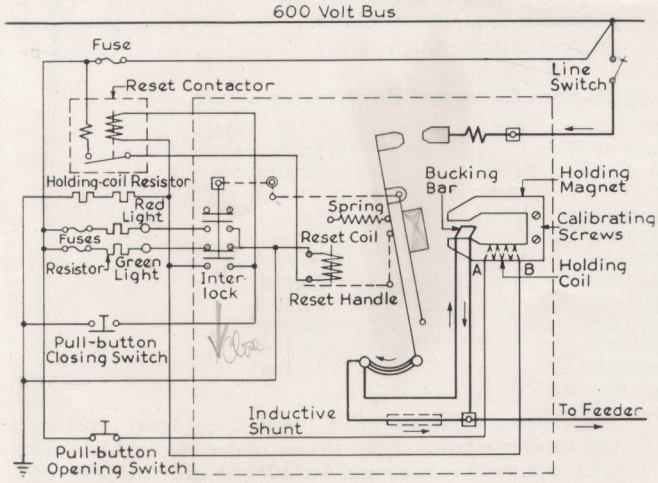
Control

Control of the Type JR high-speed breaker is quite simple. The holding coil is usually energized continually even with the breaker open. The closing circuits are energized momentarily to close the breaker. The breaker may be automatically tripped open or may be opened by momentarily interrupting the holding-coil current. Typical control circuits are shown below. Note that separate voltage sources may be used for the holding coil, the closing coil, and the indicating lights.

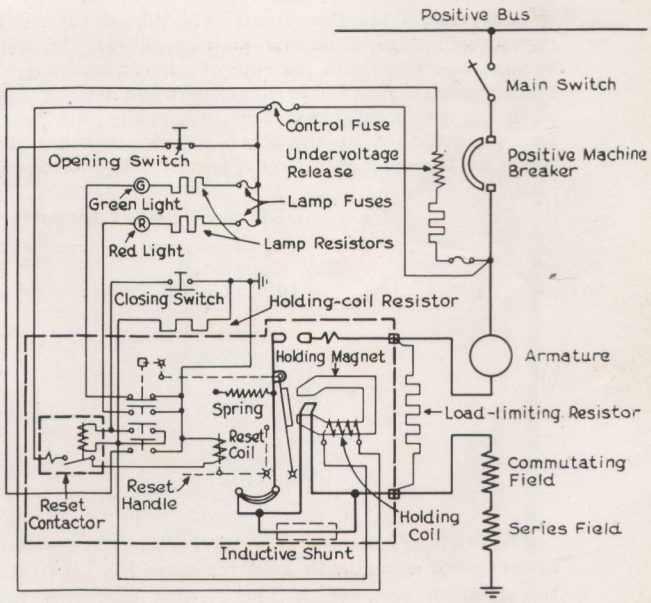
In a 600-volt station it may be desirable to use system voltage for the holding and closing circuits and supply indicating lights from the 125-volt control battery. In a 3000-volt cross-tie and sectionalizing station, the holding coil would be supplied from the system, and the closing coil and indicating lights, from a control battery.



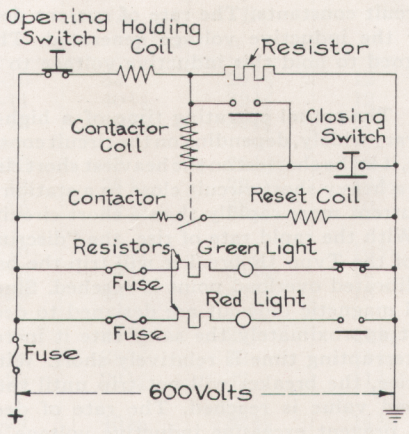
Connections for breakers connected in the positive, negative, and feeder circuits of a 1500- or 3000-volt substation equipped with either two 750-volt converters or two 1500-volt generators in series



Connections for breaker in the feeder circuit of a 600-volt substation



Connections for breaker on the grounded side of a 600-volt generator or synchronous converter



Simplified control connections for breaker in the feeder circuit of a 600-volt substation



Type JR-31, 2000-amp breakers installed in Rossville Avenue substation, Delaware, Lackawanna & Western electrification

PROTECTION CAPACITY

The Type JR breaker will provide adequate protection on practically any circuit regardless of the conversion capacity supplying the circuit. The actual current interrupted will depend largely on two things: the speed of breaker operation and the rate of current increase—while the mechanical speed of breaker operation may be regarded as being practically constant. (Actually the magnetic forces established by the short circuit somewhat tend to speed up the mechanical movement.) The rate of current increase is limited by the constants of the circuit involved. Tests have been made which show that a point is reached where the connection of additional capacity to the bus produces no measurable increases in the initial rate of current rise. As a consequence of these two factors, a definite limit in current interrupted is obtained with any particular type of installation. The following typical test results illustrate this point.

600-volt Short Circuits with .002-ohm External Resistance

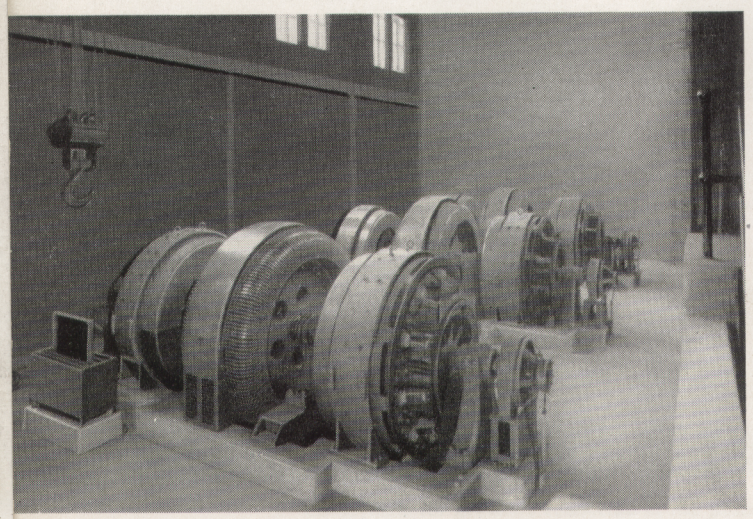
KW Connected to Bus	Max Rate of Rise, Amps per Sec	Max Amps Interrupted
2,000	3,050,000	14,100
4,000	4,250,000	22,200
6,000	6,665,000	30,800
7,000	6,050,000	27,200
8,000	7,400,000	27,700
10,000	7,600,000	28,200
11,000	7,000,000	33,100
12,000	7,000,000	28,400

The fallacy of measuring a breaker's performance by its interrupting capacity in amperes is readily illustrated by the diagram on page 3. The slowest operating breaker interrupts a larger current than the Type JR, yet the two breakers provide the same protection—the Type JR just does the job faster.

In unusual circumstances when the interrupting capacity of a high-speed breaker must be specified, it should be expressed in terms of the circuit constants and not amperes interrupting capacity. Give the voltage, total resistance, and total reactance of the circuit in question. Total resistance and reactance should include the generating or conversion apparatus. Another method of specifying circuit constants is to give the initial rate of current increase, and the maximum value of fault current; for example, the high-speed breaker on page 6 was interrupting a 600-volt circuit having an initial rate of current increase of 3,200,000 amperes per second and a maximum sustained value of fault current of 40,000 amperes.

SPEED OF OPERATION

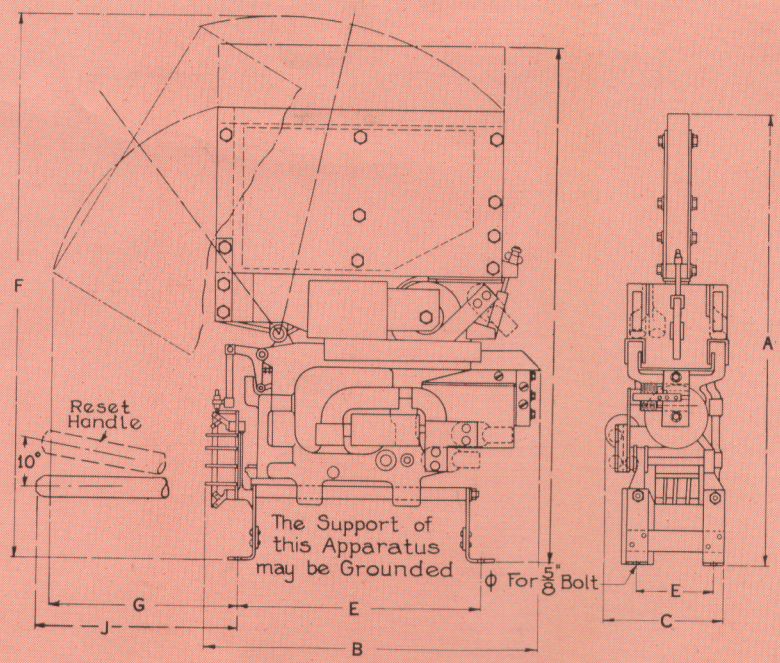
Effective Tripping ● The over-all interrupting time, like interrupting capacity of the Type JR breaker, is no index of its performance. The important part of the interrupting cycle is from the trip point until the fault current reaches the point where it is no longer of destructive magnitude. The Type JR breaker does this quickly and effectively. On heavy short circuits, it starts to open before the current reaches the calibrated overload value, and begins to reduce the fault current long before it reaches the limits set by the circuit constants. The rate of current decrease is limited by the inductive voltage generated. The arc chute is designed to hold this inductive voltage to a safe value.



Three 3000-kw, synchronous motor-generator sets with high-speed circuit-breaker protection, Cleveland Union Terminal electrification

Speed Varies ● The actual operating time of a high-speed breaker may vary widely, depending on the circuit constants. Oddly enough, it is the shortest on the heaviest short circuits. For example, a heavy short circuit close to a station tends to build up current more rapidly than a short circuit on a remote line. With the rapid rate of rise, the "discriminating" feature of the Type JR breaker will trip the breaker before the calibrated overload point is reached. Since the arc chute and magnetic blowout are designed to decrease the current at approximately the same rate it increased, the actual interrupting time is relatively short. With the slow rate of rise, the breaker will not trip until the calibrated overload value is reached. The rate of decrease being low, to prevent excessive inductive voltage across the contact tips, the interrupting is relatively slow.

Three Times as Fast ● In speed of operation the Type JR is relatively three times as fast as the conventional panel-mounted switchgear breaker. Its interrupting time will vary with the size of the breaker, the voltage of the circuit, and the circuit constants. The interrupting time for the 600-volt circuit shown on page 6, measured from the breaker trip point, was .01 second. Any specification of operating time should include data on the circuit in the same manner as given above in connection with interrupting capacity.



Outline of Type JR high-speed circuit breaker

DIMENSIONS (INCHES)

Type	OVER-ALL			Supporting Hole Spacing		Clearance Required for Arc Chute			Clearance to Remove Manual Reset Handle
	Height	Length	Width	Length	Width	To swing back		To remove	
	A	B	C	D	E	F	G	H	J*
JR-10	33	29 1/2	12	20 1/2	7	44	10 7/8	38 1/2	16 5/8
JR-11	40 1/2	32 1/4	12	22 1/2	7	48 3/4	16 7/8	46 1/2	....
JR-12	40 1/2	32 1/4	12	22 1/2	7	48 3/4	16 7/8	46 1/2	....
JR-13	33	29 1/2	12	20 1/2	7	44	10 7/8	38 1/2	16 5/8
JR-14	36 3/4	32	10 5/8	22 1/2	7	45	16 7/8	42 3/4	....
JR-15	49 1/2	38	10	22 1/2	7	57 3/4	29 7/8	55 1/2	....
JR-16	36 3/4	32	10 3/8	22 1/2	7	45	16 7/8	42 3/4	....
JR-18	40 1/2	31 5/8	12	22 1/2	7	48 3/4	16 7/8	46 1/2	....
JR-20	48	46 7/8	18	31	14	64 1/4	13 3/4	55	17 3/4
JR-21	29 1/4	32	11 1/8	22 1/2	7	40 1/4	10 3/8	34 3/4	....
JR-22	36 3/4	32	11 1/8	22 1/2	7	45	16 7/8	42 3/4	....
JR-23	29 1/4	32	11 1/8	22 1/2	7	40 1/4	10 3/8	34 3/4	....
JR-24	40 1/2	32 3/8	14 1/2	22 1/2	8 3/4	48 3/4	16 7/8	46 1/2	21 1/8
JR-25	35 1/2	32 3/8	14 1/2	22 1/2	8 3/4	45 5/8	12 1/2	41 1/2	21 1/8
JR-26	29 1/4	32	10 7/8	22 1/2	7	40 1/4	10 3/8	34 3/4	16 1/8
JR-29	49 1/2	39 1/2	9 3/4	22 1/2	7	57 7/8	29 7/8	55 1/2	....
JR-31	54 1/2	48	12	22 1/2	7	67 1/4	34 1/2	60 1/2	....
JR-33	54 1/2	48	12	22 1/2	7	67 1/4	34 1/2	60 1/2	....
JR-34	40 1/2	33 1/8	14 1/8	22 1/2	8 3/4	48 3/4	16 7/8	46 1/2	21 1/8
JR-35	33	29 1/2	11 1/8	20 1/2	7	44	14	38 5/8	14 5/8
JR-36	48	57 3/8	24	25	20	65 1/2	....	57	65
JR-42	48	57	24	25	20	65 1/2	....	57	65

*Dimension "J" when not given is less than "G."
ϕFor 1-in. bolt in JT-20 and JR-36.

STANDARD RATINGS

When ordering the Type JR breaker be sure to give complete information on the following:

Location of the breaker in the system, purpose for which it is to be used, size and capacity of machines and circuits, control voltages available and preferred.

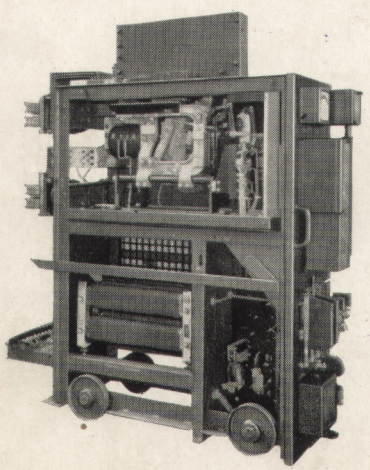
COMMONLY USED TYPE JR HIGH-SPEED CIRCUIT BREAKERS

Type	Rating			Calibration Range Amperes	Net Wt in Lb
	Volts	Amperes			
		Cont.	2 Hr		
JR-35	600	625	750	320–800 or 600–1500	285
JR-13	600	1250	1500	600–1500 or 1500–3750	310
JR-10	600	2000	2500	1500–3750 or 2000–5000	315
JR-25	600	3000	3600	2400–6000 or 6000–15,000	480
JR-20	600	4000	5000	5000–12,000	1110
JR-42	600	6250	9000	1200–2800	1930
JR-36	600	10,000	12,500	2000–4500	2040
JR-18	1500	625	750	320–800 or 600–1500	265
JR-11	1500	1250	1500	600–1500 or 1500–3750	375
JR-12	1500	2000	2500	1500–3750 or 1800–4500	400
JR-24	1500	3000	3600	2400–6000 or 4000–10,000	515
JR-33	3000	1250	1500	400–1000 or 600–1500	475
JR-31	3000	2000	2500	1500–3750 or 2000–3000	575

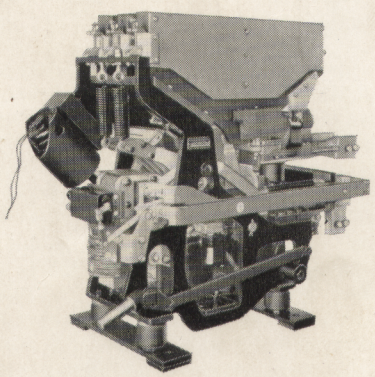
NOTE—Other calibration ranges are available on request.

TYPE JR BREAKERS FOR LOCOMOTIVES (AIR RESET)

Type	Volts	Capacity Amperes		Calibration Range, Amperes	Net Wt in Lb
		Continuous Rating	1-hour Rating		
JR-23	600	750	11,000	1500–2000	300
JR-21	600	1500	2250	3000–4000	300
JR-26	600	2000	3000	6000–10,000	300
JR-34	600	3000	4000	6500–10,000	470
JR-16	1500	625	1000	900–1500	345
JR-14	1500	1250	2000	2000–3000	340
JR-22	1500	1750	2600	3400–4400	350
JR-15	3000	625	1000	800–1200	400
JR-29	3000	1250	2000	2000–3000	400



Type JR-25, 3000-amp, 625-volt breaker, mounted in a G-E safety-enclosed removable truck. Side covers removed



Type JR breaker widely used with mercury-arc rectifiers

GENERAL ELECTRIC COMPANY

Schenectady, New York

10-43 (3M)

PRINTED IN U.S.A.