# Chapter 4

# REVERSE CURRENT CIRCUIT BREAKERS, B.T.H., LEA SERIES

## LIST OF CONTENTS



## LIST OF ILLUSTRATIONS



### Introduction

**1.** These circuit breakers are designed as protective devices for installation in d.c. aircraft power supply systems. The function of each breaker is to disconnect and isolate a faulty generator circuit, and prevent wastage of power wherever a fault gives rise to a current, flowing from the bus-bars to the generator, that is, in reverse to the normal current which flows from the generator to the bus-bars.

### Principle of operation

**2.** When the breaker is set, the main contacts (*fig.* 1) are held closed by spring pressure and a toggle mechanism. Current from the generator passes from terminal 2 to terminal 1 of the circuit breaker through a single turn coil. The current through this coil sets up a flux in a soft iron yoke, between the poles of which is pivoted a permanent magnet.

**3.** Should the direction of current reverse, the flux in the yoke reverses and the magnet will swing over to the other side of the yoke. This movement is transmitted to a trip lever which releases the latch holding the toggle mechanism with the contacts closed.

**4.** When the latch is released the toggle mechanism is returned by springs to its free position and in so doing opens the main contacts.

**5.** A timing device controls the speed with which the permanent magnet swings over, to ensure that reverse currents of only short duration will not trip the breaker.

**6.** For remote tripping, a solenoid is incorporated (*fig.* 1). When this solenoid is energized, by a remote trip switch, its armature is deflected to move the trip lever which, as for a reverse current, releases the latch and trips

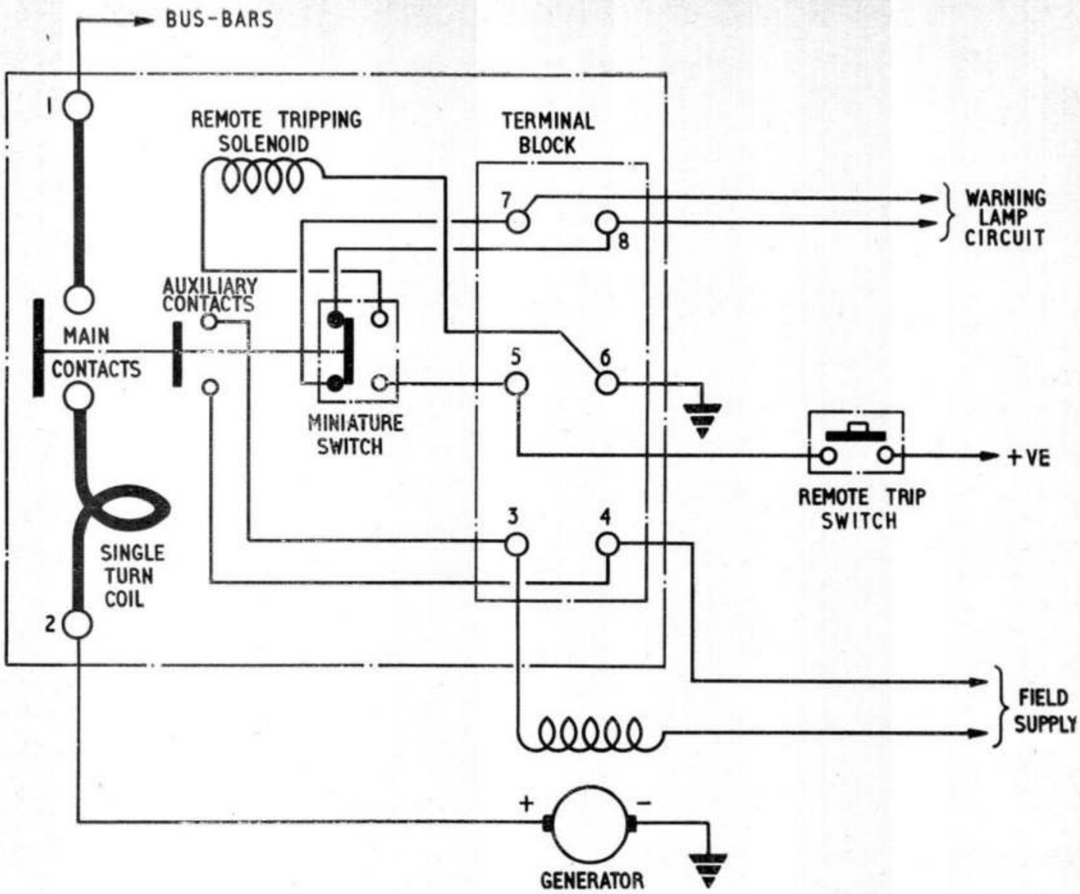



Fig. 1. Wiring diagram


Fig. 2. Typical reverse current circuit breaker of the LEA series

the breaker. The breaker can also be tripped manually by depressing a manual plunger (*fig.* 2) on the top face of the breaker. Depressing this plunger moves the trip lever, resulting in the breaker being tripped.

**7.** Re-setting, that is, closing the contacts, and setting the toggle mechanism to keep them closed, can only be accomplished by manual depression of the setting handle. This handle protrudes through the top cover and is protected by a pliable rubber shield. Re-setting is impossible if reverse current is still flowing, or if the remote trip switch is still in the closed position.

**8.** A set of auxiliary contacts (*fig.* 1), which open and close at the same instant as the main contacts, completes the circuit to the field coils of the generator when the breaker is set and isolates the field when the breaker is tripped.

**9.** A miniature switch (*fig.* 1) is housed in the mechanism and is operated by the toggle mechanism as the breaker is re-set. When the main contacts are closed, the circuit to the remote tripping solenoid is completed through this switch. As the breaker trips, the miniature switch changes over and opens the circuit to the tripping solenoid and closes a circuit containing a remote warning lamp or indicator. On some models the single miniature switch is replaced by two separate switches to separate the two circuits.

**10.** A mechanically operated indicator can be viewed through an inspection window (*fig.* 2) to determine whether the breaker is set or tripped.

**11.** The mechanism is housed in a light alloy case, the top of which carries the manual trip button and houses the setting handle (*fig.* 2). A six-point terminal block (*fig.* 1) at the end facilitates connection to the trip solenoid and the auxiliary contacts and miniature switches.

## DESCRIPTION

**12.** The case of the circuit breaker is secured to the main base (19, *fig.* 3) consisting of Bakelite mouldings secured onto a metal base plate (18). A number of recesses in the upper moulding contains the main conducting copper bars. Input (20) and output (10) terminals are located one at each end and secured directly to these conducting bars, one of which is formed into a large loop forming the coil (21) and terminates with a main contact (17) riveted to the bar. The second bar also terminates with a main contact (16) close to the other contact but separated by a vertical barrier (15) consisting of an asbestos-cement moulding. This barrier resists burning by electric arcs and is highly resistant to electrical creepage.

**13.** A contact bar (14), freely pivoted at the end of the plunger (30), carries two moving contacts positioned above the main fixed contacts. As the breaker is closed, the plunger carrying the contact bar moves down until the moving contacts meet the fixed contacts, thus completing the circuit through the breaker. The freely pivoted contact bar ensures that each contact is made with equal pressure. The upper Bakelite moulding (12) forms a complete housing around the contact assembly with a bushed hole at the top acting as a slide bearing for the plunger. A spring (13) on the underside of this bush presses onto the contact bar to ensure that the bar remains level when the contacts open so that both contacts break at the same time.

### Toggle mechanism

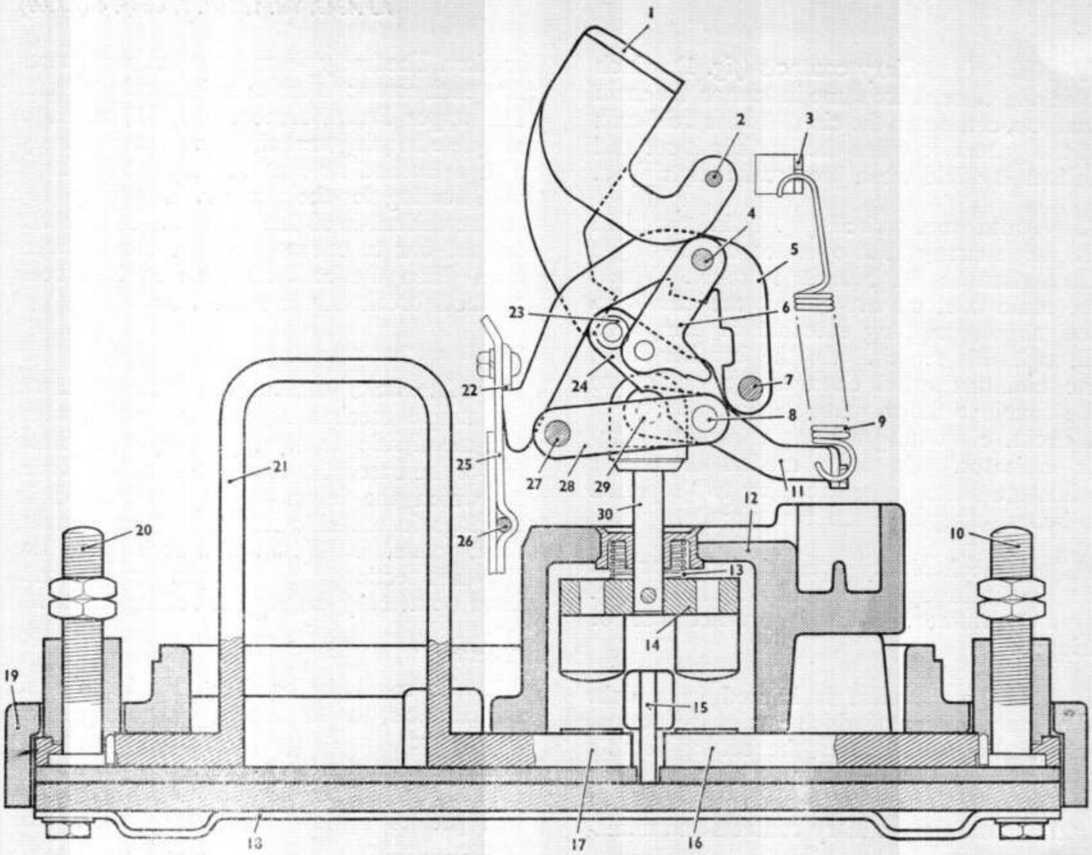
**14.** The links and levers which constitute the toggle mechanism are located between two metal side frames (*fig.* 6) secured to the top of the base. Some of the pins and pivots on which the levers rotate are located in bearings in the side frames and are termed fixed points. In fig. 3 and 5 such points are shown in section; the toggle pin (4, *fig.* 3) is a fixed point only during the setting action.

#### *Re-setting*

**15.** To re-set the breaker, that is, to close the contacts, the handle (1, *fig.* 3) is pressed downwards, a sharp pressure being more effective than a steady force. As the handle rotates on the fixed handle pin (2), the lower end presses against the setting roller (23) housed between the two setting links (24). The link pin (8) will be moved downwards as the two parallel links (28) rotate on the fixed spindle (27), and the two parallel toggle links (6) rotate about the toggle pin (4). As the handle (1) is pressed further downwards, the toggle links (6) and setting links (24) will become in line and the link pin (8) is forced further downwards, tensioning the return springs (47, *fig.* 4) located between the extension of the link pin (49) and a fixed pin in the side frames.

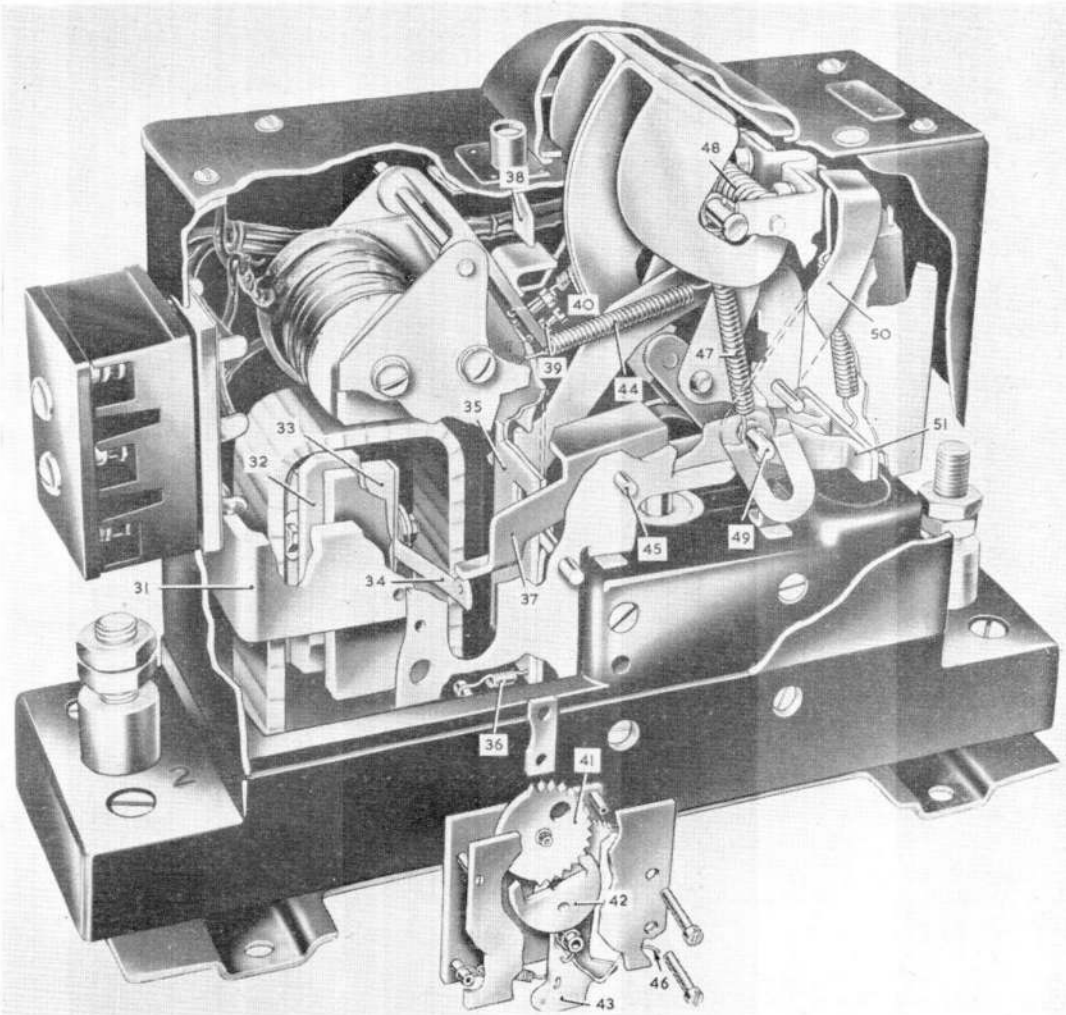
**16.** When the toggle links (6, *fig.* 5) and setting links (24) have passed the neutral point, that is, when they move beyond the point where they are in line, the return springs (47, *fig.* 4) will tend to re-close the toggle action, but this is restricted when the setting roller (23, *fig.* 5) comes into contact with a recess in the edge of the latch. When the handle is released it will return to its free position under the action of its own coiled return spring (48, *fig.* 4), leaving the toggle mechanism set.

**17.** As the link pin (8, *fig.* 5) is lowered, the plunger pin (29) will also be lowered since the contact lever (11) will rotate about the link



1 SETTING HANDLE
2 HANDLE PIN
3 BRACKET
4 TOGGLE PIN
5 LATCH
6 TOGGLE LINKS
7 LATCH PIVOT
8 LINK PIN
9 CONTACT SPRING
10 OUTPUT TERMINAL
11 CONTACT LEVER
12 UPPER BAKELITE MOULDING
13 CONTACT BAR SPRING
14 CONTACT BAR
15 CONTACT BARRIER
16 MAIN CONTACT
17 MAIN CONTACT
18 METAL BASE PLATE
19 BAKELITE BASE
20 INPUT TERMINAL
21 SINGLE TURN COIL
22 TRIP PLATE
23 SETTING ROLLER
24 SETTING LINKS
25 TRIP LEVER
26 TRIP LEVER SHAFT
27 SPINDLE
28 LINKS
29 PLUNGER PIN
30 PLUNGER

**Fig. 3. Section of base, contacts and toggle mechanism**



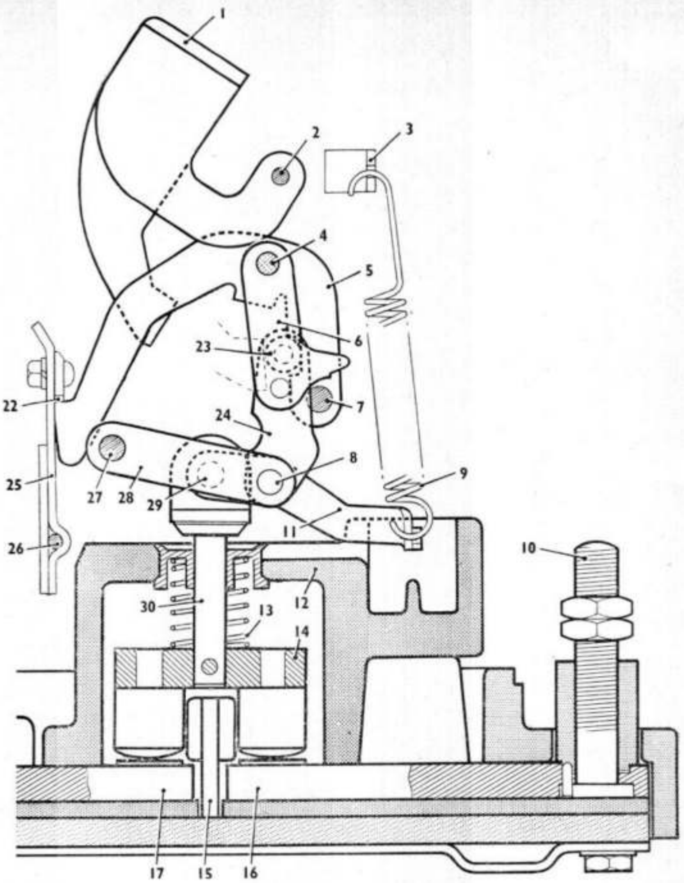

| | | | |
|---|---|---|---|
| 31 | YOKE | 42 | PALLET |
| 32 | POLE FACE | 43 | QUADRANT |
| 33 | PERMANENT MAGNET | 44 | TENSION SPRING |
| 34 | RE-SET ARM | 45 | SPINDLE |
| 35 | TRIP LEVER (BACK PLATE) | 46 | TIMING SPRING |
| 36 | TRIP LEVER RETURN SPRING | 47 | RETURN SPRING |
| 37 | RE-SET LEVER | 48 | SETTING HANDLE RETURN SPRING |
| 38 | MANUAL TRIP PLUNGER | 49 | LINK PIN EXTENSION |
| 39 | TRIP SETTING SCREW | 50 | FLAG LEVER |
| 40 | SOLENOID ARMATURE RETURN SPRING | 51 | CONTACT LEVER SIDE EXTENSION |
| 41 | ESCAPE WHEEL | | |

**Fig. 4. Sectional perspective**

pin (8), due to the contact spring (9) holding the side extension of the contact lever (51, *fig.* 4) against the side frames. The plunger (30, *fig.* 5) is lowered, carrying with it the main contact bar (14), until the main contacts connect. This fixes the position of the plunger pin (29), and continued downward movement of the link pin (8) will cause the contact lever (11) to rotate about the plunger pin (29) and extend the contact spring (9). When the link pin (8) comes to rest, the contact pressure of the main contacts is derived mainly from the contact spring (9) acting through the contact lever (11).

#### Tripping

**18.** The breaker is tripped by rotating the trip lever (25, *fig.* 5) sufficiently to move the trip plate (22) away from the end of the latch (5), allowing the latch to rotate on its fixed pivot (7) under the force of the return springs (47, *fig.* 4) acting through the toggle mechanism. As the latch rotates on its pivots (7, *fig.* 5) the toggle pin (4) will move upwards and to the right, whereas the setting roller (23) will still be constrained in the recess of the latch. A point will be reached where the toggle links (6) and setting links (24) will be in line and a further slight movement of the latch (5) will allow the return springs to force the link pin (8) and toggle pin (4) towards each other and throw the setting roller (29) over and away from the recess in the latch.




| | | | |
|---|---|---|---|
| 1 | SETTING HANDLE | 14 | CONTACT BAR |
| 2 | HANDLE PIN | 15 | CONTACT BARRIER |
| 3 | BRACKET | 16 | MAIN CONTACT |
| 4 | TOGGLE PIN | 17 | MAIN CONTACT |
| 5 | LATCH | 22 | TRIP PLATE |
| 6 | TOGGLE LINKS | 23 | SETTING ROLLER |
| 7 | LATCH PIVOT | 24 | SETTING LINKS |
| 8 | LINK PIN | 25 | TRIP LEVER |
| 9 | CONTACT SPRING | 26 | TRIP LEVER PIVOT |
| 10 | OUTPUT TERMINAL | 27 | SPINDLE |
| 11 | CONTACT LEVER | 28 | LINKS |
| 12 | UPPER BAKELITE MOULDING | 29 | PLUNGER PIN |
| 13 | CONTACT BAR SPRING | 30 | PLUNGER |

**Fig. 5. Toggle mechanism, breaker set**

**19.** As the latch rotates, the tension spring (44, *fig.* 4), which is secured between the toggle pin (4, *fig.* 5) and a fixed bracket on the side frame, is tensioned. Once the toggle mechanism has been tripped this tension spring returns the latch to its free position to engage under the trip plate (22). This trip plate should return with the trip lever (25) as it rotates about its fixed pivot (26) under the action of its own return spring (36, *fig.* 4).

**20.** The upward movement of the link pin (8, *fig.* 5) is limited by its extensions (49, *fig.* 4) which come to rest at the top of the cut-outs in the side frames.

#### Magnet and timing assemblies

**21.** The current flowing through the single turn coil (21, *fig.* 3) will produce a magnetic field the polarity of which depends upon the direction of the current through the coil. This

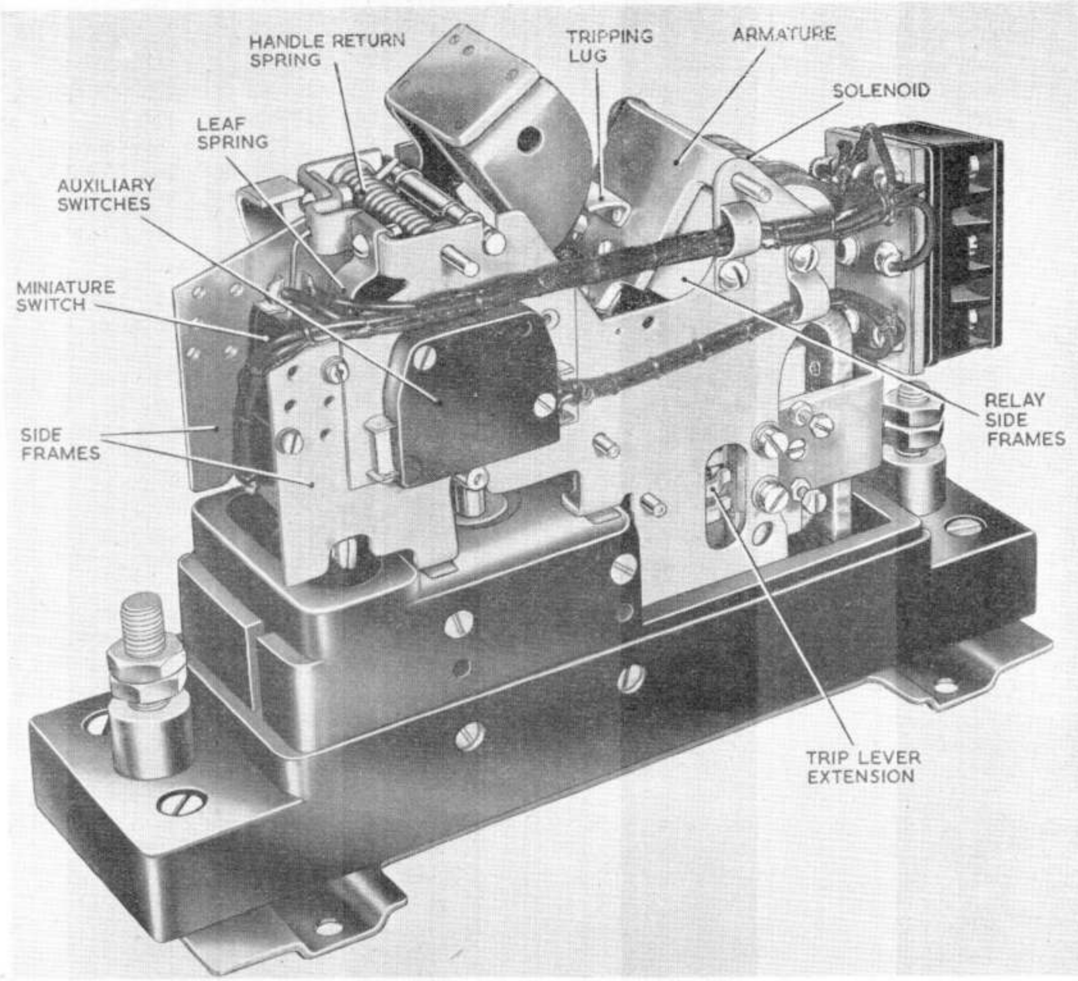



**Fig. 6. Rear view, cover removed**

magnetic field is concentrated in the soft iron yoke (31, *fig.* 4) secured between the side frames around one vertical side of the coil and terminates in two pole faces (32). One of these pole faces carries a bracket locating two pivots on which a permanent magnet (33) is able to rock, its movement being limited by the two pole faces of the armature. This magnet carries two extending arms. On one side an arm is poised over an extension of the trip lever (*fig.* 6), and, if the magnet swings over, this arm will deflect and strike the trip lever extension, rotating the trip lever sufficiently to free the latch and allow the breaker to trip open.

**22.** The re-set arm (34, *fig.* 4), projecting from the magnet to the other side of the breaker, has a hole through which one end of a coiled timing spring (46) engages. This arm is poised under a re-set lever (37), which is an extension of the link, although it is separately pivoted on the spindle (45). The other end of the coiled spring (46) engages a pivoted quadrant (43). The top of the quadrant has gear teeth which engage with a pinion secured to a shaft on which is attached a toothed escape wheel (41). This wheel engages with the arms of a pallet (42). The quadrant escape wheel and pallet are pivoted on pins located between two plates which are screwed together. This assembly forms the timing mechanism and is located on the side of the yoke between the yoke and the main side frame. Fig. 4 shows an exploded view of the timing mechanism to illustrate the components.

#### Reverse current tripping

**23.** With normal current flowing through the circuit breaker, the magnetic polarity of the yoke is such that the permanent magnet remains stationary with one of its arms poised above the trip lever extension (*para.* 21) and the other arm poised below the setting lever (*para.* 22).

**24.** If the current in the coil is reversed, the polarity of the yoke is reversed and the permanent magnet will swing over on its pivots. In doing this the two arms attached to the magnet will be deflected. The one above the trip lever extension will move downwards whilst the other, the re-set arm (34, *fig.* 4), will move upwards. As the latter arm moves upwards, it tensions the timing spring (46) of the timer, which will cause the quadrant (43) to rotate and drive the escape wheel (41). As the escape wheel rotates, the pallet (42) will oscillate about its pivot as it engages the teeth of the escape wheel. The speed with which the escape wheel can rotate, and so allow the quadrant to rotate and relieve the force on the timing spring, depends upon the size and mass of the wheel and pallet and also upon the force exerted by the spring due to the displacement of the permanent magnet and its re-set arm.

**25.** Thus the permanent magnet will not swing over on its support completely, but, whilst the force (due to the reverse current) causing it to swing over persists, it will exert a force on the quadrant and the quadrant will rotate on its pivot at a rate depending upon the magnitude of this force. As the quadrant rotates, the timing spring allows the resetting arm and the magnet to be displaced further. After some predetermined movement of the magnet, the arm above the trip lever extension will strike the extension and trip open the breaker.

**26.** Thus the time taken for the breaker to trip, from the instant when the reverse current exceeds the trip setting, will depend upon the magnitude of the reverse current. If this reverse current is large the breaker will be tripped in a shorter time than if it is small, since the force exerted by the magnet on the timing spring will be large and the pallet will oscillate more rapidly.

**27.** It is found in most aircraft installations that the normal switching on and off of the various loads gives rise to transient currents. Part of these currents will, in effect, be reverse currents often of high magnitude but of very short duration, but with the timing device the breaker will not trip. Once the transient has disappeared and normal current is resumed, the magnet will return to its set position and the timing spring and quadrant will likewise resume their normal positions.

**28.** If the reverse current exceeds a predetermined value (approximately 1,000 amp.) and tends to persist, the force on the magnet will be very large and will overcome the force of the timing spring completely and trip the breaker before the timing mechanism can check its movement. This ensures that for very large short-circuit currents the breaker will trip and open the circuit almost instantaneously.

**29.** As the toggle mechanism returns to its tripped position, the re-set lever (37, *fig.* 4) is forced to rotate about the spindle (45) by the links, as they return to their tripped position. The end of the re-set lever strikes the re-set arm (34) of the permanent magnet, ensuring that the magnet and timing mechanism are fully returned to their set positions. This is necessary since if the magnet is not fully returned, small reverse currents of short duration may trip the breaker.

#### Remote tripping

**30.** Between the main side frames are located two separate relay side frames (*fig.* 6), and between these is located a solenoid, wound on to a core. Poised above the gap formed between the two relay side frames is an armature hinged on a fixed pivot located through the main side frames. An armature return spring (40, *fig.* 4), secured to the free end of the armature and a pin on the main side frames, holds the armature away from the relay side frames whilst a stud, screwed into one relay side frame and passing through an oversized hole in the armature with a nut and lock-nut on the end, serves to limit the position of the armature. A setting screw (39, *fig.* 4), secured in a tapped hole at the extreme end of the armature, rests on the end of a trip lever, just above the trip plate.

**31.** When the solenoid coil is energized, the magnetic flux produced across the gap between the two relay side frames attracts the armature causing it to rotate about its pivot. The armature return spring (40, *fig.* 4) will be stretched whilst the screw (39) will rotate the trip lever disengaging the trip plate from the latch, thus allowing the entire toggle mechanism to trip the breaker. When the solenoid is de-energized the armature, trip lever and latch return to their normal positions under the action of their return springs, with the latch engaged under the trip plate ready for the breaker to be re-set. The solenoid may be energized deliberately or can be connected to trip the breaker automatically when the system is overloaded or the generator voltage rises too high.

#### Manual tripping

**32.** A small lug riveted to the solenoid armature engages under a plunger (38, *fig.* 4) located in a housing secured to the top of the cover. The top of the plunger projects through the top of the cover, and when pressed, against the pressure of a return spring located in the housing, it will swing the armature on its pivot and trip the breaker, in exactly the same manner as when the solenoid coil is energized.

#### Indicator flag and switches

**33.** The coiled return springs (47, *fig.* 4), located at each end of the link pin and secured to fixed pins on the side frames, returns the link pin to its highest position when the breaker is open. Extensions (49, *fig.* 4) of the link pin project through the side frames and on one side move in a slot of the flag lever (50) which is pivoted on the outside of the side frame. The top of the flag lever appears under a transparent window in the top of the case to show whether the breaker is tripped or set. The other extension of the link pin engages under a plunger projecting from the auxiliary switch mounted on the other side frame (*fig.* 6).

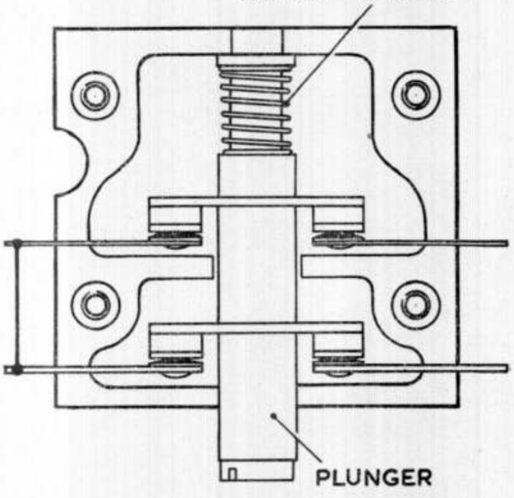



**Fig. 7. Auxiliary switch assembly**

**34.** A recessed Bakelite moulding carries the auxiliary switch assembly (*fig.* 7) consisting of four pairs of contacts wired in series. The moving contacts are carried on arms secured to the plunger, with a return spring which is compressed whenever the plunger is moved upwards by the link pin extension. The four contacts open simultaeously whenever the main contacts of the breaker open circuit.

**35.** One or two miniature switches (*fig.* 6) of the B.T.H. LHE 11–A series are mounted inside and at the end of the side frames. Further details of these switches will be found in A.P.4343B, Vol. 1, Sect. 20, Chap. 20. The plungers of these switches are operated by leaf springs, secured at the top to brackets on the side frames. Whenever the breaker is closed, projections on the toggle links (6, *fig.* 3) press on to the curved ends of the leaf springs which exerts sufficient pressure on to the plungers to trip the switches. The leaf springs prevent excessive movement of the toggle links from damaging the switches.

## INSTALLATION

**36.** The breaker may be installed in any position and is secured by four screws through holes in the metal base plate (*fig.* 2). There must be sufficient space above the case to allow the breaker to be set and mechanically tripped and also to observe the indicator window.

## SERVICING

**37.** It is not intended that the mechanism should require servicing and any electrical or mechanical failure will necessitate returning the equipment to an appropriate depot for repair. Prior to installation the electrical insulation should be tested with a 250-volt insulation resistance tester, and the reading should not be less than 2 megohms between any terminal and the case.



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