TTE Training Ltd.

Phase 1
Electrical Course Notes

E-CN-007

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Electrical Protection

Protective Devices

There are many types of protective devices all of which are primarily designed to protect the consumer in the event of a fault occurring. This section will concentrate on the following types of protection:

- Fuses
- Miniature Circuit Breakers (MCB's)
- Residual Current Devices (RCD's)
- Earth Leakage Circuit Breakers (ELCB's)

1.1 FUSES

1.1.1 Fuse

A device that by the fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

1.1.2 Fuse Element:-

A part of a fuse designed to melt when the fuse operates.

1.1.3 Fuse Link

A part of a fuse, element(s), that has operated and which requires replacement by a new or renewable fuse link before the fuse is put back into service.

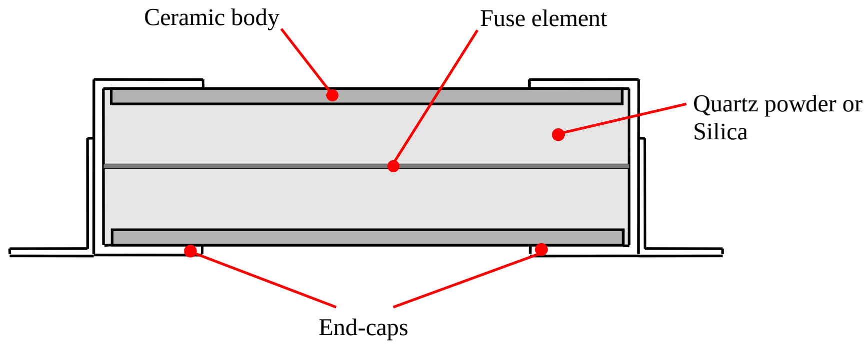
1.1.4 HRC Fuses

HRC stands for High Rupture Capacity fuses and are to **BS88.** They are used in many circuits because they are easy to replace, and they come in different sizes and current values. They are also very reliable and good value for money.

The HRC fuses are constructed with quartz powder or silica around the main fuse element (see Fig 1:1). This is so because in the event of the element melting the quartz powder or silica would move between the ends of the wire and therefore reduce the risk of an arc being produced.

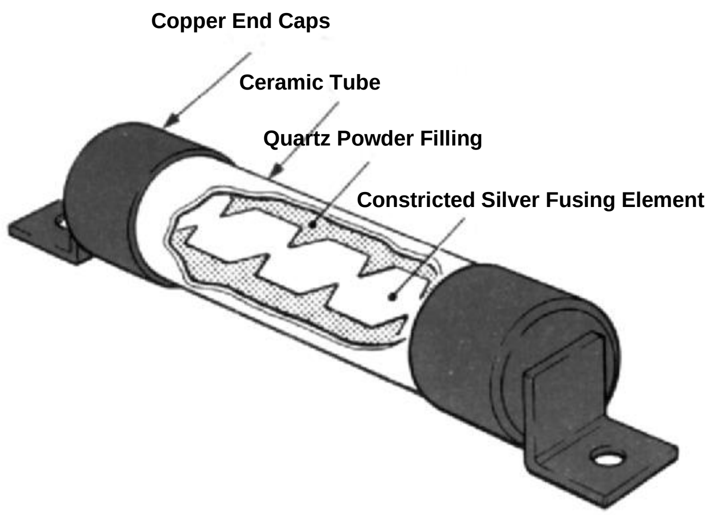
The fuse element has a designed weak point, so when they over heat and melt, the quartz powder or silica can move and stop an arc occurring.

Fig. 1:1



1.1.5 Fusing Element

It is normal with small fuses to use silver wire as the fusing element but for larger ones a silver (or sometimes copper) strip is often used, as shown below



The strip has a number of constrictions which form hot spots and assist rapid melting under short-circuit conditions. For the heaviest currents a number of such strips may be connected in parallel within the common housing, or many separate fuse links may be permanently bonded in parallel to form a single multiple link.

1.1.6 Types of HRC Fuses

HRC fuses are categorised in the following way:

☐ ag

☐ aM

☐ gG

☐ gm

a - Partial break capacity interrupts short circuit currents only,

g - Full range breaking capacity – interrupts short circuit and overload currents safely,

G - Fuse link for general application including protection of motor circuits

M - Fuse link protection of motor circuits

The commonly used “Red Spot” fuse links are classified as either gG or gM.

There are three main types of HRC fuses. These are:-

S.S. These are mainly used in lighting circuits.

N.I.T. Used in lighting circuits and power circuits.

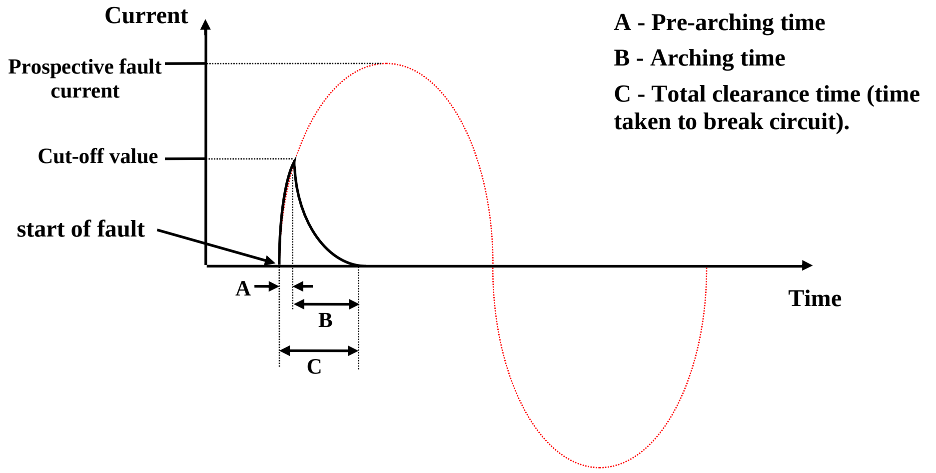
T.I.A. This the general purpose fuse, they are used in most circuits.

These fuses can be found in a range of sizes and a range of standard current ratings.

1.1.7 Operating Characteristics

In order to protect the consumer and the circuit an HRC fuse must act rapidly. In order to achieve this each fuse has a "cut-off" value of prospective fault current. This means that the short circuit current is interrupted before it can reach its full value in the first half cycle of short circuit (see Fig. 1:2 below).

Fig. 1:2



The energy that is allowed through the circuit before the fuse disconnects can be calculated by the formulae (I^2t).

Under short circuit conditions, a fuse must disconnect a circuit in sufficient time to ensure that the heat generated from the fault current does not damage the cable insulation. For this to be achieved the disconnection time "t" must not exceed the time/current characteristic total clearance time.

$$t = (k^2 \times S^2) \div I^2$$

Where: S = cross-sectional area of cable (mm's)
I = fault current (amps)
K = constant

(115 for 70 ^{0}C insulated copper cable less than 300mm^2: see Chapter 43, Table 43.1, I.E.E. Regulations).In order to protect the user against electric shock, the I.E.E. Regulations require that, under fault conditions, any circuit protected by an HRC fuse should have an earth fault loop-impedance sufficiently low enough to ensure that the fuse will disconnect the final circuit of a TN system within 0.4 seconds, for TT this is further reduced to 0.2 seconds.

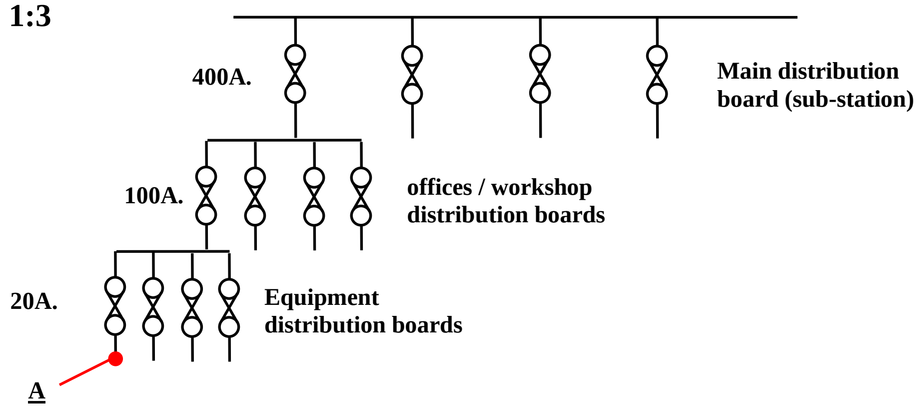
Fuses have to be designed for different applications due to the varying types of load. Typically, steady load circuits would use a fuse that is rated equal to, or just above, the load rating. Alternatively when selecting a fuse rating for a fluctuating load circuit e.g. a motor, you must take into account the load current fluctuations. Whilst the fluctuating current peaks are of comparatively short duration, the selected fuse should have a time/current characteristic that will allow the fluctuation to be carried without blowing.

It is extremely important that correctly rated fuses are used in all applications; whilst they cannot prevent faults, the potential consequences, particularly of using a higher rated fuse, may be fatal. In order to prevent fuse ratings being accidentally changed, any fuses that are removed for the purpose of electrical isolation should be taped together (if they are from a three-phase circuit), labelled, (listing the circuit details), and stored in a secure area.

1.1.8 Discrimination

In any distribution system it is important to ensure that, in the presence of an electrical fault, the lower rated fuses should blow before the higher rated fuses. Each fuse rating would be selected according to the prospective load of the circuit that it is protecting. The diagram below, (Fig. 1:3), indicates how discrimination is achieved in a simple distribution system.

Fig. 1:3



In the event of a fault at point "A" the protection device immediately up-stream of the fault should operate and isolate the faulty circuit. It is desirable that only the upstream device should operate if it is able to clear the fault by itself, hence leaving the healthy circuits unaffected. This is known as discrimination.

If the fault is greater than the breaking capacity of the upstream device then the next device in line should operate as well. This is known as back-up protection.

These are some of the reasons that HRC fuses are used:-

- They reduce danger to personnel, damage to equipment and risk of fire.
- They reduce electromagnetic stresses which would, in the event of a fault, tend to distort and/or damage other current carrying parts of the equipment.
- They reduce thermal stresses to other current carrying parts of the equipment (heat is produced as a result of fault current).
- They reduce arc-splash damage.

- They retain all of their characteristics without the need for maintenance however long in service (laboratory tests on 34 type "T" H.R.C. fuse links of various ratings after some 16 to 25 years of service showed no significant changes in any of their original characteristics).

- They operate without emission of smoke or flames.

- They ensure continuity of supply to healthy circuits when electrical faults occur.

- High breaking capacity and energy limitation.
- Restriction of electromagnetic stress.

- Proven reliability and non deterioration.

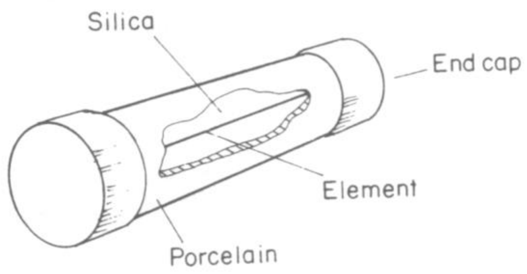
- Accurate discrimination.

- Reliable short circuit and back up protection.

- Low over current protection.

1.1.9 Cartridge Fuses

The construction of a cartridge fuse to **BS1362** is shown below and consists of a porcelain tube with metal end caps to which the element is attached. The tube is filled with silica.



These fuses are generally found in 13Amp plug tops, and in some distribution boards and at the mains intake positions (Electricity Board fuse).

You can calculate the correct fuse for domestic appliance by using the following formula:-

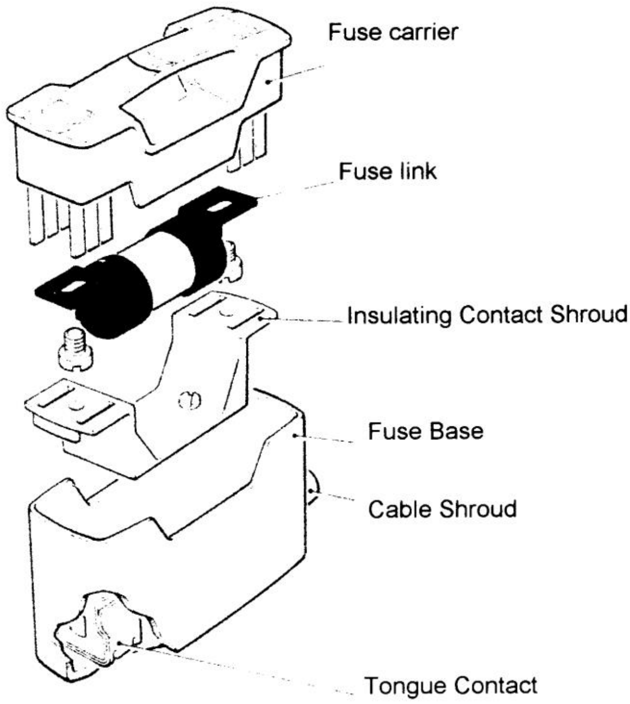
$$\text{Current} \quad \mathbf{I} = \frac{\text{Power } \mathbf{P}}{\text{Voltage } \mathbf{V}}$$

1.1.10 Normal Current Rating

A fuse has a *normal current rating*, which is the current, which it can carry continuously without melting or deteriorating and without altering its character.

1.1.11 Fuse Mountings

On low voltage boards, fuses are housed in a fuse assembly such as the typical one shown below. The replaceable ceramic cartridge with its metal terminal caps is known as the *fuse link* and is held in an insulated *fuse carrier*, which completely shrouds all live metal. The carrier is supported on an insulated *fuse base*, where it is firmly fixed by various mechanical means, amongst them tongue contacts, butt contacts held by insulated screw pressure, or wedge contacts pressed in by insulated screws. A typical fuse carrier is shown below.



1.1.12 Motor Protection Fuses

Fuses

In any motor starter circuit, the use of fuses is of paramount importance in short circuit protection, but limited in motor protection. In the larger motor starter, there are two different sets of fuses:-

1. Motor Fuses
2. Control Fuses

Motor Fuses

These fuses being the main fuses in the circuit provide protection against short circuits in the motor cable and motor terminal box. They do not provide motor overload protection, the reason being that they are rated to withstand the inrush current, which occurs on motor start. In the case of star connected motors this can be 6-7 times full load current, so close protection against electric motor overload is supplied by motor overload protection units (overload units). These units are capable of being graded in minute percentage of full load current, thereby fulfilling this role

Control Fuses

These fuses protect only the control circuit e.g. Contactor Solenoid, push buttons etc, together with all ancillary devices and cables.

They are generally on very small current ratings i.e. 2- 4 amperes.

1.1.13 AC Motor Current/Fuse Rating Guide

kWATTs	HP	FL Current	Fuse Rating
0.37	0.5	0.9	4.0
0.55	0.75	1.7	6.0
0.75	1.0	2.0	10.0
1.1	1.5	2.7	10.0
1.5	2.0	3.2	16.0
2.2	3.0	4.5	16.0
3.0	4.0	6.7	20.0
4.0	5.5	7.7	25.0
5.5	7.5	10.2	32.0
7.5	10.0	14.5	35.0
9.0	12.5	18.7	50.0
11.0	15.0	21.2	50.0
15.0	20.0	26.0	63.0
18.5	25.0	33.0	80.0
22.0	30.0	50.0	80.0
30.0	40.0	53.0	125.0
37.0	50.0	56.0	125.0
45.0	70.0	70.0	160.0
55.0	75.0	95.0	200.0
75.0	100.00	105.0	250.0
90.0	120.00	125.0	250.0

1.2 CIRCUIT BREAKERS

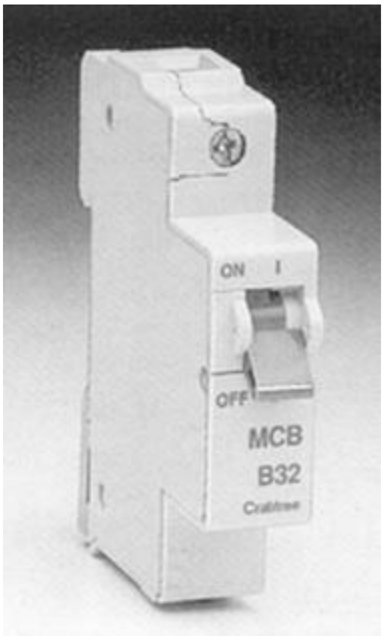
Circuit breakers are sub-divided into three types:

- Air Circuit Breakers - ACB
- Moulded Case Circuit Breakers - MCCB
- Miniature Circuit Breakers - MCB

We will only look at the MCB

1.2.1 MCB – Miniature Circuit Breaker

The miniature circuit breaker or MCB for short finds wide application as an effective means of over current protection. The main advantage of the MCB is that it may be reset at the operation of a switch, i.e. resetting is easy and quick. However, the following note of caution should be borne in mind – resetting of an MCB should only be carried out when the fault responsible for its operation has been cleared. Whilst MCB's may be used widely for protection, they must be backed up by HRC fuses where the fault level is too great to be handled safely and effectively by the MCB itself. Therefore, the choice of the appropriate type of over current is a matter of professional judgement and should be made by a Competent Electrical Person. The appearance of an MCB is shown below. Most commonly available MCB's have two modes of operation:



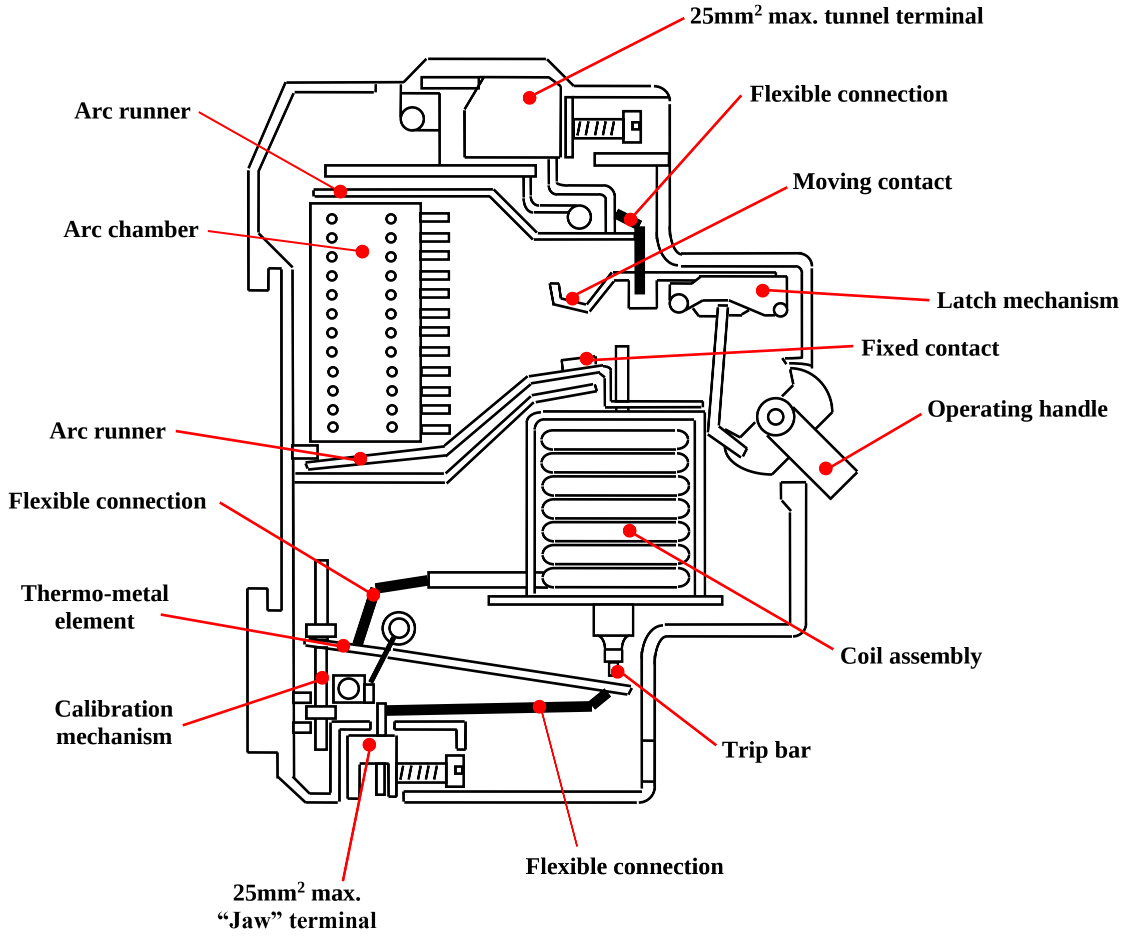
Ratings of MCB's are in the range 6A to 100A.

Thermal overload protection - to protect cables and equipment from "long term" over current damage i.e. generated heat.

Magnetic short circuit protection - to protect cables and equipment from very high fault currents; caused by catastrophic component failure.

All MCB's are rated by the normal current carrying capacity, operating voltage and by the maximum fault current and voltage that they can repeatedly break.

Fig. 1:4



The diagram shown above, (Fig. 1:4), shows a "Polestar" MCB manufactured by Crabtree. It has three modes of operation:

Small overload conditions

Light overload currents are detected by the use of thermo-metal which deflects at a rate in proportion to the size of the overload. The thermo-metal moves against a latching system which releases the contacts allowing them to open under spring pressure.

Large overload conditions

If the overload current reaches a predetermined level (which depends on the current rating and type classification of the MCB), then the current in the coil produces a magnetic field in the solenoid which is strong enough to pull in the armature and operate the latching mechanism to open the contacts.

Short circuit conditions

If the fault current is of a high enough level, not only does the solenoid trip the mechanism, it also forces the contacts apart very rapidly in a process known as "hammer trip". Under these conditions as the contacts separate an arc is drawn between them. The combination of magnetic fields in the MCB and the flow of the current in the arc acts to push the arc along the runners and into the arc chamber where it is quickly extinguished. The rapid opening of the contacts and extinction of the arc gives a total operating time that is typically 3.5 to 5 milliseconds.

1.2.2 Residual Current Devices (R.C.D's), (RCCD)

a) In a healthy circuit the currents in the phase (live) and neutral conductors should be equal.

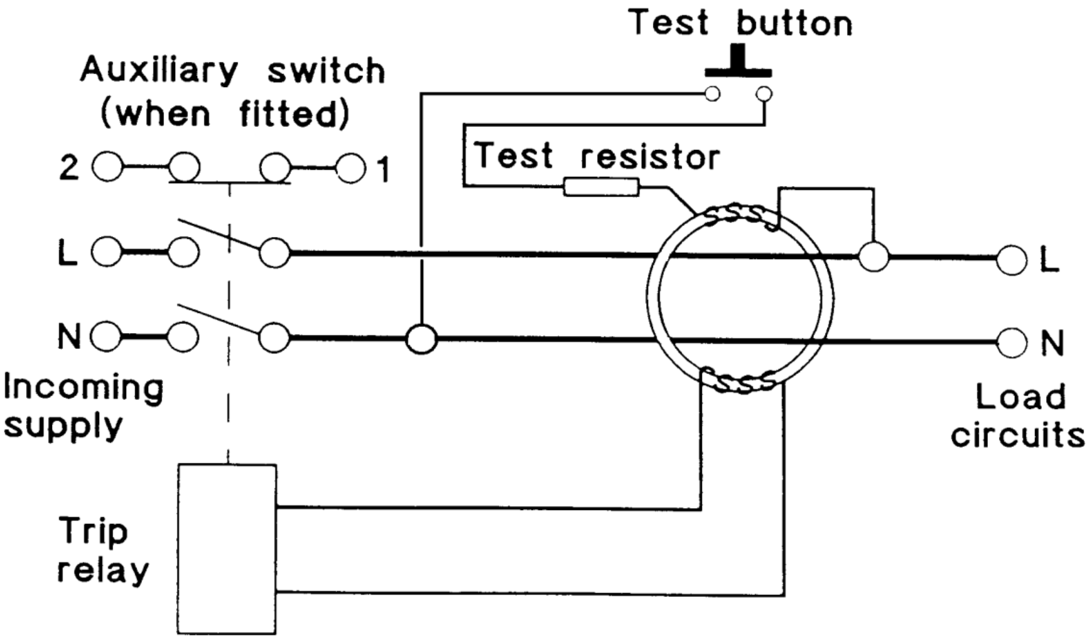
b) A fault which results in a leakage to earth causes an imbalance in the phase and neutral currents.

c) This creates a magnetic field in the current balance transformer; which creates a current in the fault detector coil.

d) This operates the tripping relay; which disconnects the mains supply.

Speed of Operation

RCD's typically operate on earth fault currents as low as 30 mA and with response times as fast as 30mS. The response time of 30mSec complies with the requirements of the IEE regulations



NOTE

The IEE wiring regulations now specifically require the use of an R.C.D for socket outlets intended to supply portable electrical equipment outdoors i.e. outside the zone of earthed equipotential bonding.

1.3 THE OVERLOAD UNIT

The overload unit is purely a safety device. It is used to protect the motor from excessive currents.

On start up, a motor can draw as much as eight times the supply current from the mains. The fundamental operation of the overload unit is to differentiate between the high current due to a fault condition and a high current due to start up characteristics. The main problem would occur, if the overload unit would shut off, when the high current is caused by the starting up process.

The effect of this shut off would therefore prevent the motor from starting. The overload could also be set to allow the large current on start up to flow, the overload may never detect a fault condition and this would cause a motor to burn out. To overcome these problems the overload system is equipped with a timer device. This timer is set so that it will allow the large current to pass through on start up. Then the current will be restricted and any large fluctuations in current will cause the overload to trip.

There are two main designs of the overload units, which although they perform the same function, carry out motor protection in two completely different ways.

1.3.1 Thermal Overload Protection

Where the timer device is a carefully designed bi-metallic strip wrapped around a heater element, which expands a set amount under a designated current in a pre-determined time.

Eli Lilly have various makes of thermal overload units, but all new or replacement units are Telemechanique.

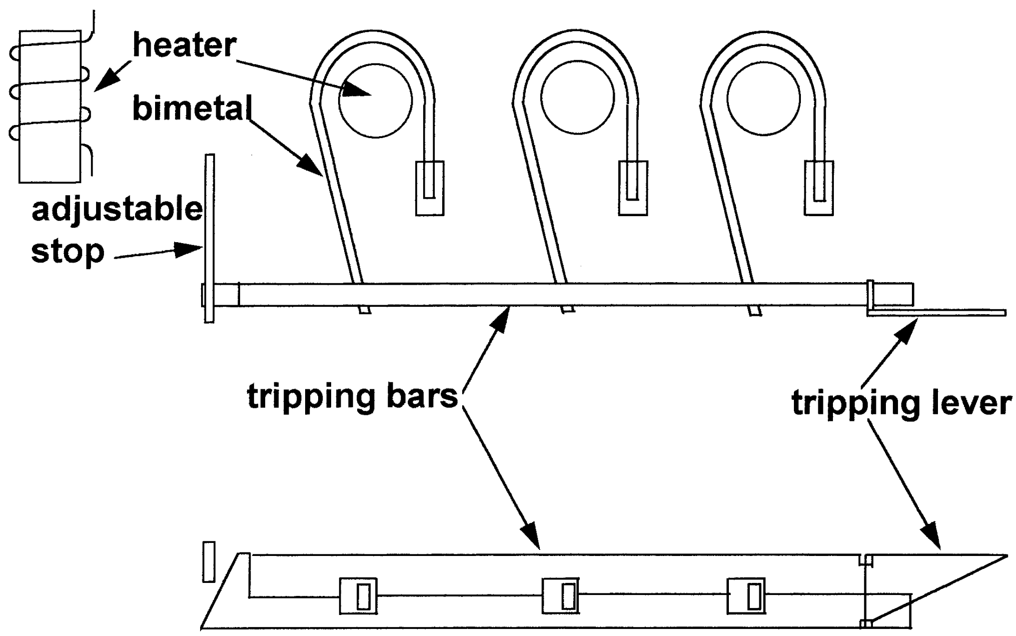
1.3.2 Oil Dashpot Damped Magnetic Units

These units although old in technology still perform effectively if correctly set. The principle action is that the motor current passes through an electro-magnet acting as a solenoid, thereby attracting the armature, this would normally instantaneously operate but to supply the timing device a piston or plunger is fitted on the end of the armature. This piston is immersed in oil in a carefully machined container (Dashpot) which in effect supplies the damping; this can be varied via a section of small holes in the piston and washer assembly.

Eli Lilly use this type of overload unit in the Allan West starter equipment.

BIMETALLIC STRIP TYPE OVERLOAD RELAY

The diagram shows a simple coarse thermal overload device.



ALLAN WEST CONTRACTOR OVERLOAD UNIT

Cross section view of magnetic overload unit