Protection Devices

Protection Methods

The most common types of protective devices are:-

i. Rewirable or semi-enclosed fuses.

ii. Cartridge or totally enclosed fuses

iii. High rupturing capacity (HRC) fuse

iv. Miniature circuit breakers.

v. Oil immersed circuit breaker.

vi. Combination switch fuse units (C.S.

Protective Devices

- There is a range of devices designed for protection purposes.
- Each have differing characteristics, advantages & disadvantages.
- Some devices will protect against different faults or protect different things, the circuit itself or people.

Protection Device Types

- Fuses & Circuit Breakers
  - Protect against “short circuits” & “overloads”.
  - They are designed to protect the installation not people.

- Residual Current Device
  - Protect against “earth faults” or earth leakage.
  - They primarily protect people, as a benefit they also protect the installation.

CIRCUIT PROTECTION

Fuses & Circuit breakers are used to protect conductors, transformers and measuring equipment from excessive heat caused by overcurrent.

Overcurrent may be very high due to either a short circuit or to overload due to misuse or poor design.

Circuit breakers have the following ratings:

i. **Maximum operating voltage,**

ii. **Full load or continuous current rating.**

iii. **Rupturing capacity. This is the maximum fault conditions, either current or MVA, which they are able to interrupt.**

Fuses

- Essentially consists of a short length of wire (known current carrying capacity) referred to as the element enclosed in a suitable carrier.
- Connected in series with the circuit it is protecting.
- If excessive current flows, the element will melt, therefore interrupting the supply.

Fuse Ratings

- They are rated to the maximum current they will carry under normal operating conditions, **not the current at which it will interrupt the supply**.

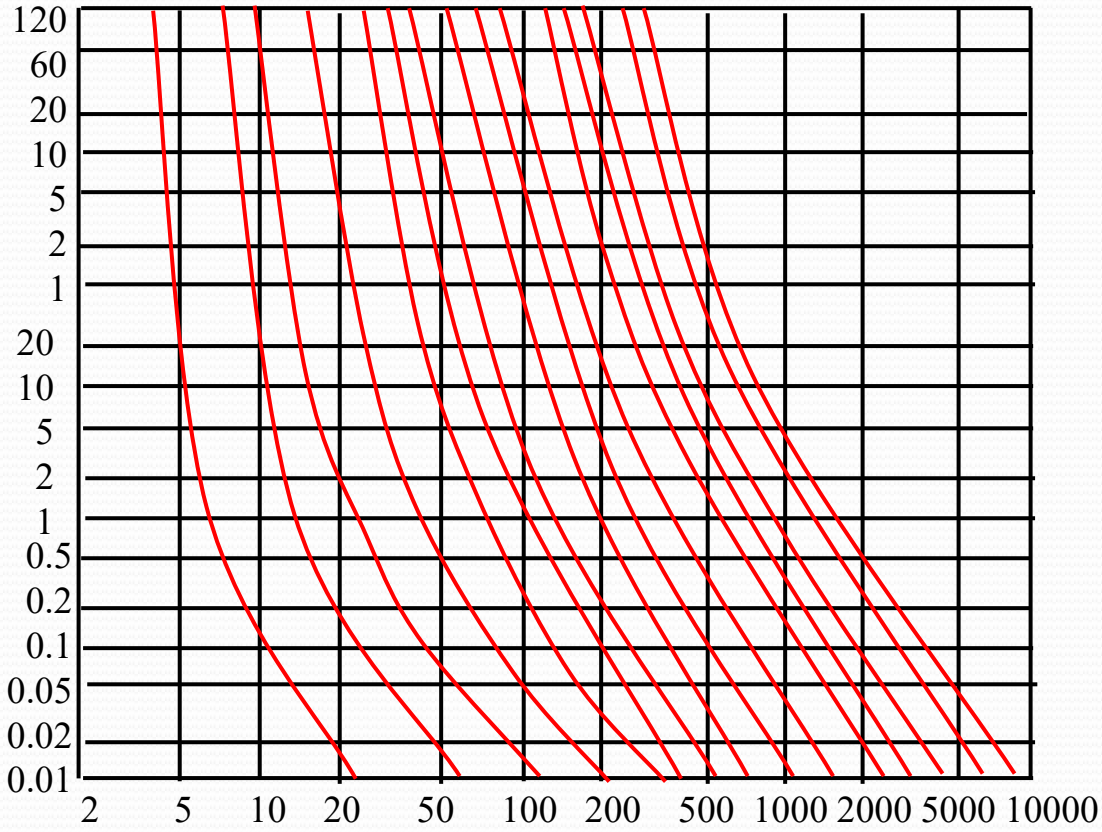
- A 10 amp fuse does not blow at 10 amps!!

Characteristics of Fuses

- Fuses will provide protection against high short circuit currents, but not relatively small spikes.
- HRC fuses have a much more predictable “blow capacity” than glass & rewirable type fuses.
- Re-wirable fuses are no longer recommended for use in domestic installations.

Time / Current Characteristics of Fuses

- Suppliers can provide the characteristics of specific fuses.
- The graph provided indicates the amount of time required to activate a specific size fuse, depending on the current in the circuit.
- It can be seen fuses may take some time with excessive current draw to activate, therefore they provide little protection against direct contact (electric shock).



- Suggested fuse order: 2 A, 5 A, 10 A, 15 A & so on….

Fuses

The simplest form of overcurrent protection is reduction of the cross-sectional area of a very small part of the circuit

Although it still carries the full load current safely.

Any increase in the current flowing will heat the reduced section of the circuit, which will eventually melt, thus opening the circuit.

The current rating of a fuse is the maximum current that the fuse will carry continuously without undue deterioration.

This rating is the one marked on fuse carriers and links.

Copper Contacts

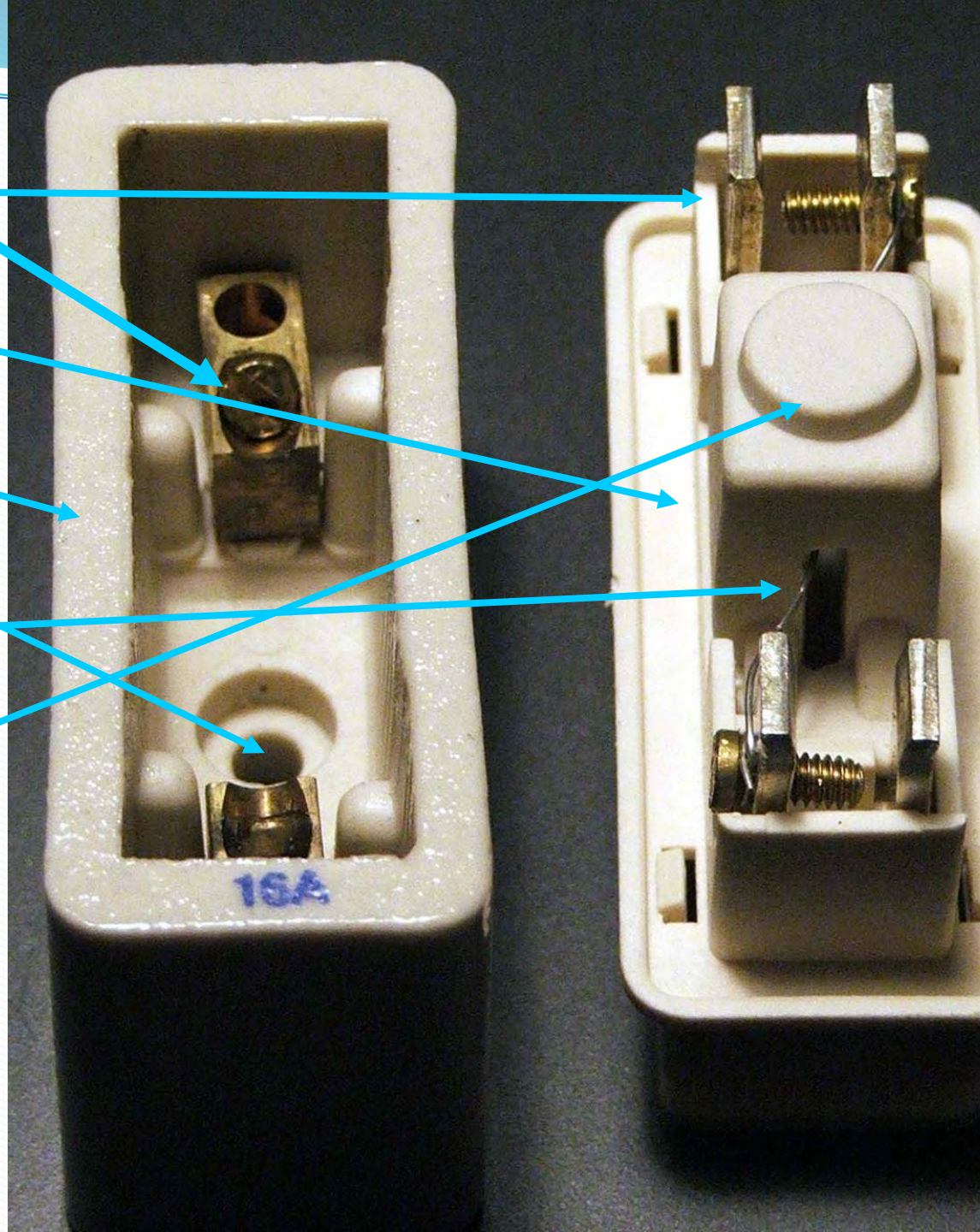
Carrier

Base

Fixing hole

Wire Element

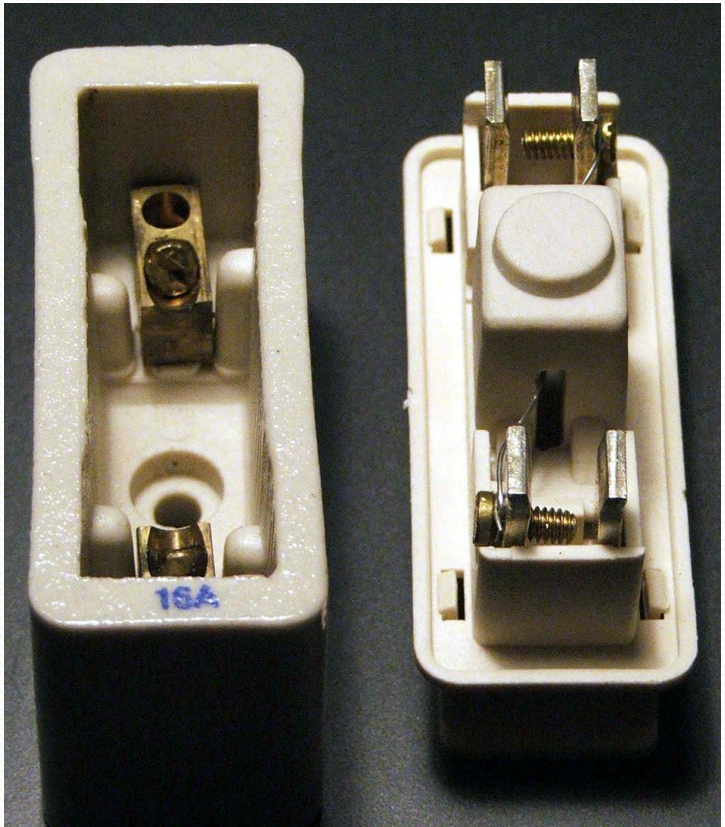
Wire Element in Porcelain shroud




240V
35A

The time taken for the fuse to operate is called the **OPERATING TIME,** and the greater the excess current, the shorter the operating time.

The carrier is made of an incombustible material, such as porcelain or moulded plastic.



A semi-enclosed fuse has the following advantages as against other types,

i. Relatively inexpensive

ii. Can be rewired

iii. A short circuit or overload can be determined from the appearance of the fused element.

Disadvantages

i. Rewired with over size fuse wire.

ii. Fusing time is unpredictable

iii. Since 2000 use has been restricted.

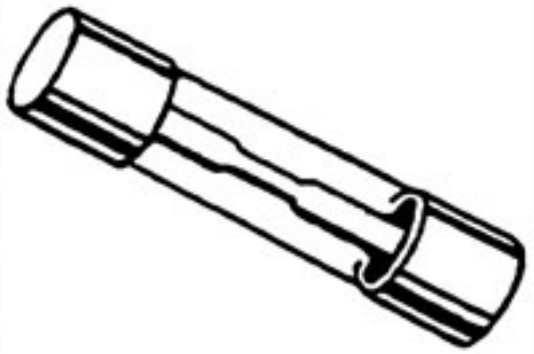
Cartridge or Totally Enclosed Fuses

A cartridge or totally enclosed fuse has a link that consists of a fuse element totally enclosed in a cartridge.

The cartridge is made of an incombustible insulating material, such as glass, porcelain or ceramic, through which the fuse element passes to contacts at each end of the cylinder.

Cartridge fuses are manufactured in standard sizes varying in current rating from under 1 mA to over 1000 amperes.

Some of the smaller fuse links are used in domestic appliances, radios, clocks, motor vehicles, instruments, etc.

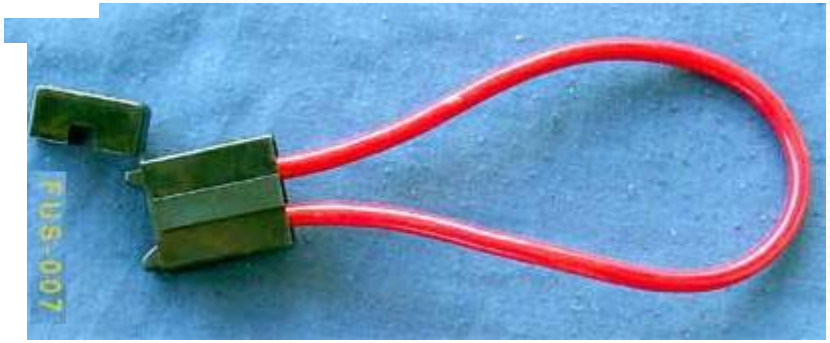


Automotive Fuses

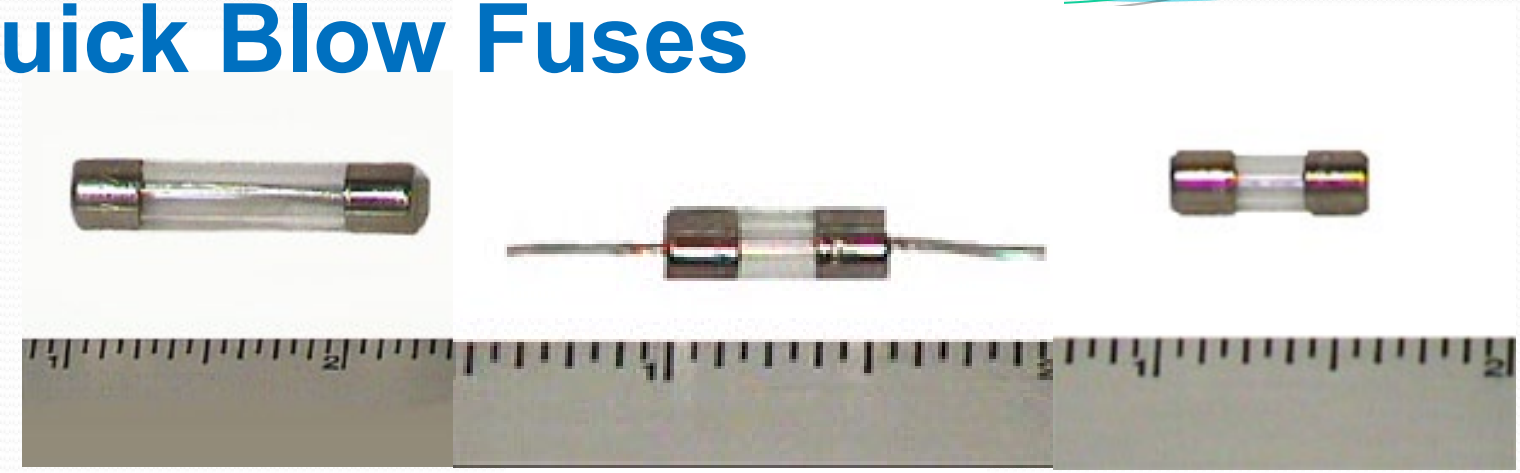
The colour of the fuse represents its current rating,

eg Red = 10 Amp

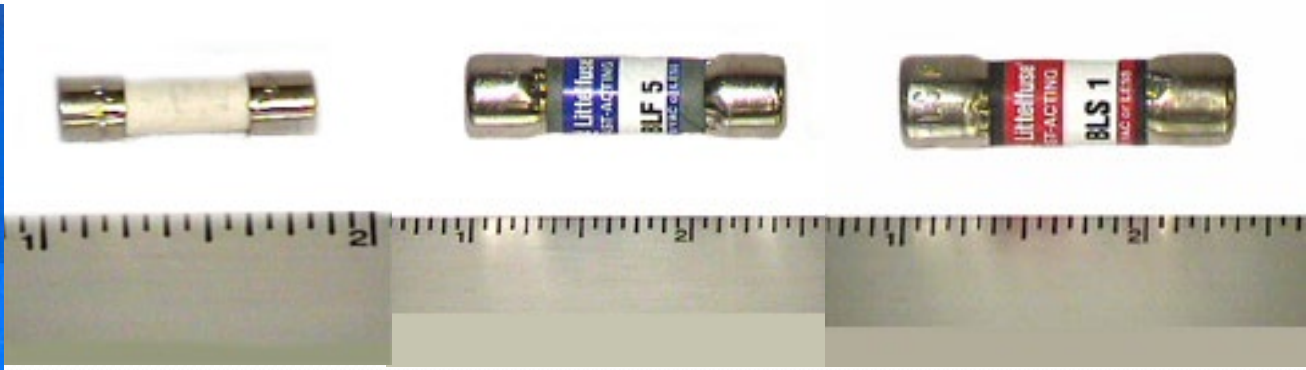
Yellow = 20 Amp



Quick Blow Fuses



Porcelain Fuses



High Rupturing Capacity (H.R.C.) Fuses

- A high rupturing capacity fuse is a cartridge fuse having a category of duty not less than AC 3 and DC 3. That is, it has a rupturing capacity of at least 16 500 amperes.

- The fusible elements consist of several pure-silver wires, surrounded by a compact filling of fine silica sand.

- To restrict the voltage rise across the link during operation, high-resistance shunt wires are fitted.

- An indicator resistance wire is also shunted across the link.

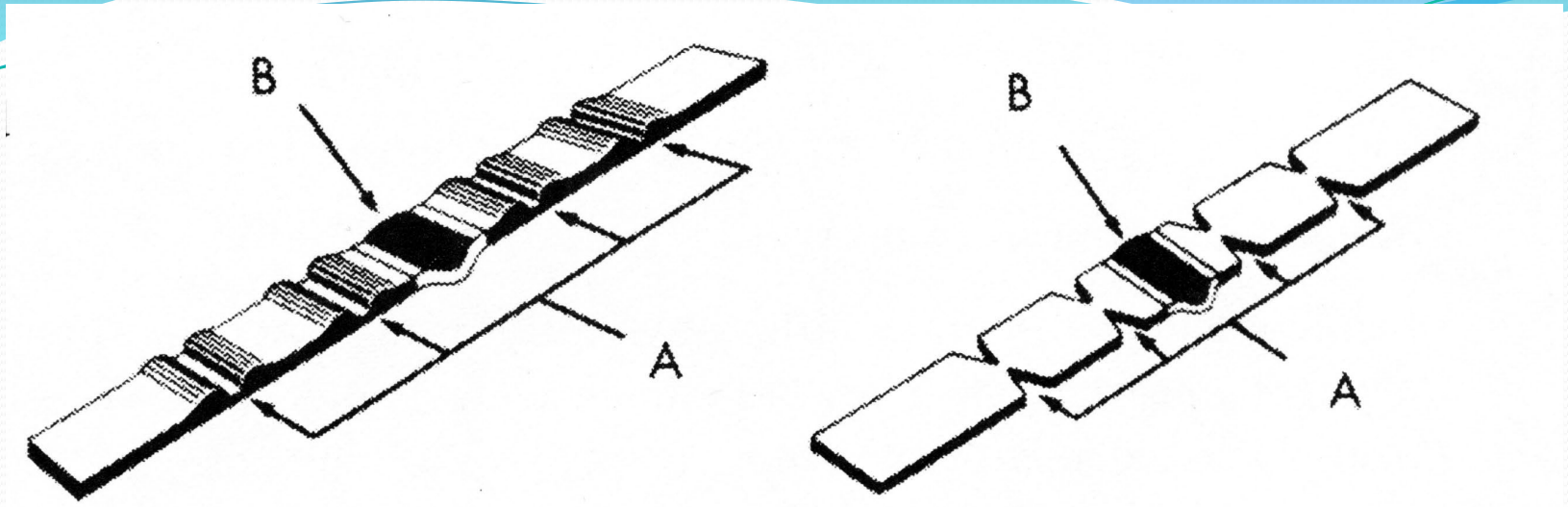
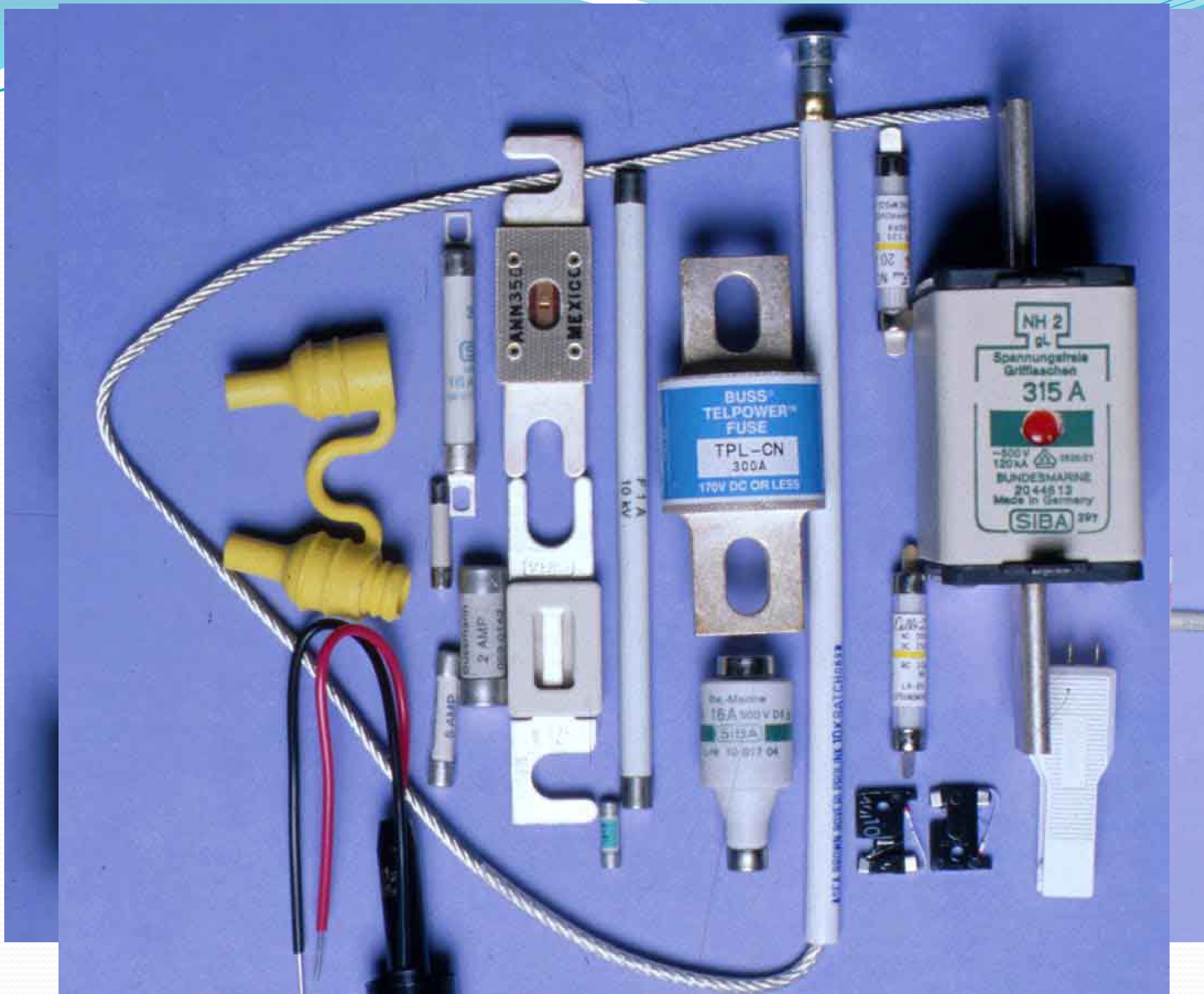


Figure 6.2 - Picture provided courtesy of ALSTOM

A. **Reduced sections in copper portions, where arcing is initiated when a short circuit fault occurs.**

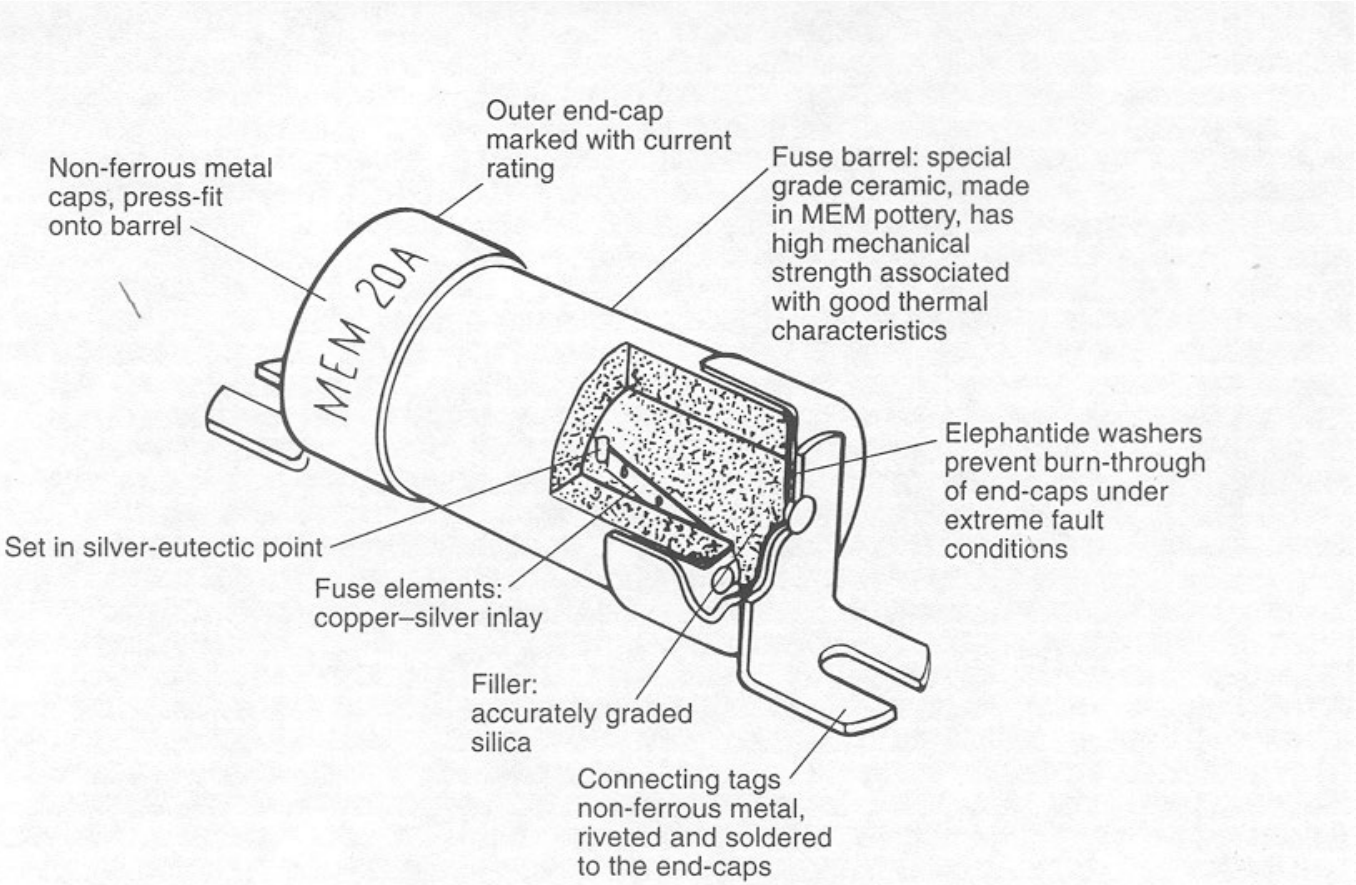
B. **Central silver section, in which a trough is formed and filled with tin, to produce 'M' effect when a prolonged overload fault occurs**

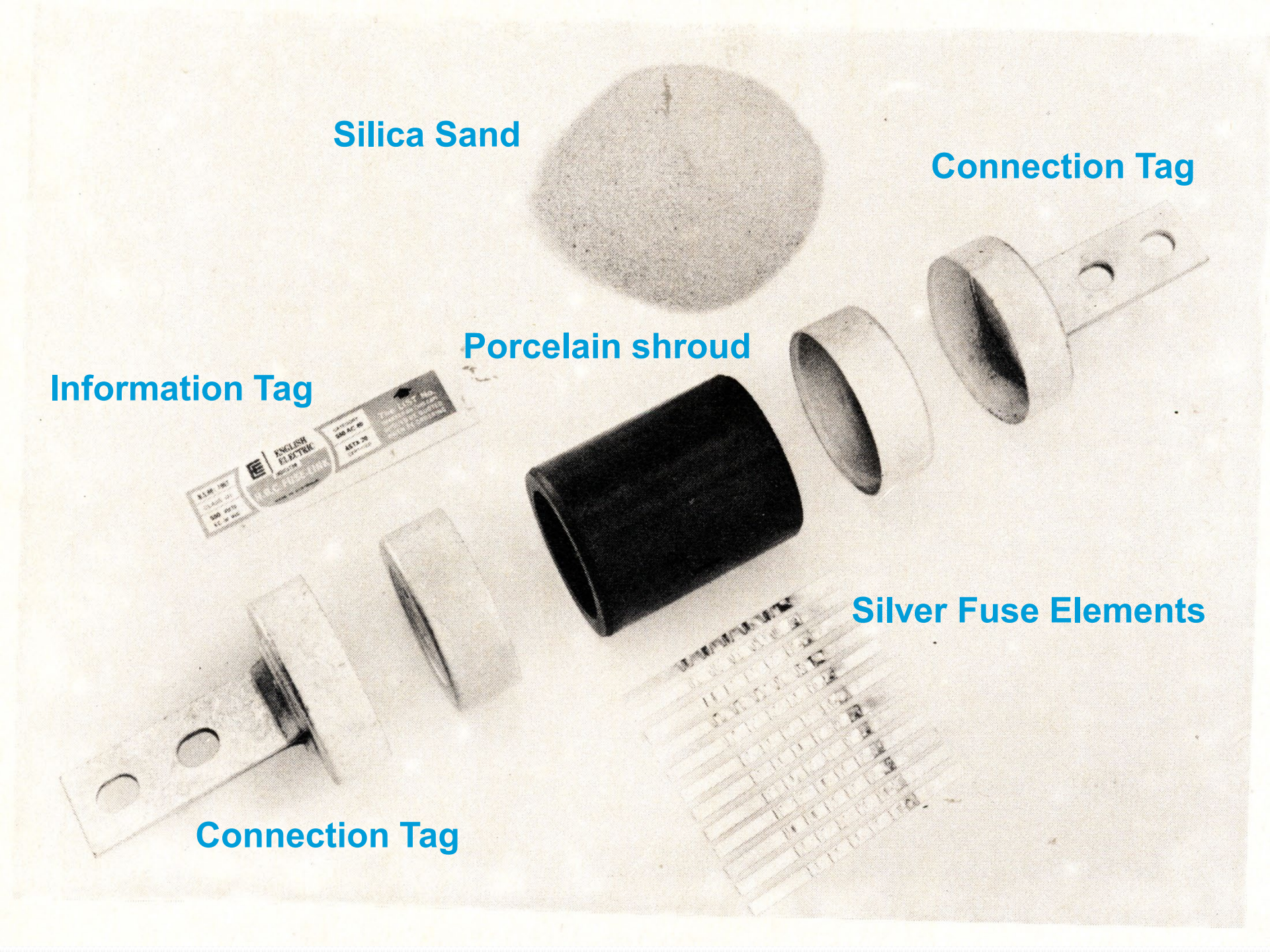

ANN350
MEXICO
BUSS
TELPOWER
FUSE
TPL-CN
300A
170V DC OR LESS
NH 2
gL
315 A
BUNDESMARINE
Made in Germany
SIBA
2 AMP
16A

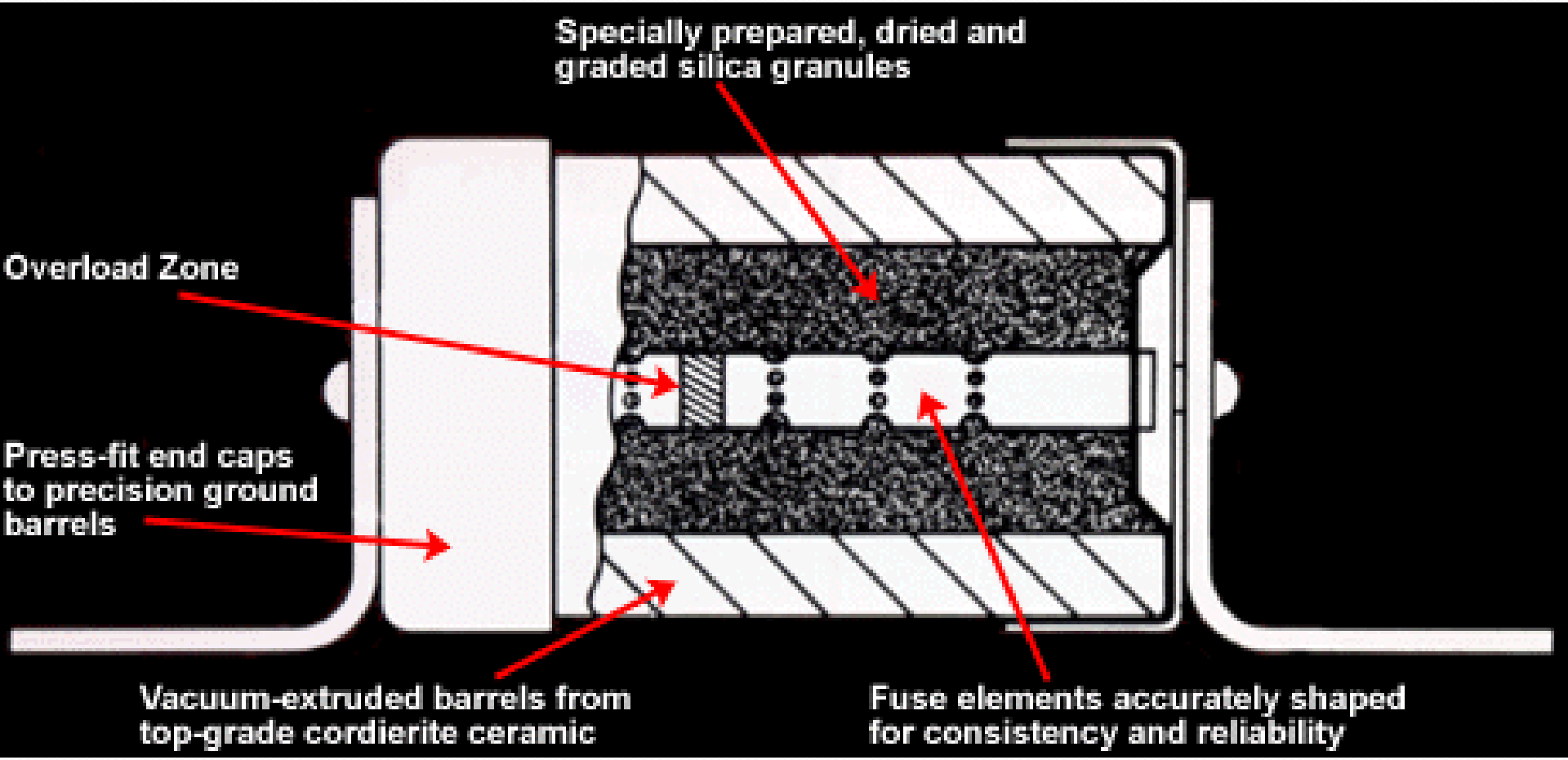
HRC Fuses

- High Rupturing Capacity. A category of duty not less than AC 3 (16.5 kA) and AC 6 (80 kA). That is, it has a rupturing capacity of at least 16, 500 & 80, 000 amperes.
- Fast acting compared to re-wirable fuses, usually within 1/3 of the supply cycle.
- Special slower acting fuses for “motor starting” to withstand high inrush current during start up.

HRC Fuse Construction




Silica Sand
Connection Tag
Porcelain shroud
Information Tag
ENGLISH ELECTRIC
Silver Fuse Elements
Connection Tag


Specially prepared, dried and graded silica granules
Overload Zone
Press-fit end caps to precision ground barrels
Vacuum-extruded barrels from top-grade cordierite ceramic
Fuse elements accurately shaped for consistency and reliability

Type D Fuse

Ampere Ratings: 2 to 30 Amps.

Voltage Ratings: 600 Vac

Interrupting Rating: 200kA

Type CGL Fuse

Ampere Ratings: 2 to 600 Amps.

Voltage Ratings: 600 Vac

Interrupting Rating: 200kA

Type CIF Fuse Bolt On mounts
Ampere Ratings: 1 to 30 Amps.
Voltage Ratings: 600 Vac, 250 Vdc
Interrupting Rating: 200kA

Type CIF Fuse Clip in Mounts
Ampere Ratings: 1 to 30 Amps.
Voltage Ratings: 600 Vac 250 Vdc
Interrupting Rating: 200kA

Type CIF Fuse Bolt On mounts
Fast Acting
Ampere Ratings: 1 to 30 Amps.
Voltage Ratings: 600 Vac 250 Vdc
Interrupting Rating: 200kA


Bussmann


Bussmann
60 AMP
MF
100A
415V


Holder For HRC Fuse
(FUS-040/042/043/044)

Normal H.R.C. fuses are fast acting to protect circuitry

- When the circuit involves surge currents due to motor starting, a special slow acting fuse cartridge is used.

- "Fault Current Limiters" are extremely fast acting fuses. They are designed to clear short circuit circuits, not overloads. The clearing time is approximately 0.005 seconds, and is fast enough to protect solid state electronic devices.

Advantages of H.R.C. over Semi-Enclosed Fuses

i. **Accurate Calibration:**

The time/current characteristics of H.R.C. fuses are constant.

ii. **Rapid rupture:**

The largest rating made will interrupt a full-capacity short circuit in less than half a cycle at 50Hz.

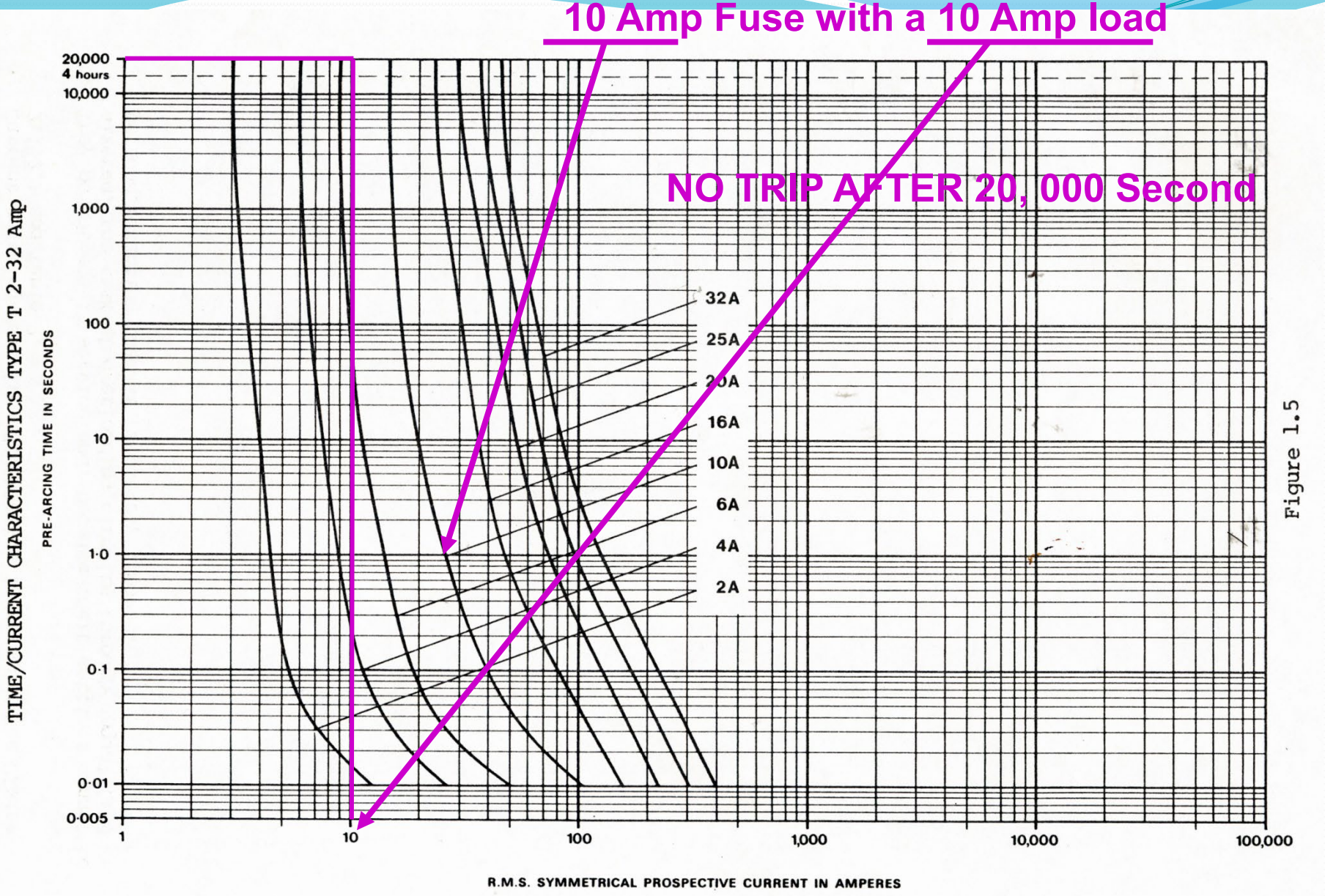
The high speed of operation of the H.R.C. fuse reduces thermal and magnetic strains on the equipment and helps discrimination between fuses.

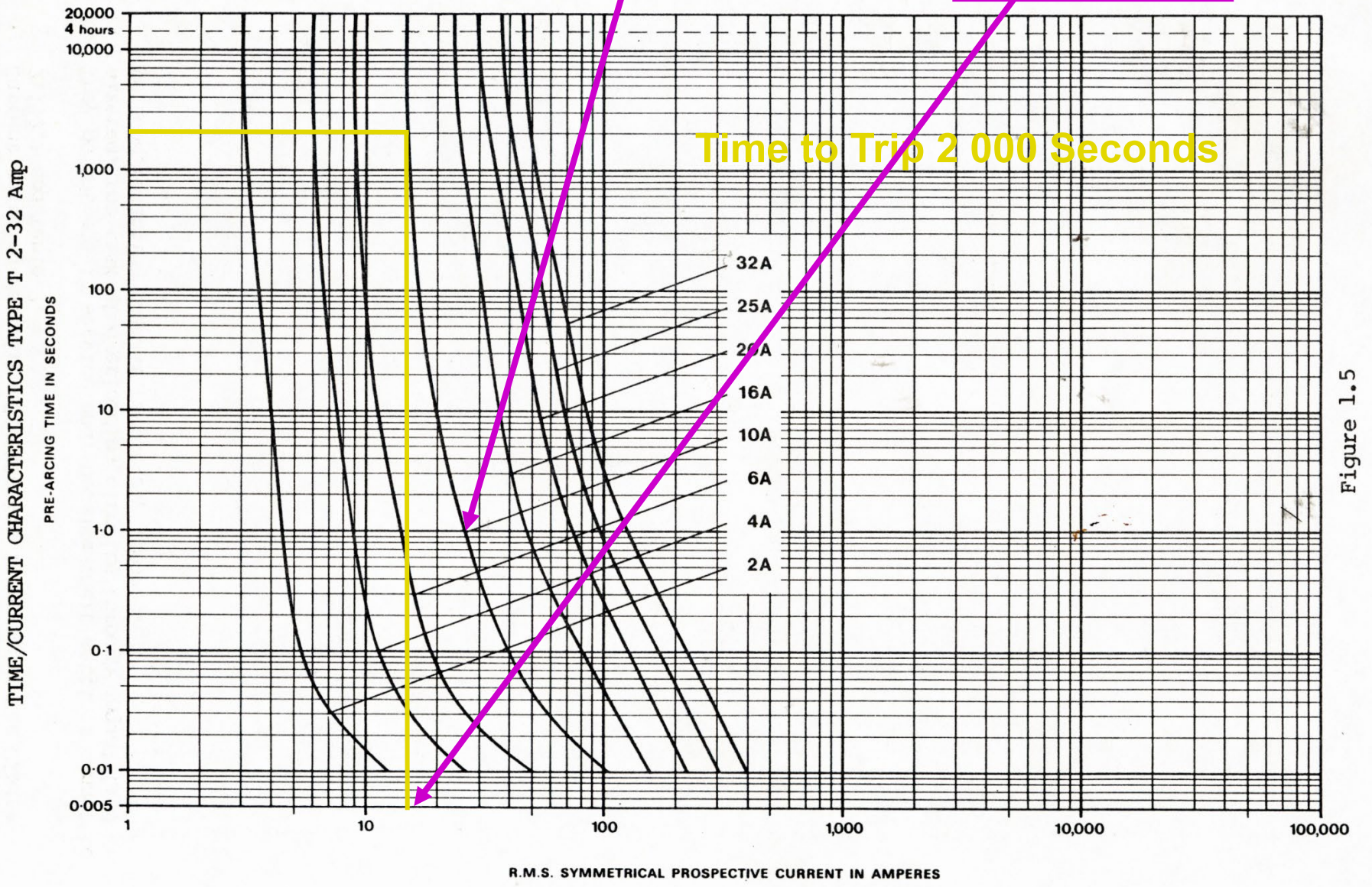
Time/Current Characteristics for H.R.C. Fuses

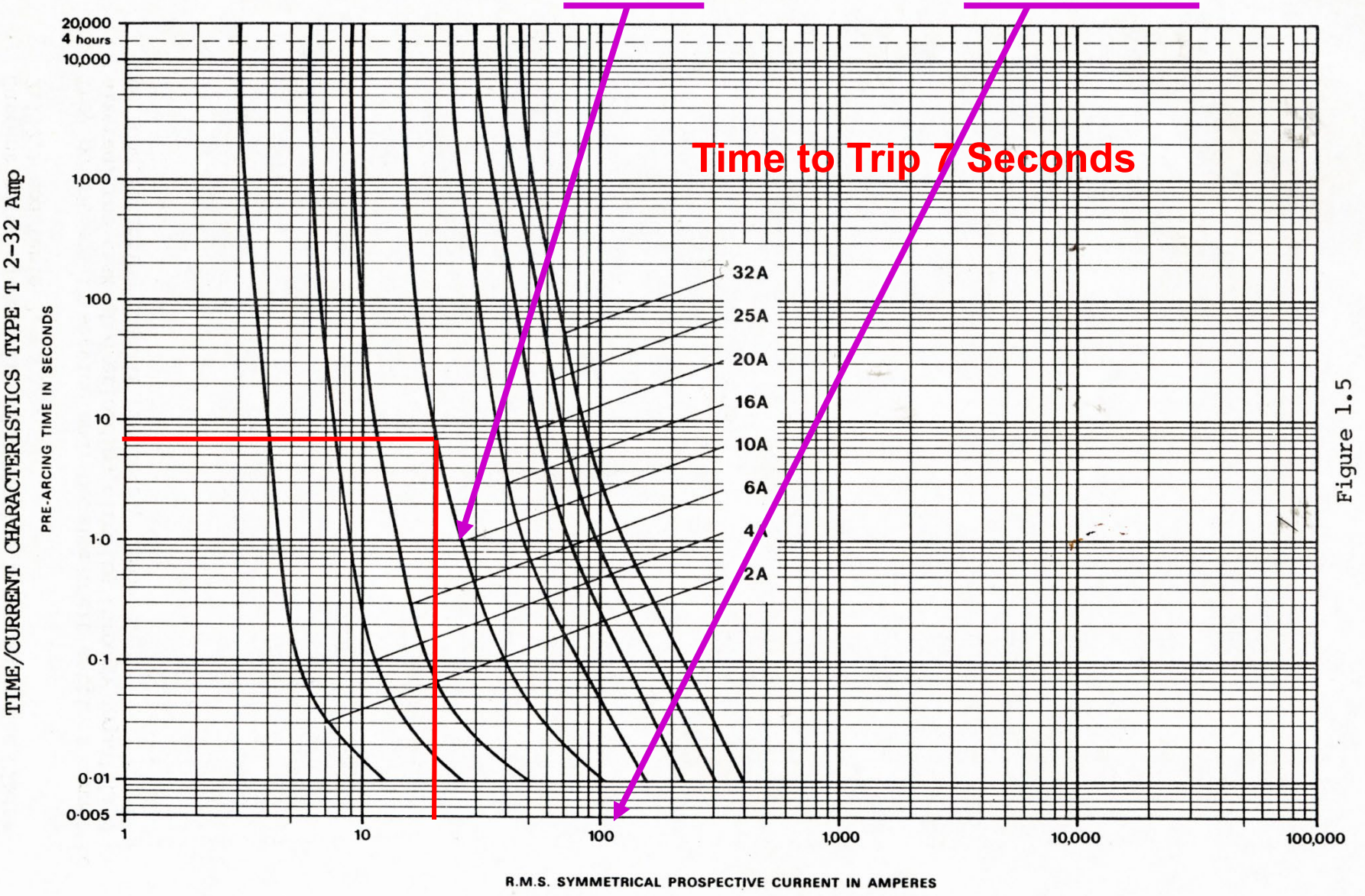
The time-current characteristics for various fuses is a graph showing the relationship between the fusing current and time which is supplied by the manufacturer.

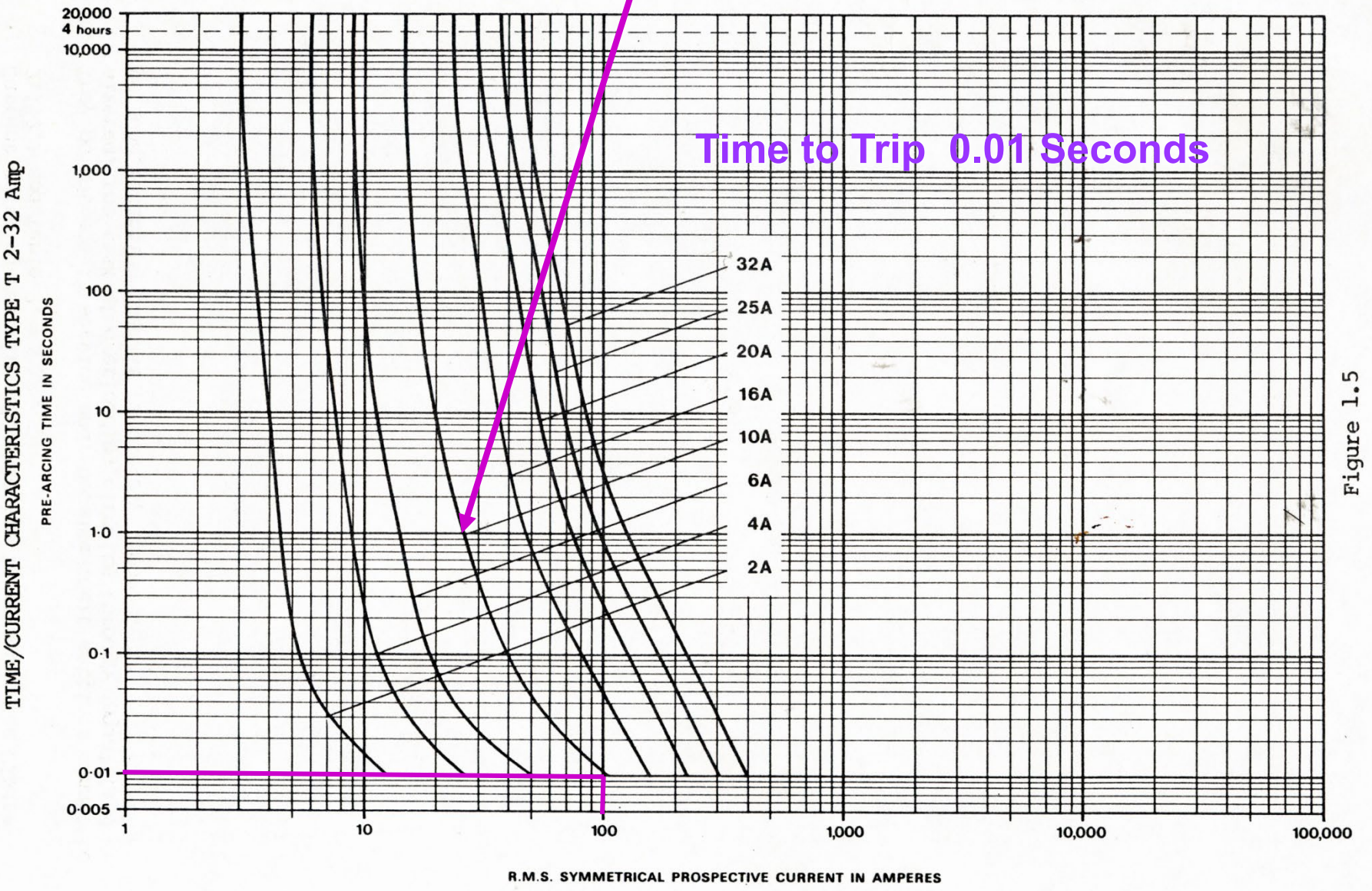
A typical GEC time/current characteristics.

Note:- The spacing between each curve, which gives, what is known as 'Discrimination' between fuse ratings.


10 Amp Fuse with a 10 Amp load
NO TRIP AFTER 20, 000 Second
TIME/CURRENT CHARACTERISTICS TYPE T 2-32 Amp
PRE-ARCING TIME IN SECONDS
20,000
4 hours
10,000
1,000
100
10
1·0
0·1
0·01
0·005
32A
25A
20A
16A
10A
6A
4A
2A
1
10
100
1,000
10,000
100,000
R.M.S. SYMMETRICAL PROSPECTIVE CURRENT IN AMPERES
Figure 1.5


10 Amp Fuse with a 1.5 x Overload
Time to Trip 2 000 Seconds
TIME/CURRENT CHARACTERISTICS TYPE T 2-32 Amp
PRE-ARCING TIME IN SECONDS
20,000
4 hours
10,000
1,000
100
10
1·0
0·1
0·01
0·005
32A
25A
20A
16A
10A
6A
4A
2A
1
10
100
1,000
10,000
100,000
R.M.S. SYMMETRICAL PROSPECTIVE CURRENT IN AMPERES
Figure 1.5

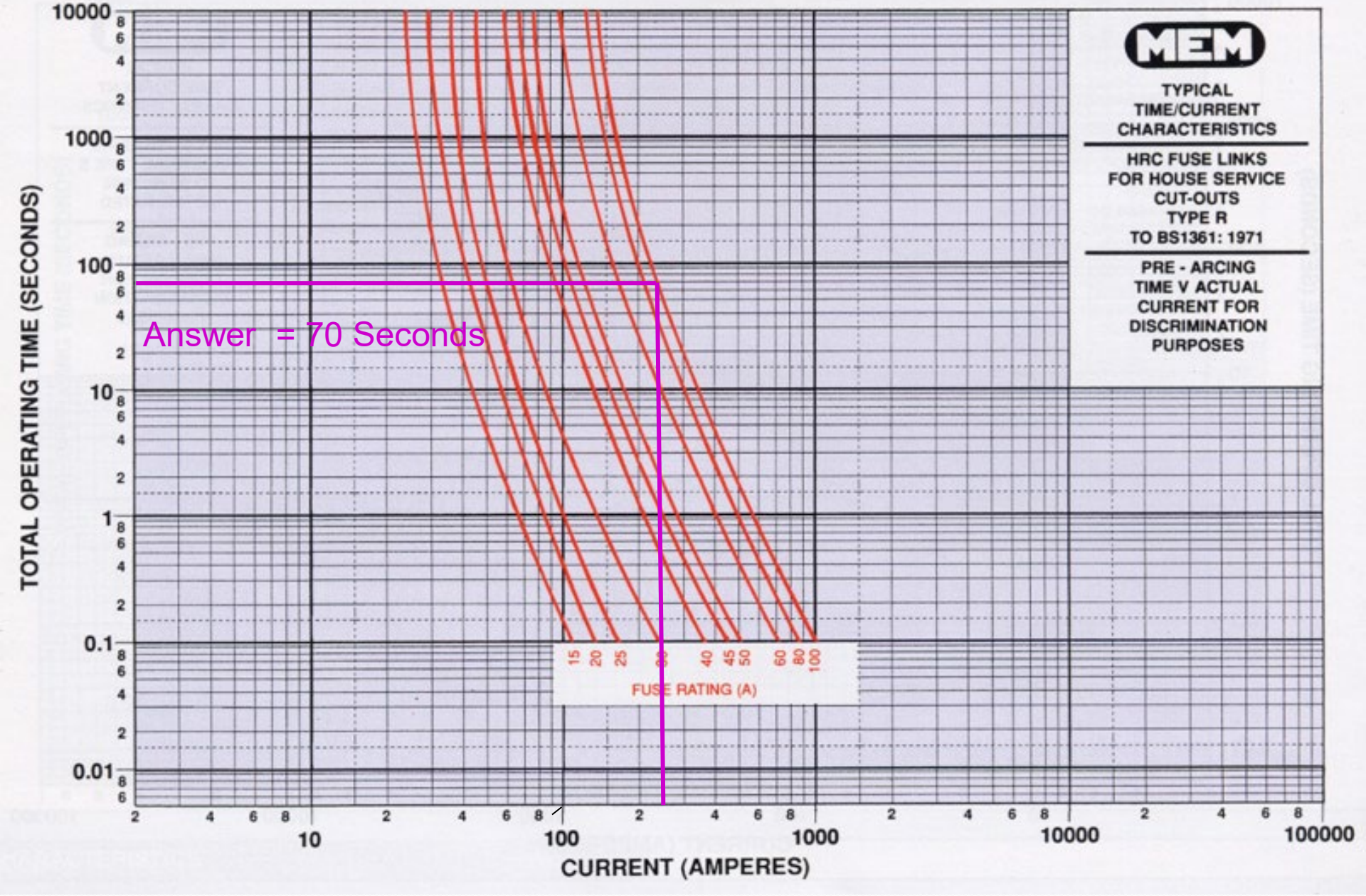

10 Amp Fuse with a 2 x Overload
Time to Trip 7 Seconds
TIME/CURRENT CHARACTERISTICS TYPE T 2-32 Amp
PRE-ARCING TIME IN SECONDS
20,000
4 hours
10,000
1,000
100
10
1·0
0·1
0·01
0·005
32A
25A
20A
16A
10A
6A
4A
2A
1
10
100
1,000
10,000
100,000
R.M.S. SYMMETRICAL PROSPECTIVE CURRENT IN AMPERES
Figure 1.5

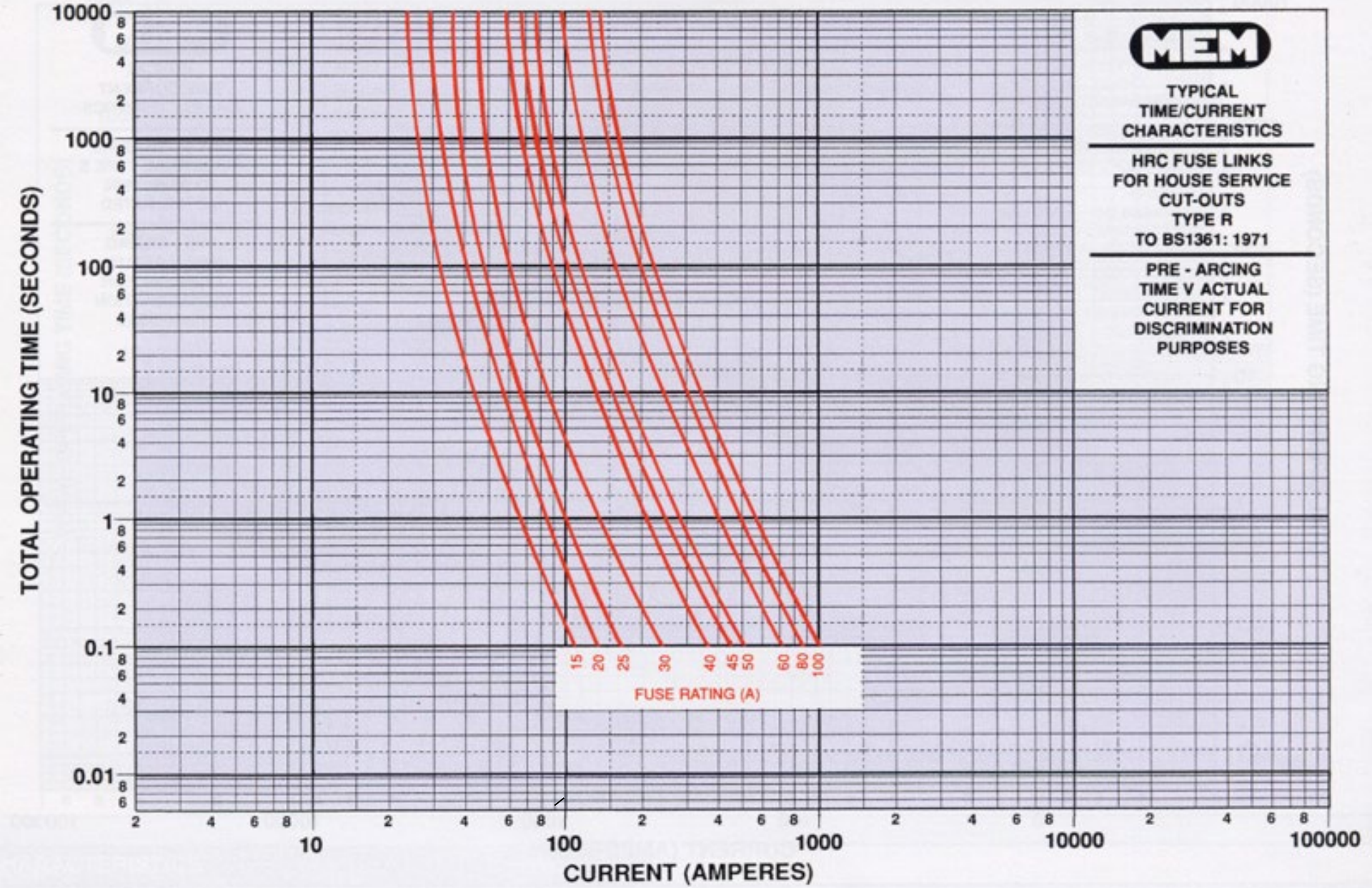

10 Amp Fuse with a 10 x Overload
Time to Trip 0.01 Seconds
TIME/CURRENT CHARACTERISTICS TYPE T 2-32 Amp
PRE-ARCING TIME IN SECONDS
20,000
4 hours
10,000
1,000
100
10
1·0
0·1
0·01
0·005
32A
25A
20A
16A
10A
6A
4A
2A
1
10
100
1,000
10,000
100,000
R.M.S. SYMMETRICAL PROSPECTIVE CURRENT IN AMPERES
Figure 1.5

Student Exercise

A power circuit has a prospective fault current of 256 amps.

How long will it take for the 100 Amp HRC Fuse to operate?

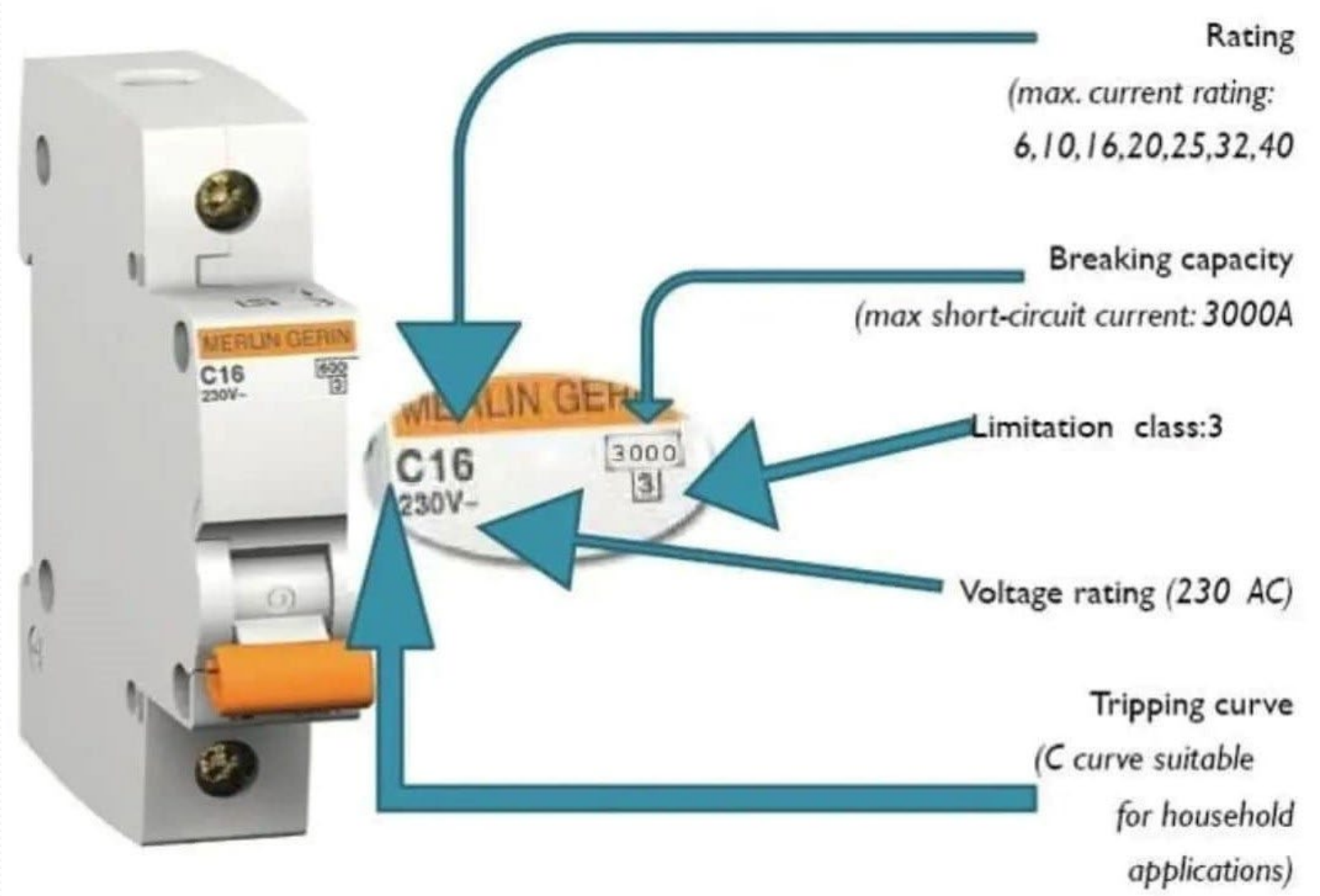

MEM
TYPICAL TIME/CURRENT CHARACTERISTICS
HRC FUSE LINKS FOR HOUSE SERVICE CUT-OUTS TYPE R TO BS1361: 1971
PRE - ARCING TIME V ACTUAL CURRENT FOR DISCRIMINATION PURPOSES
Answer = 70 Seconds
TOTAL OPERATING TIME (SECONDS)
10000
1000
100
10
1
0.1
0.01
15 20 25 30 40 45 50 60 80 100
FUSE RATING (A)
10 100 1000 10000 100000
CURRENT (AMPERES)


MEM
TYPICAL
TIME/CURRENT
CHARACTERISTICS
HRC FUSE LINKS
FOR HOUSE SERVICE
CUT-OUTS
TYPE R
TO BS1361: 1971
PRE - ARCING
TIME V ACTUAL
CURRENT FOR
DISCRIMINATION
PURPOSES
TOTAL OPERATING TIME (SECONDS)
10000
1000
100
10
1
0.1
0.01
15
20
25
30
40
45
50
60
80
100
FUSE RATING (A)
10
100
1000
10000
100000
CURRENT (AMPERES)

Circuit Breakers

- Consist of a thermal / electro-mechanical device for making & breaking a circuit.
- They have a time delay so they are unaffected by transient overloads, such as in motor starting.
- Have a much faster tripping time when compared to fuses.
- They are commonly installed in preference to fuses & is a standard recommended by AS/NZS 3000 for domestic installations.

Circuit Breakers



MINIATURE CIRCUIT BREAKERS (M.C.B.)

A miniature circuit breaker is defined as a compact mechanical device for making and breaking a circuit, both under normal conditions and under abnormal conditions.

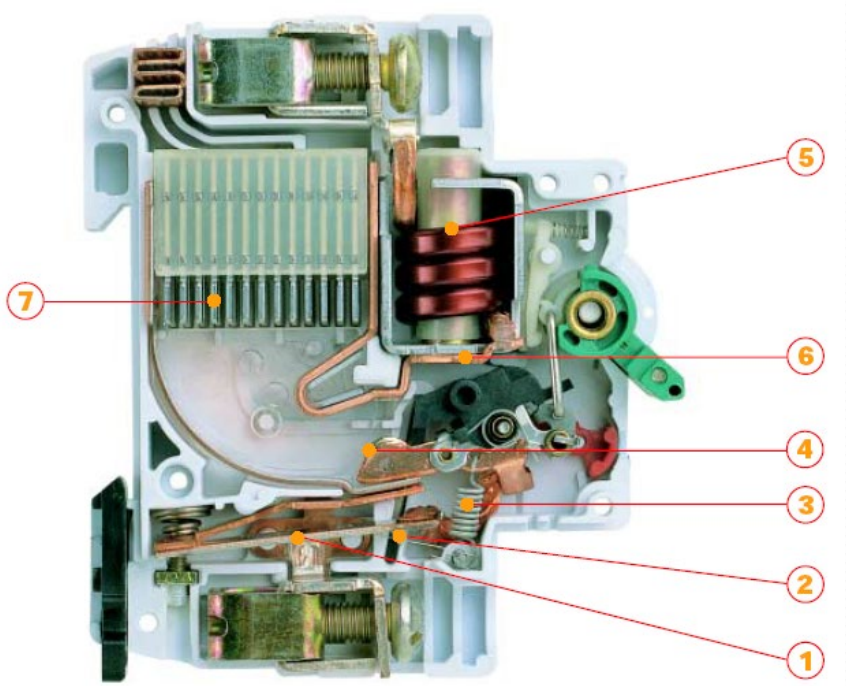
M.C.B.s normally have a time-delay tripping characteristic, the operating time being controlled by the magnitude of the over current.

Therefore, M.C.B.s are not affected by transient overloads, such as motor starting currents and switching surges.

Advantages of Circuit Breakers

- Easily Re-setable.
- Provide Visual Indication.
- Increase “current carrying capacity” of cable used.
- Generally do not age in service.
- Unalterable settings, (numpties can not change the protective device rating if they are deliberately overloading it!).

Circuit Breaker Construction



1: Bi-metal element

2: Tripping Lever

3: Tension Spring

4: Contacts

5: Solenoid Coil

6: Armature

7: Splitter plates,
break the ionised gas when opened extinguishing the arc.

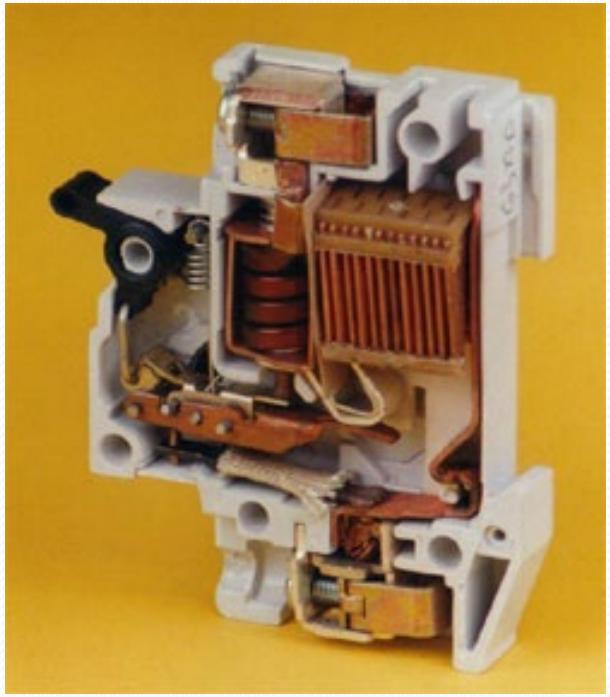
The tripping operation is either

i. Magnetic

ii. Thermal

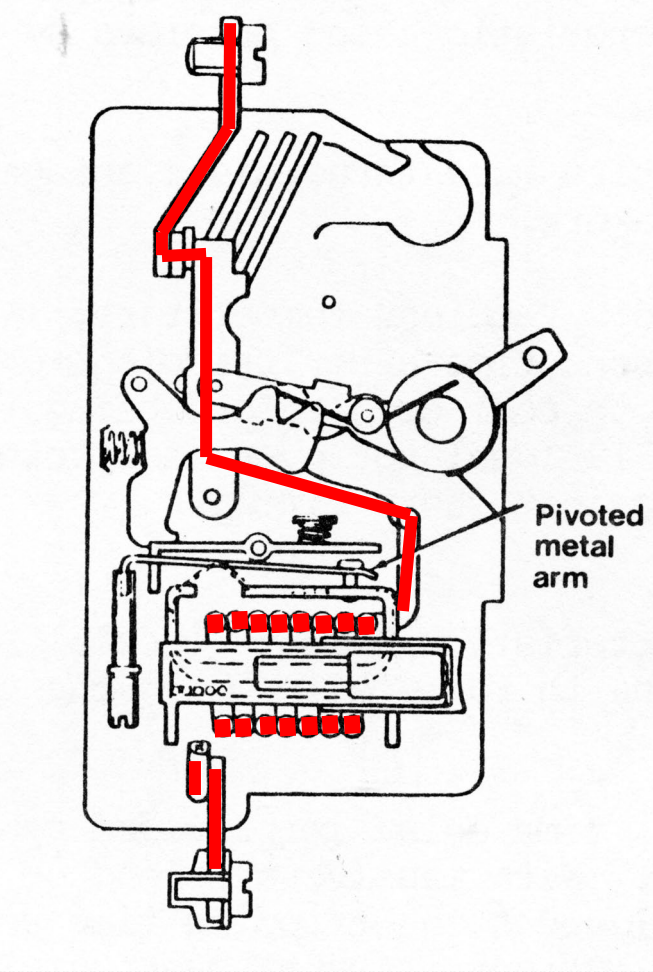
iii. Combination of magnetic and thermal

Magnetic/thermal type being most common.



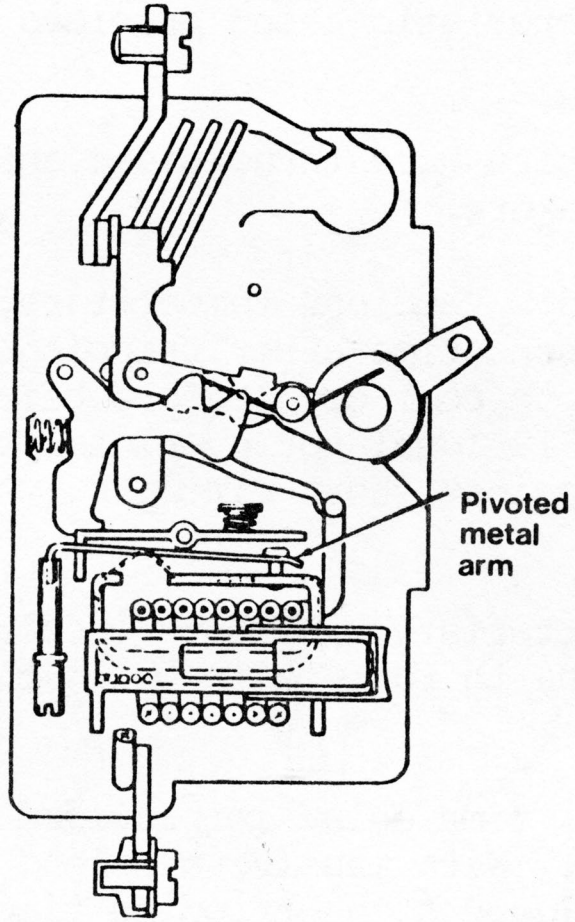
Magnetic Tripping

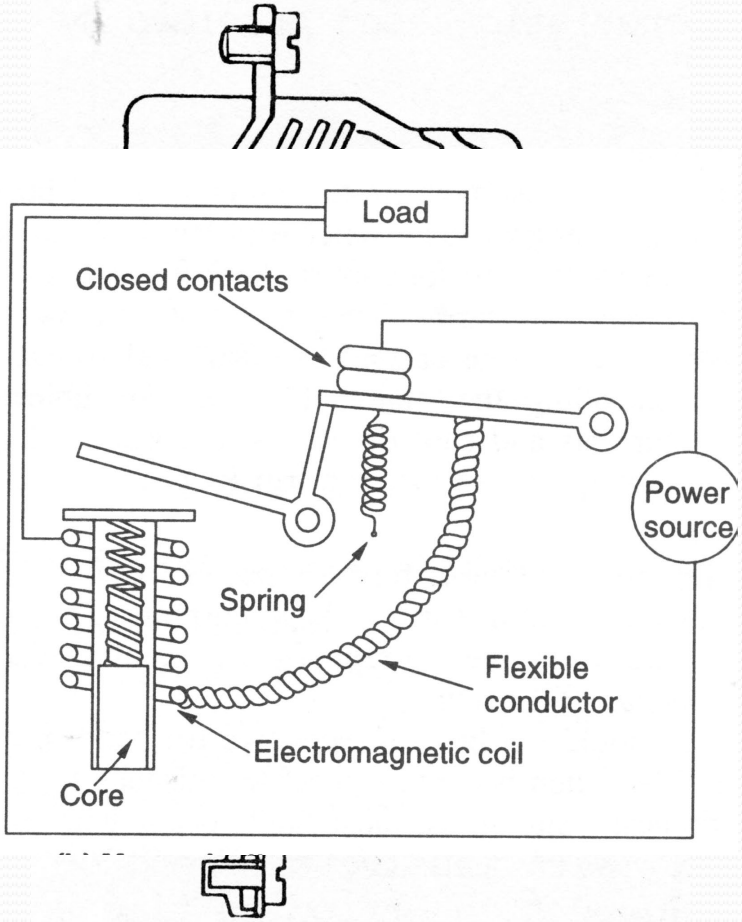
The current through the circuit breaker passes through an electromagnet that has a pivoted metal arm at a set distance from one end.



Magnetic Tripping

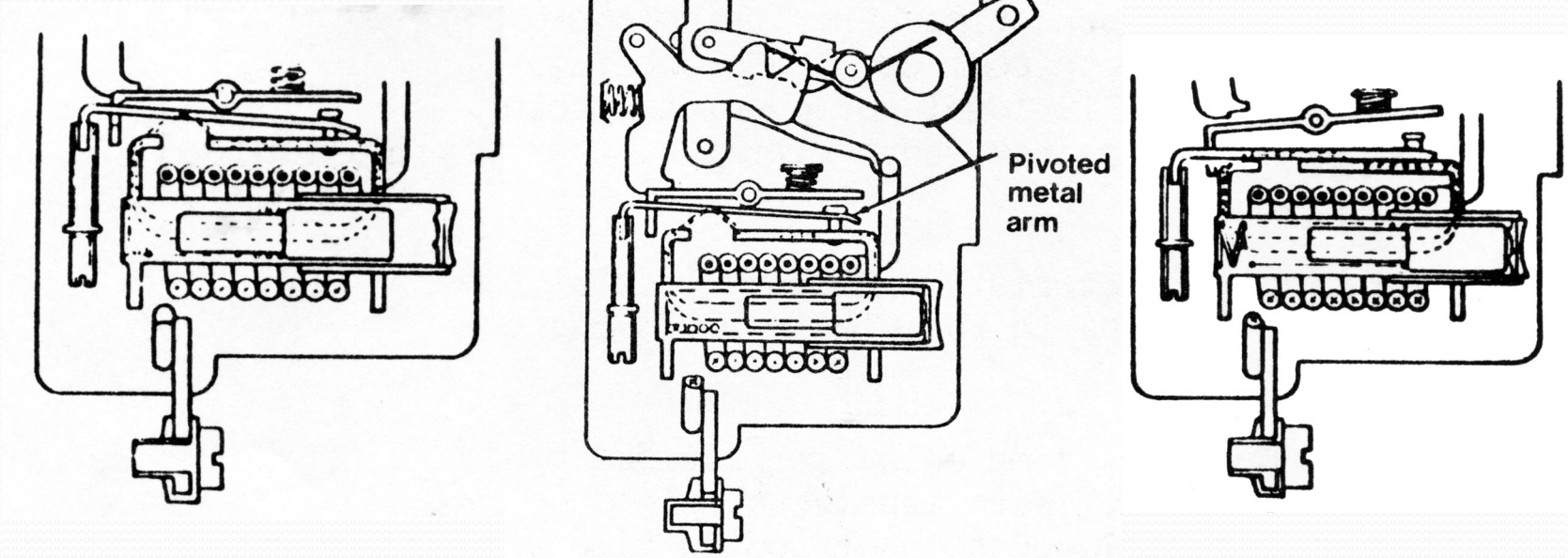
When an overload occurs, the magnetic pull is increased and the arm is attracted to the magnet and trips the switch.





When an overload occurs the slug nears the end of the tube the air gaps in the magnetic circuit are greatly reduced, and this increases the magnetic pull on the arm.

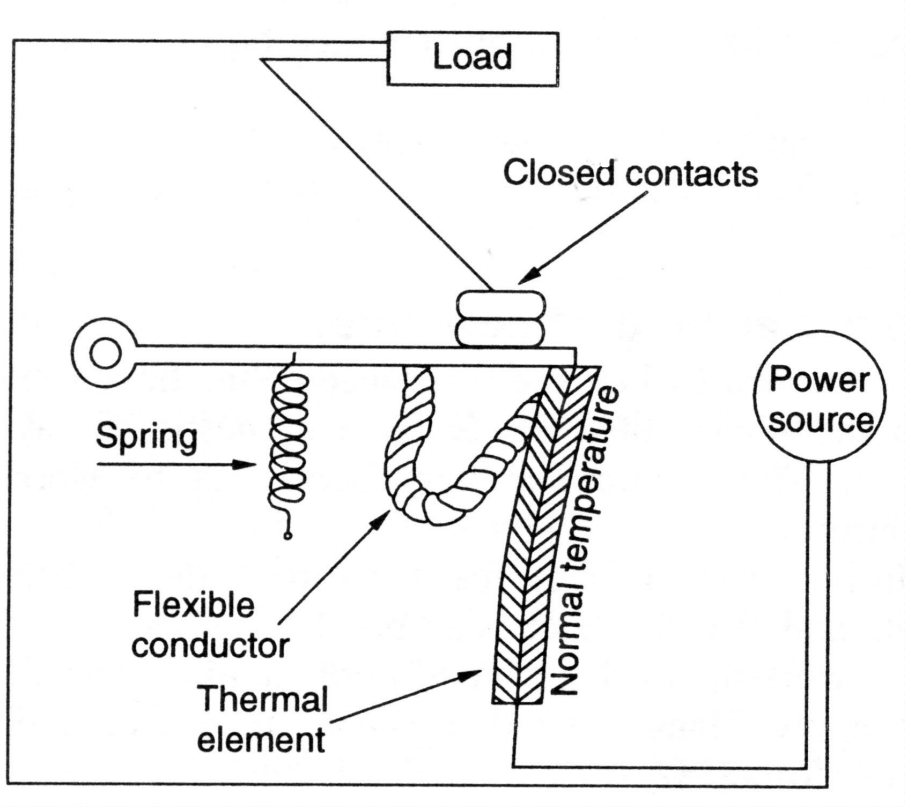
Under heavy overload or short circuit conditions the magnetic pull on the armature is large enough to trip the circuit breaker instantaneously.



Thermal Tripping

The principle of operation is a bimetal strip which bends when heated.

The time-delay characteristic being provided by the time taken to heat the element.



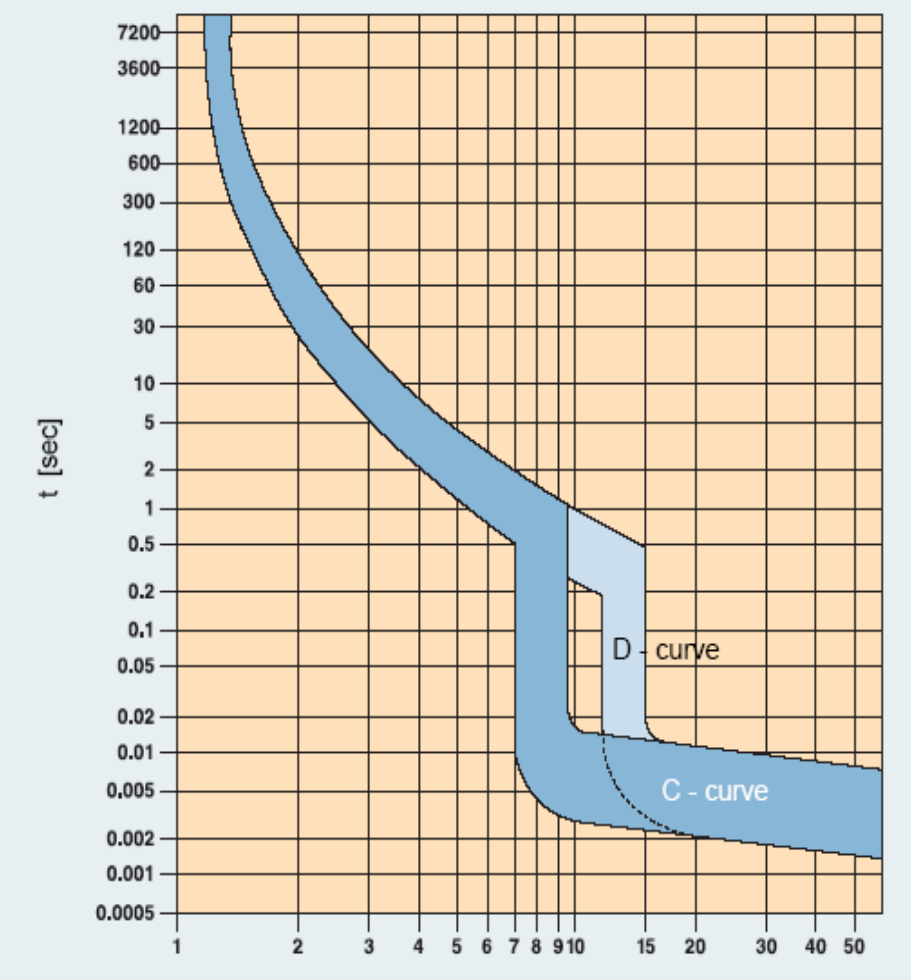
Thermal circuit breakers have three disadvantages compared with purely magnetic circuit breakers,

i. They are affected by ambient temperature;

ii. They require a short time after tripping to enable the bimetal strip and heater to cool down before being reclosed;

iii. Thermal tripping is ideal for overload protection but unsatisfactory against short-circuits.

Time / Current Characteristics of Circuit Breakers



- The curve represents the time taken to trip, for a multiple of the rated current.
- At 7.5 x the rated current a “C curve” circuit breaker will activate almost instantaneously.
- This region is the specified “fault region”.
- The “D curve” will take slightly longer to trip (12.5 x rated current).
- “D curves” are used for transient loads, such as induction motors.

Thermal Magnetic

Because of the characteristics of both thermal and magnetic, led to the development of the third type in which the characteristics are combined.

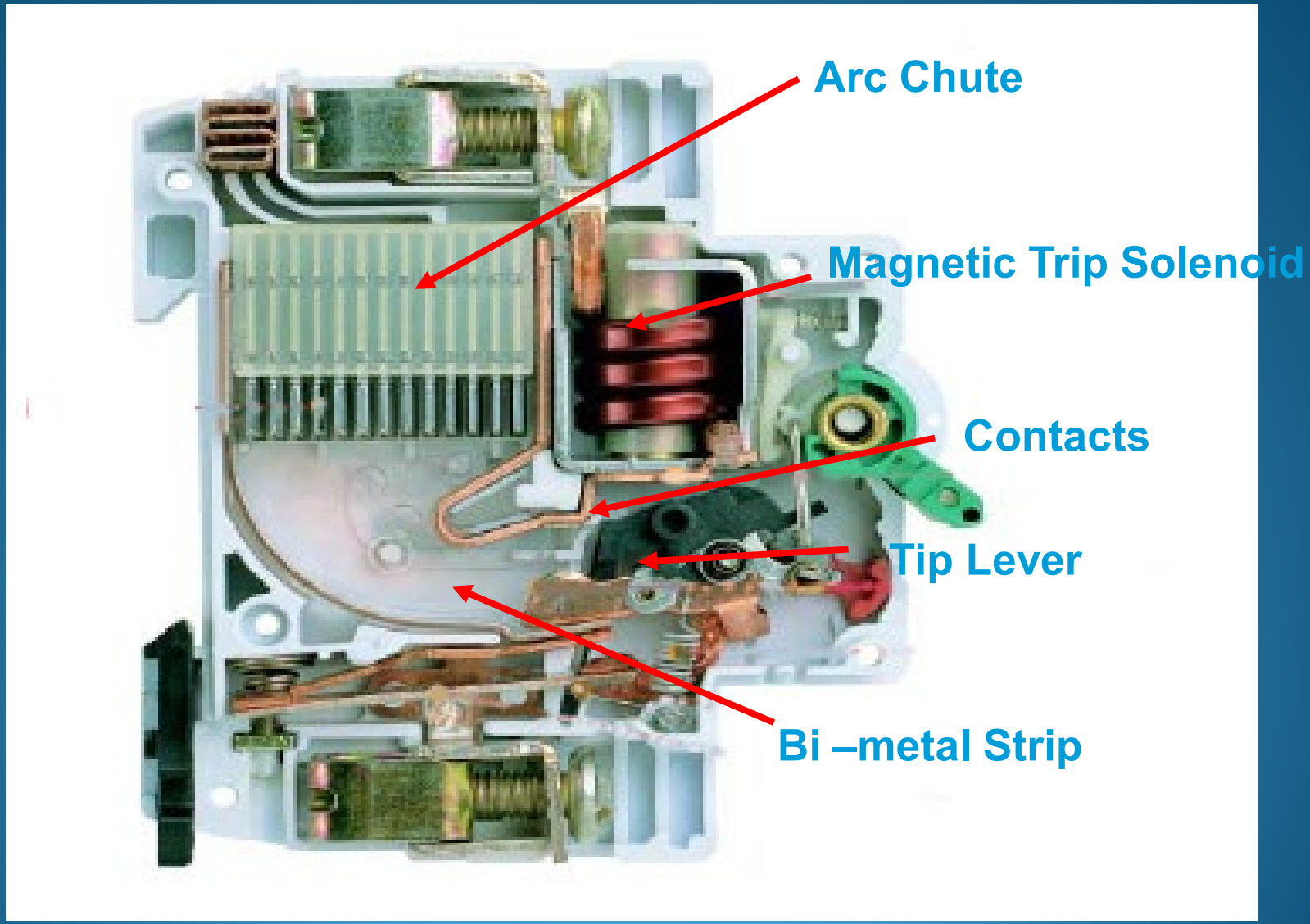
When overload occurs, time delay is provided by the time taken to heat the bi-metal element.

With massive overload or on short-circuit, the magnetic element influences the tripping time and is so adjusted that with ten times rated current it takes over completely to provide almost instantaneous tripping with a typical interrupting time of 0.01seconds.

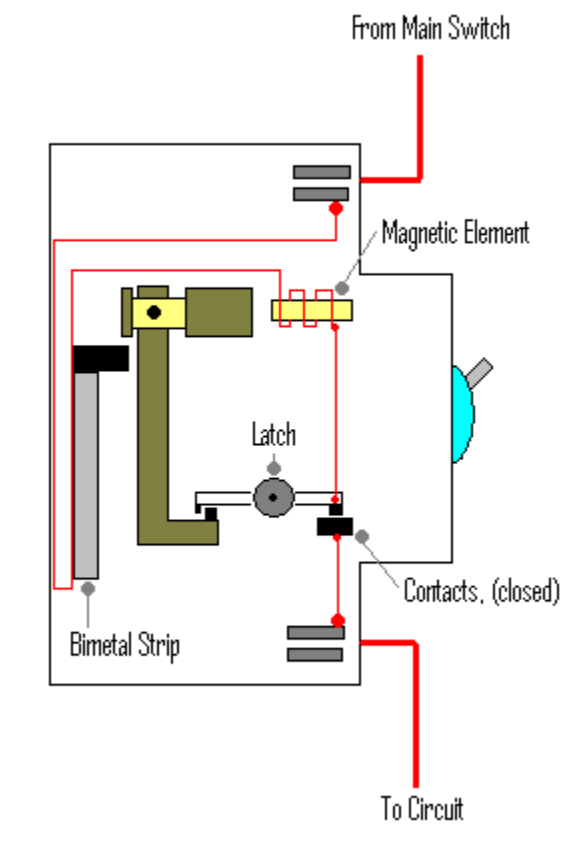
Operation

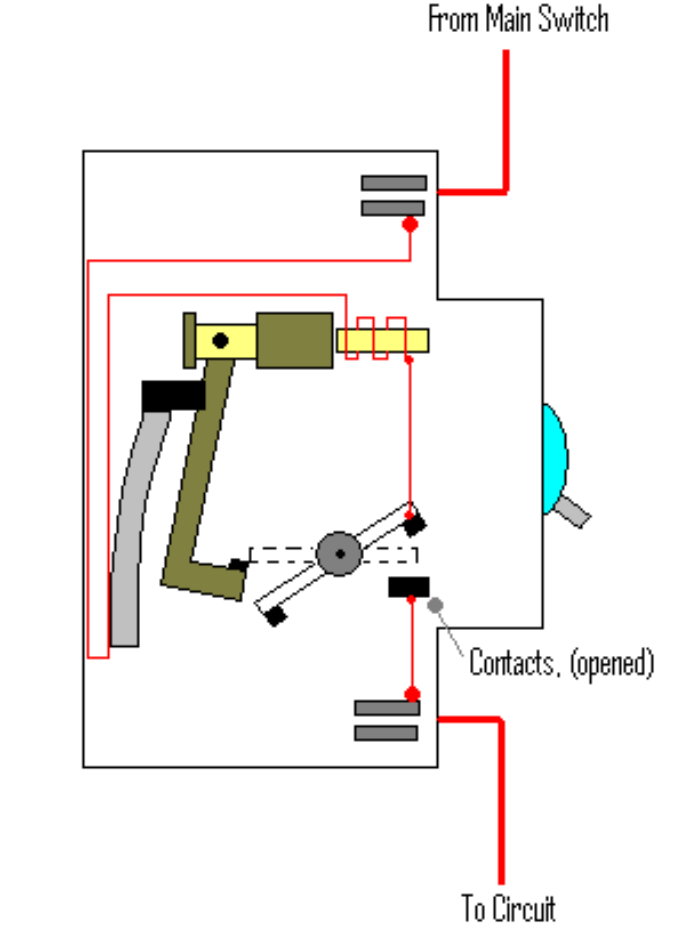
- **Thermal Operation**
  - When the “bi-metal element” is heated due to excessive current it deflects (bends).
  - this releases the “tripping lever” which is under tension.
  - As the “tripping lever” moves the “contacts” will open.
- **Magnetic Operation**
  - The solenoid coil will create a strong magnetic field under excessive current condition.
  - The solenoid attracts the armature.
  - Movement of the armature causes the tensioned contacts to be released.

Clipsal Circuit Breaker Type C & D



Simplified Tripping Mechanism of Combined Circuit Breakers





Advantages of Combined Action Circuit Breakers

- Time delay is provided by the heating of the bimetal element, no nuisance tripping from small transients.

- Under excessive current draw (10 x normal operating conditions), the magnetic mechanism will trip, providing almost instantaneous tripping, 0.01 seconds.

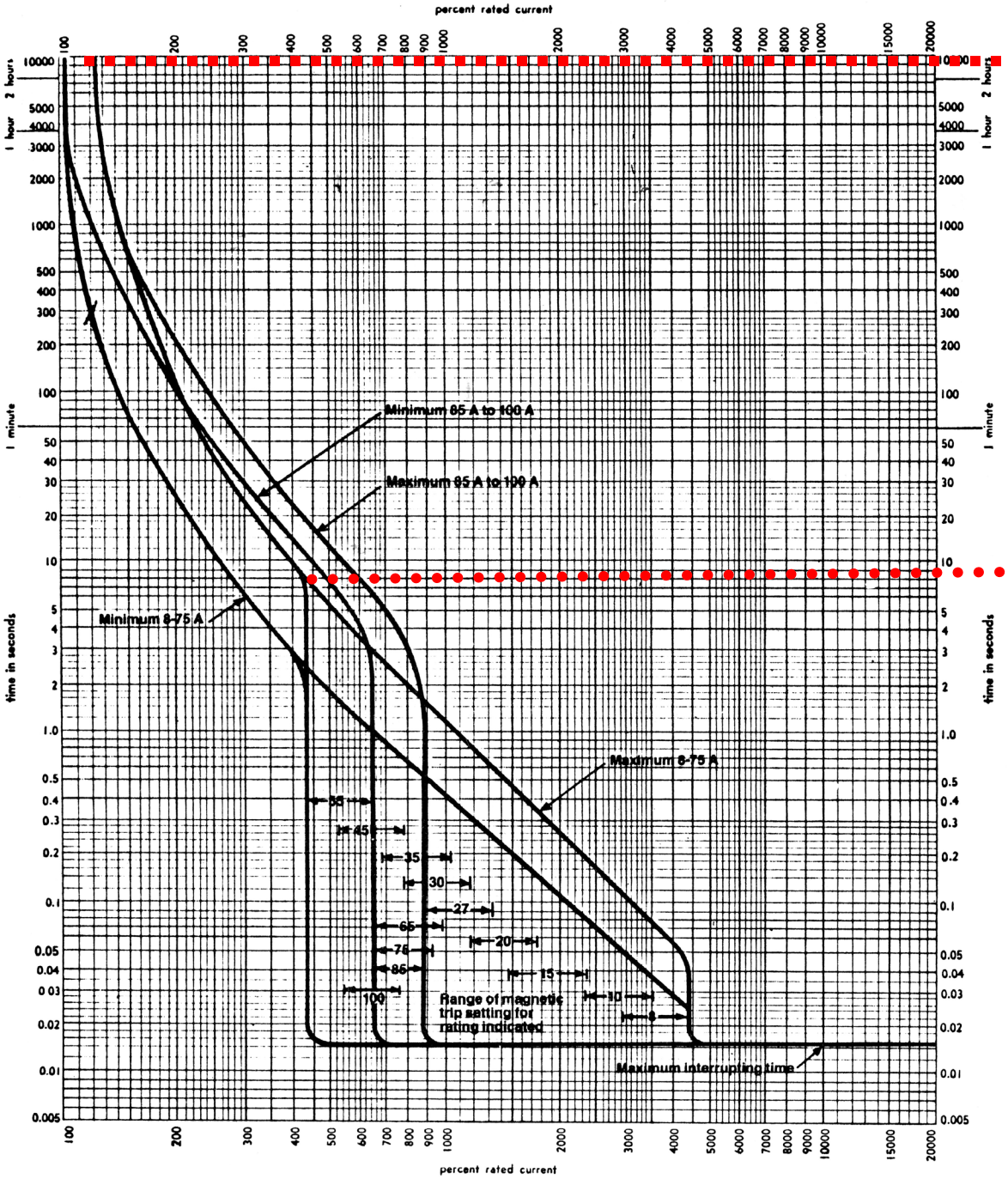
Time/Current Curves

Time/Current Curves show response time in seconds for applied overloads expressed in percentages of rated current.

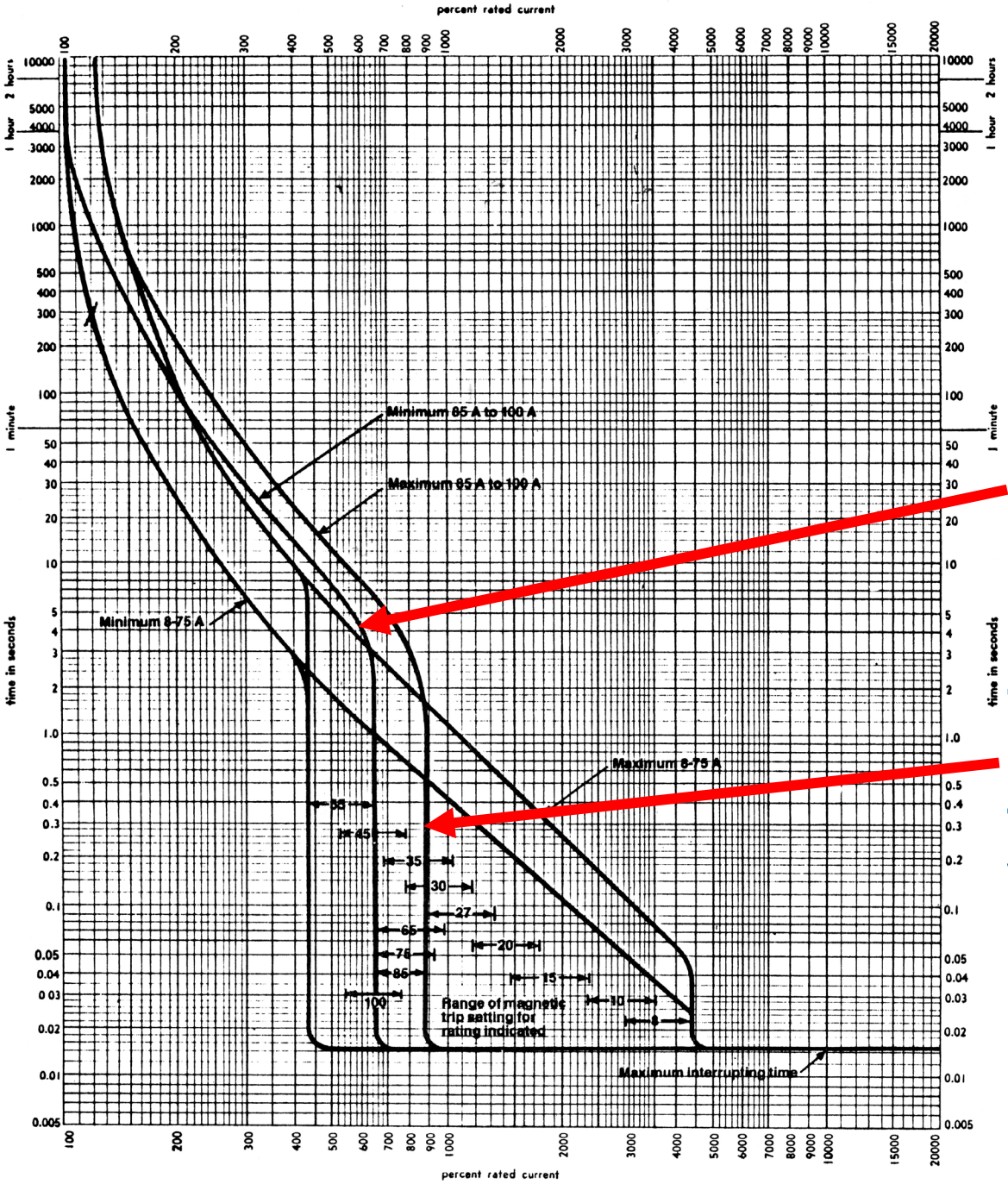
The time-current characteristics are presented not as a single curve but as a band defined by maximum and minimum curves.

The characteristic for any particular breaker will lie within this band.

Refer to figure for the time/current curves to see the smooth upper portions of the curves known as the **INVERSE TIME** characteristics, produced by the thermal action alone.



Refer to figure of the time/current curves to see the smooth upper portions of the curves known as the **INVERSE TIME** characteristics, produced by the thermal action alone.



The "knees" in the curves represent the tripping of the breaker under co-operative thermal-magnetic action.

The vertical portions represent the current at and above which the magnetic trip instantly opens the breaker.

Large Fault Currents (e.g. 1000% rated current)

For some installations where the supply impedance is relatively low a 'short circuit' can cause very large currents to flow.

In these special circumstances, a dead short, will cause the H.R.C. fuse to blow before the circuit breaker.

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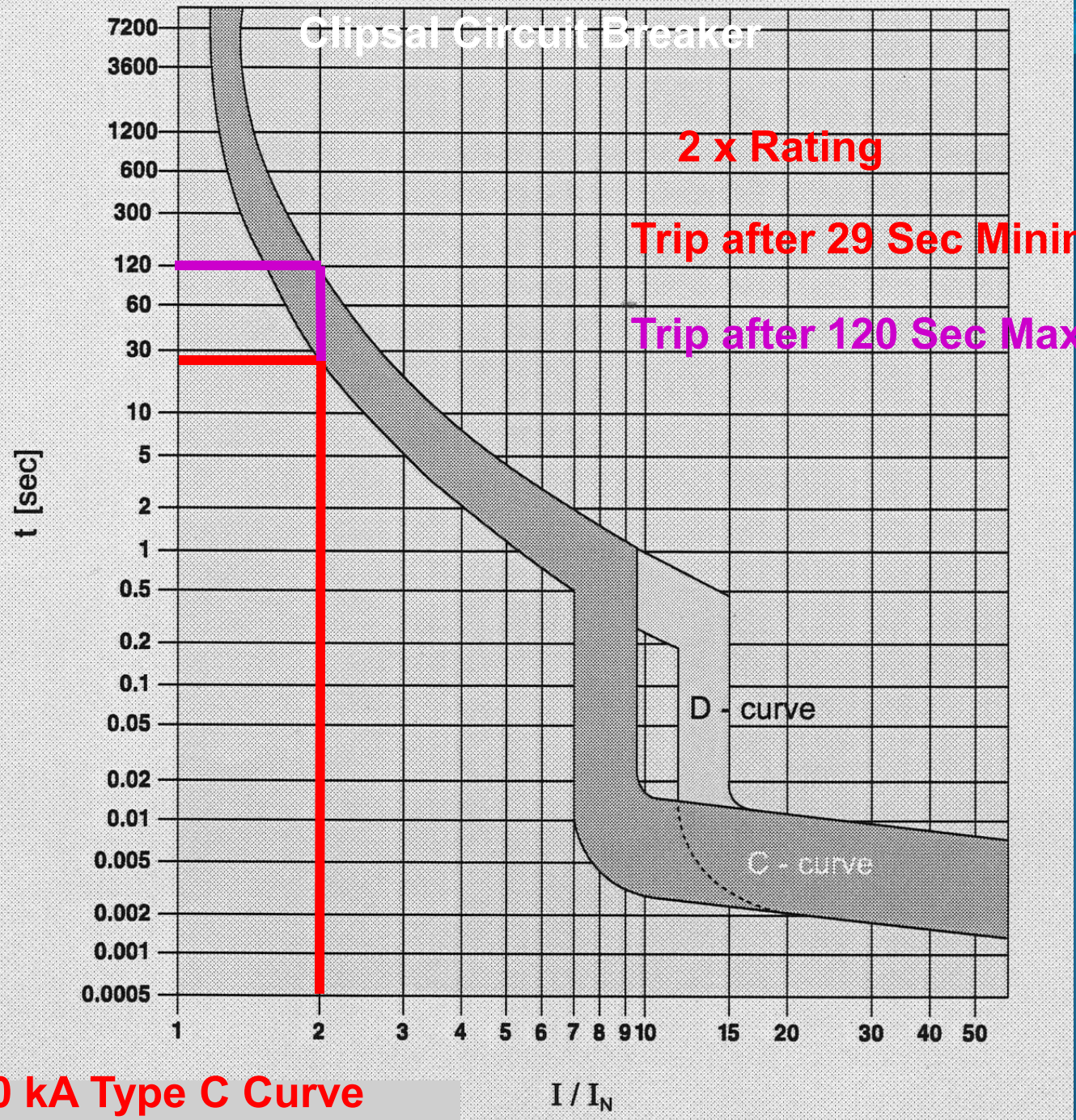
20 Amp Fuse with a 10 x Overload = 200 Amps

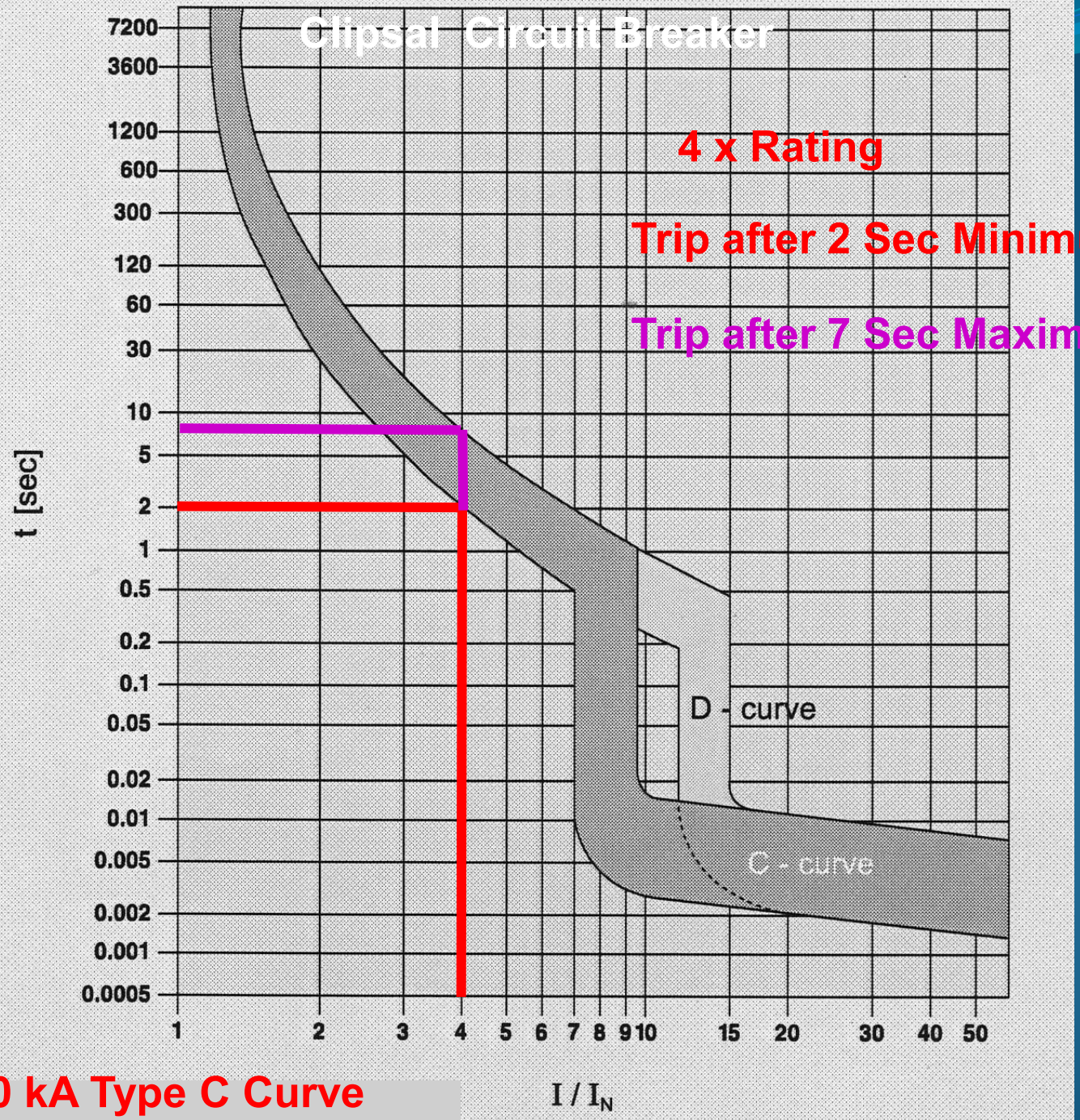
Time to Trip 0.01 Seconds or 10 mSecs

20 Amp Circuit breaker 10 x Rating = 200 Amps

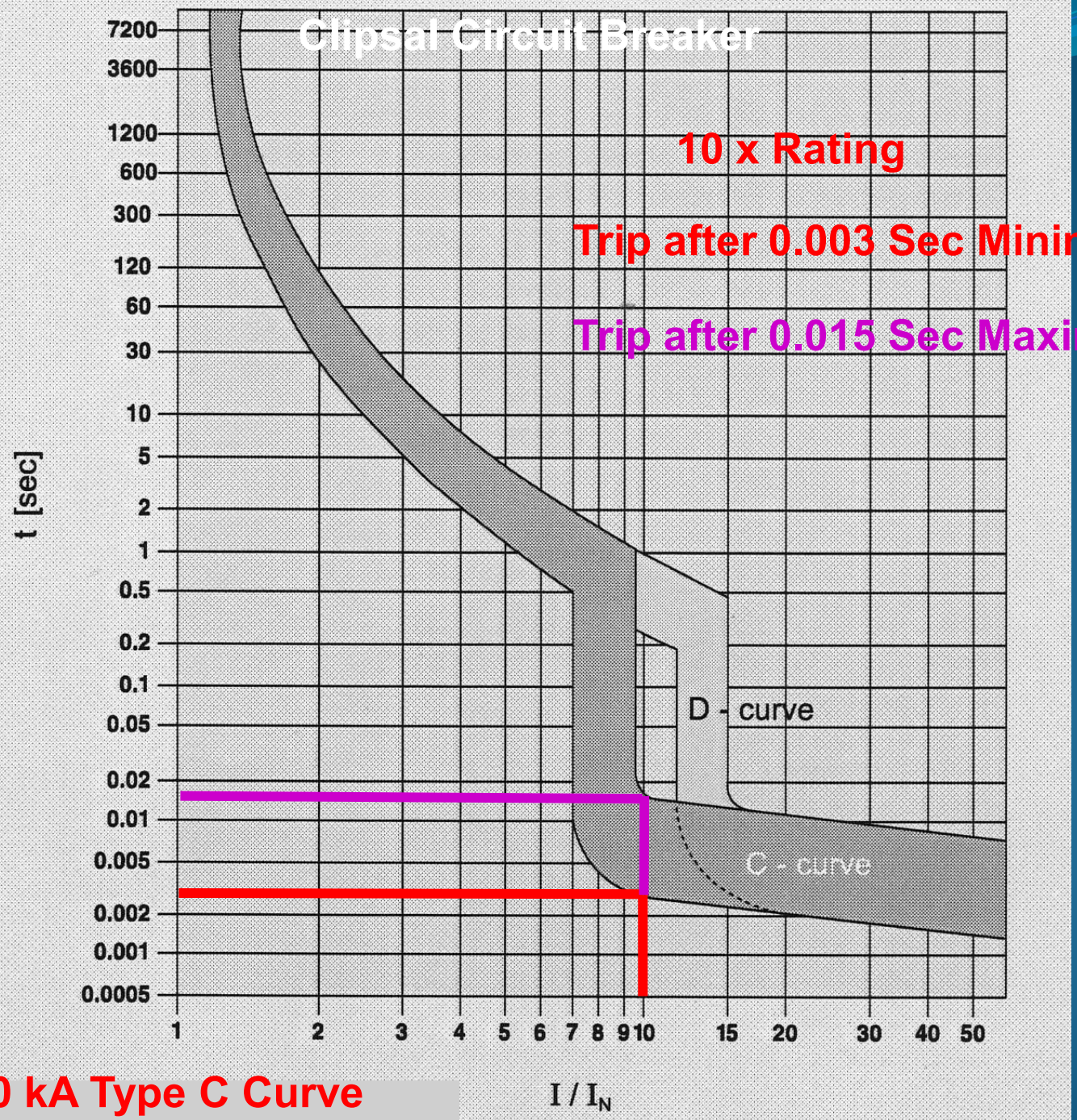
Trip after 0.015 Seconds or 15 mSec

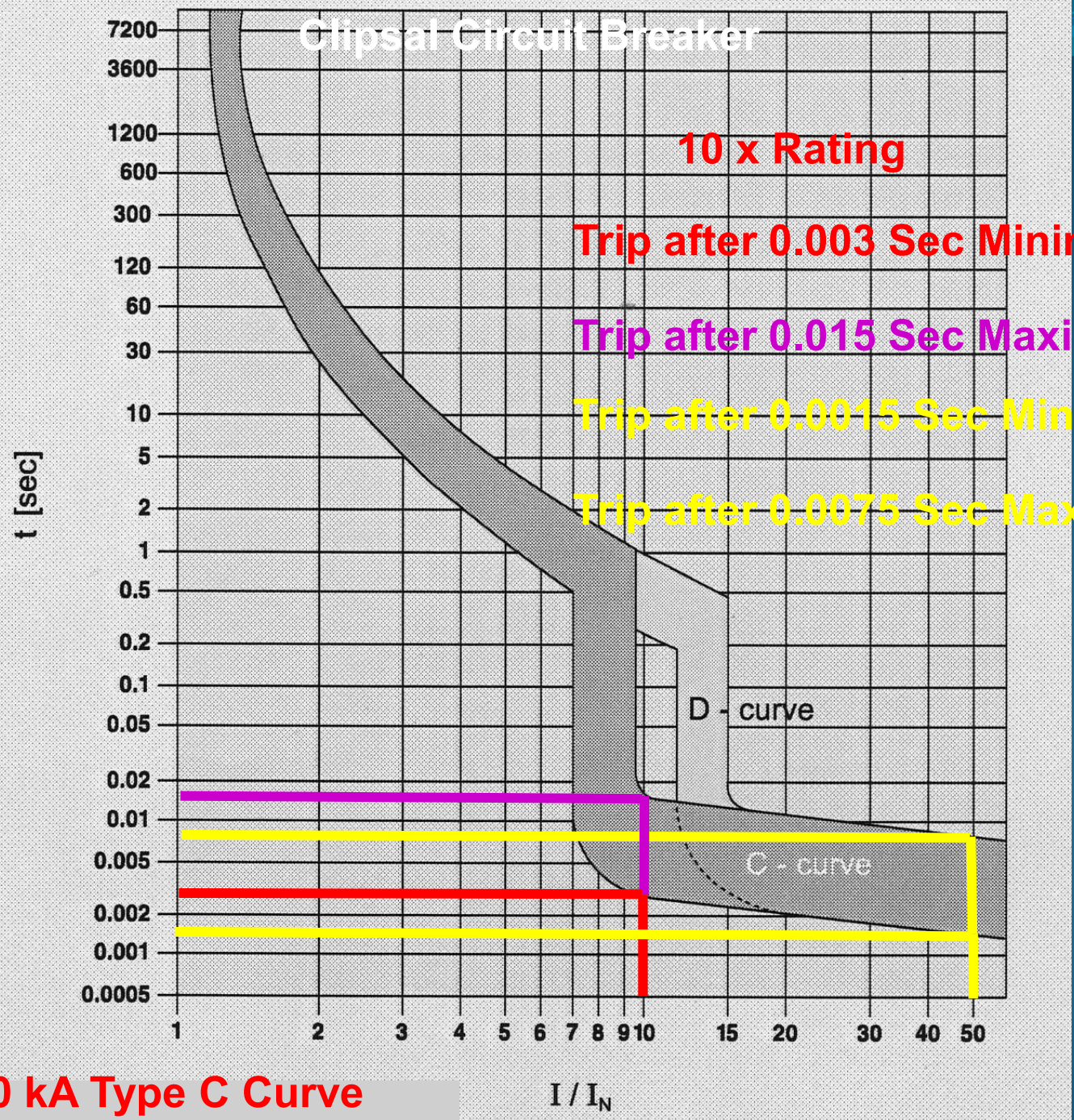


10 kA Type C Curve



10 kA Type C Curve


Clipsal Circuit Breaker
10 x Rating
Trip after 0.003 Sec Minimum
Trip after 0.015 Sec Maximum
t [sec]
7200
3600
1200
600
300
120
60
30
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.0005
D - curve
C - curve
1
2
3
4
5
6
7
8
9
10
15
20
30
40
50
I / I_N
10 kA Type C Curve



10 kA Type C Curve

Arcing

- Arcs may occur when opening circuits under load, especially with high current involved.
- Arcs should be considered as a current carrying conductor surrounded by a magnetic field.
- Arcs may cause “flash overs” where the air around the device ionises & combusts.
- This can result in serious injury.

Methods of Arc Quenching

- Several methods can be used to reduce the risk of arcing while disconnecting a supply under load.
  - De-ion Arc Quenching.
  - Magnetic Blow Out.
  - Oil Quenching.
  - Air Blast Quenching.

Arc Quenching Methods

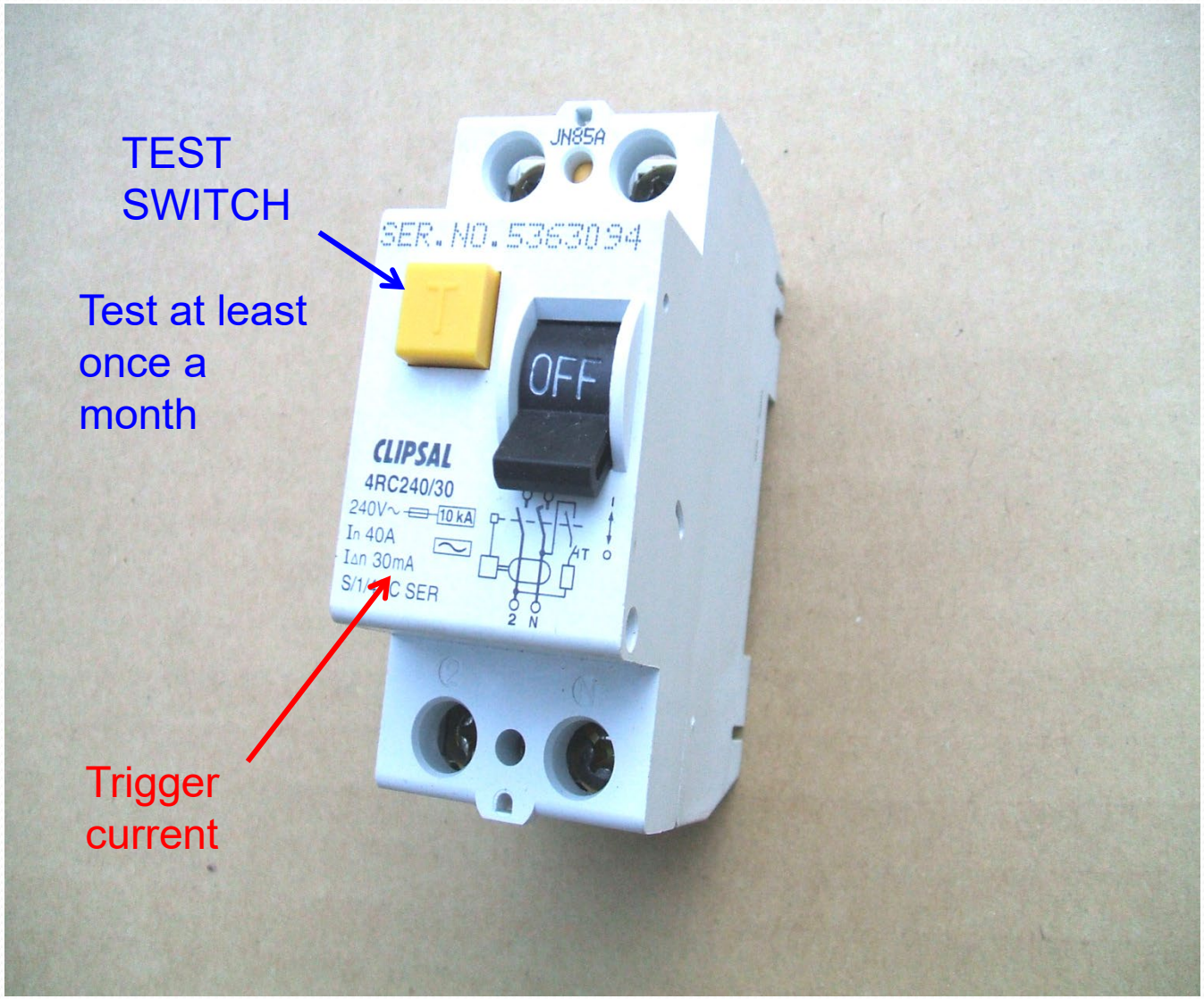
- De-ion Arc Quenching
  - Stretches & breaks the arc.
  - The circular magnetic field is distorted, this pushes the arc into several plates.
  - The plates cut the arc into smaller segments, therefore extinguishing it.
- Magnetic Blow Out
  - Is an arrangement of the contacts where when disconnected, the arc will bend outwards & stretch until broken.
  - Once broken the arc is considered extinguished.

Arc Quenching Methods

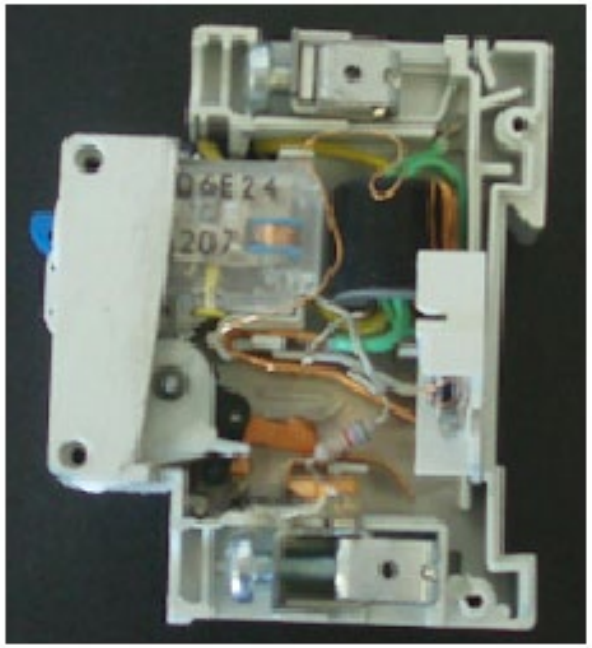
- Oil Quenching
  - A specially designed circuit breaker known as a “OCB”.
  - The circuit breaker is filled with non conductive oil which will quench & cool the arc very quickly.
- Air Blast Quenching
  - Very large ACB’s as used by the supply authority operate from this method.
  - As the contacts are separated, a blast of air across the contact gap stretches & breaks the arc.

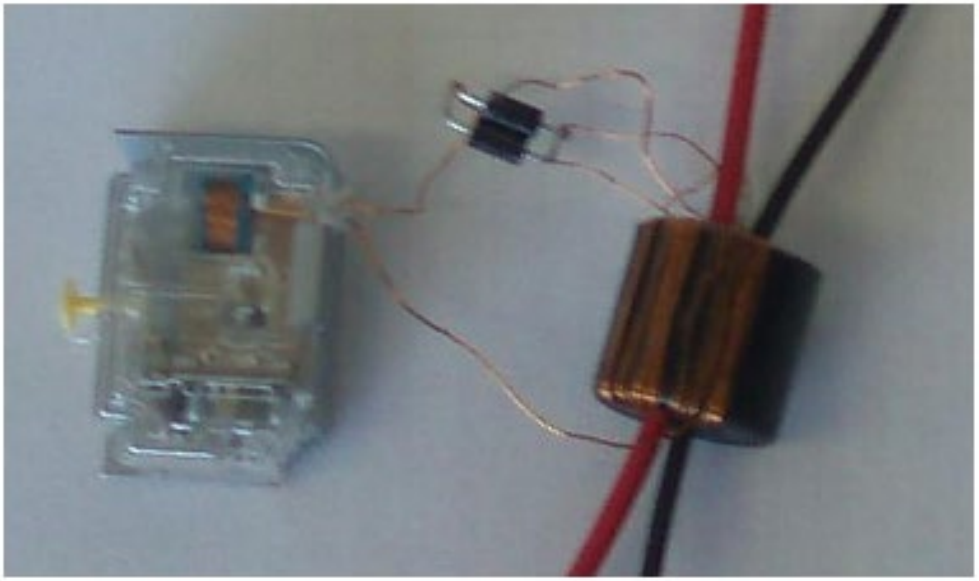
RCD's

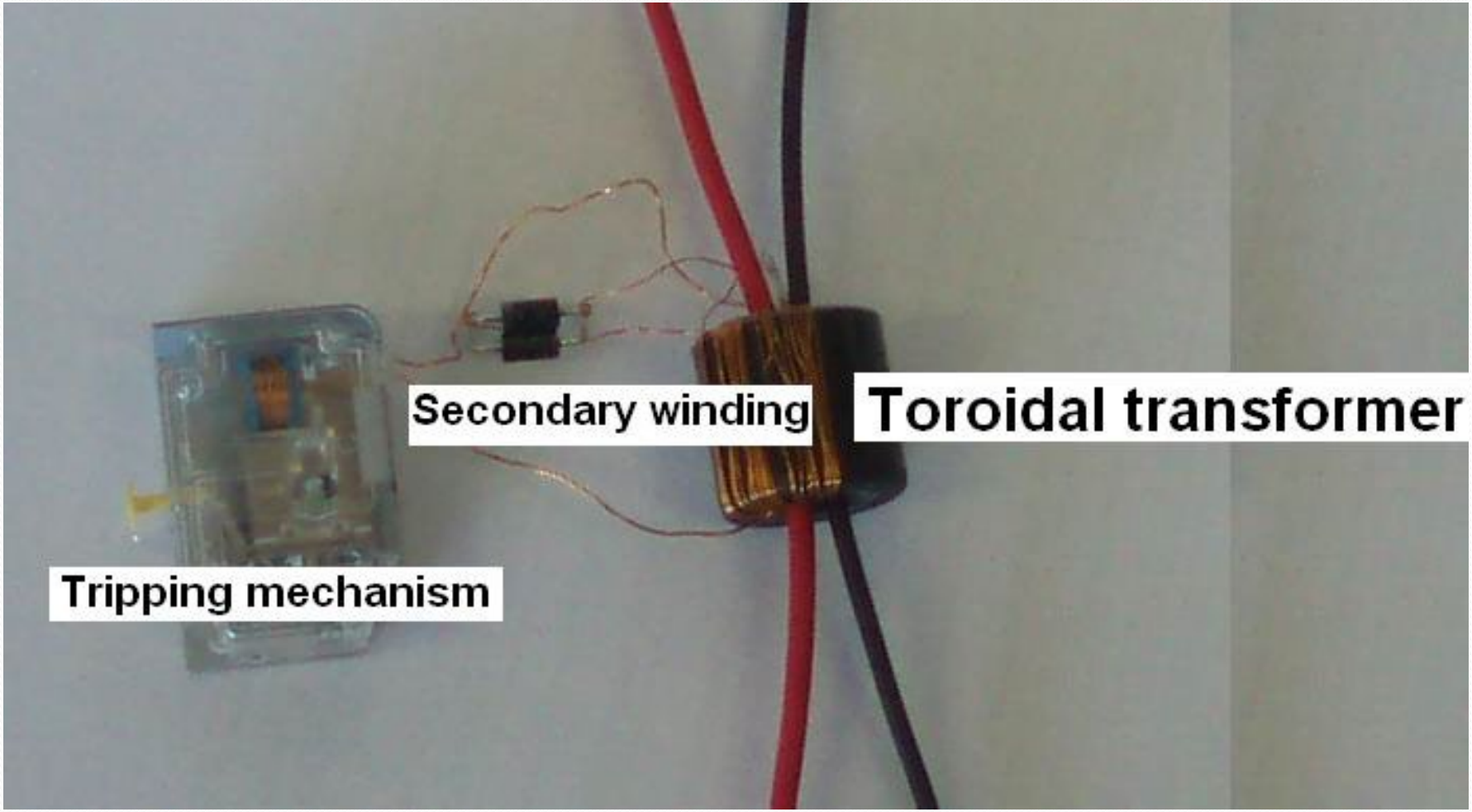
- Designed to disconnect the supply if "earth leakage" occurs.
- Protects us from shock hazards (Safety Device)
- Are mandatory on light & power circuits in domestic installations.
- Required on all portable appliances on a construction site.


TEST SWITCH
Test at least once a month
Trigger current
JN85A
SER.NO.5363094
OFF
CLIPSAL
4RC240/30
240V~
10 kA
In 40A
IΔn 30mA
C SER
2 N


CLIPSAL
RCBM210/30
C10

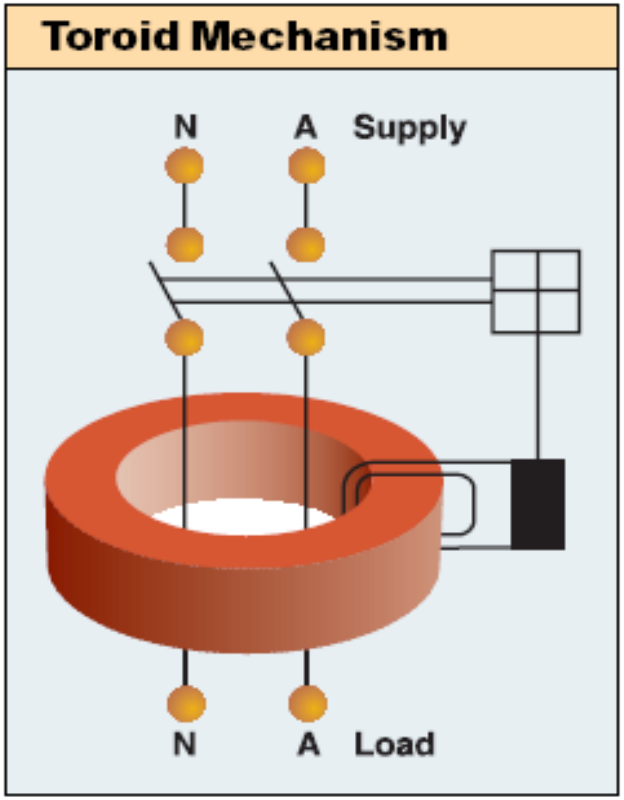


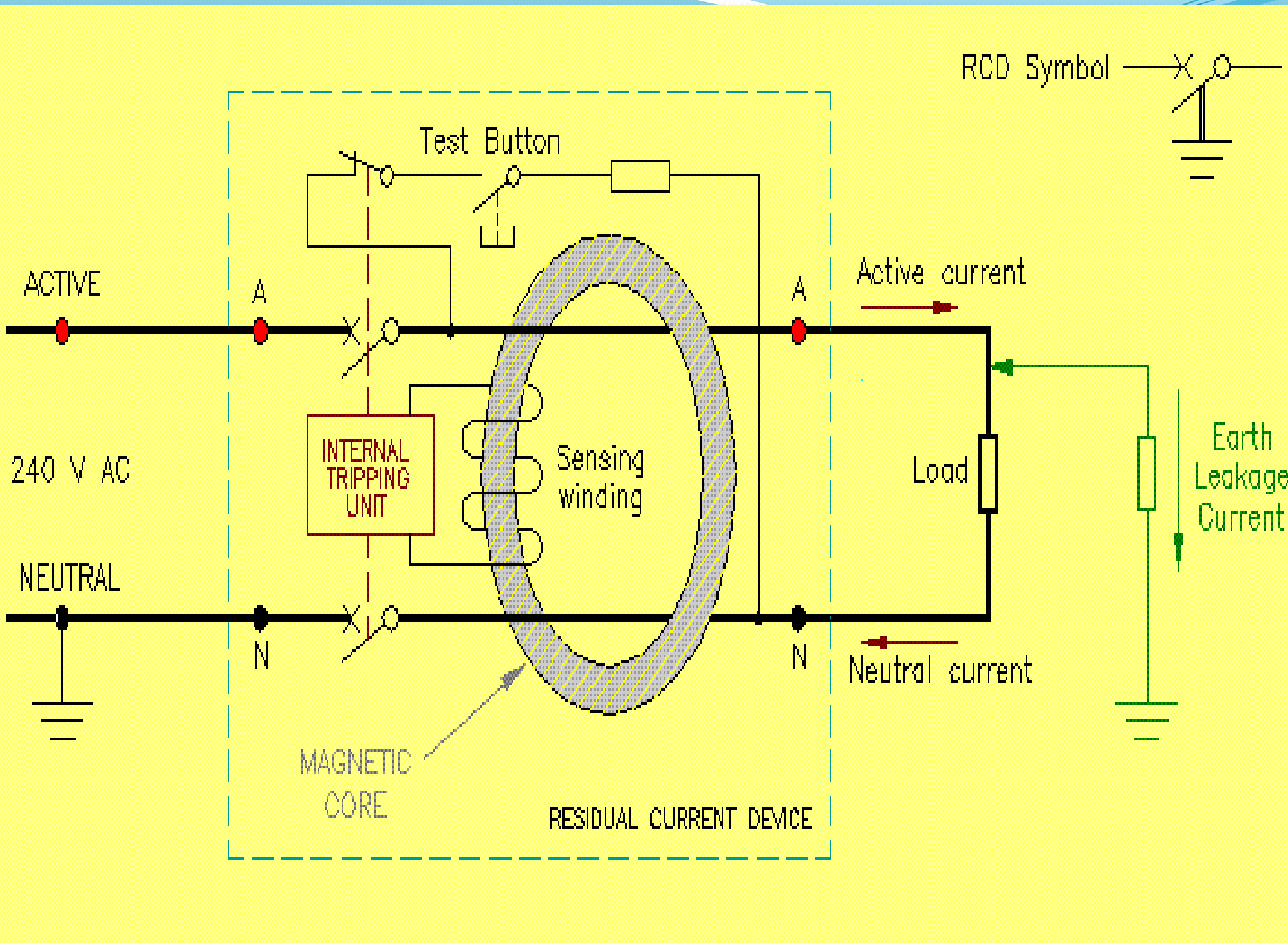



Secondary winding
Toroidal transformer
Tripping mechanism

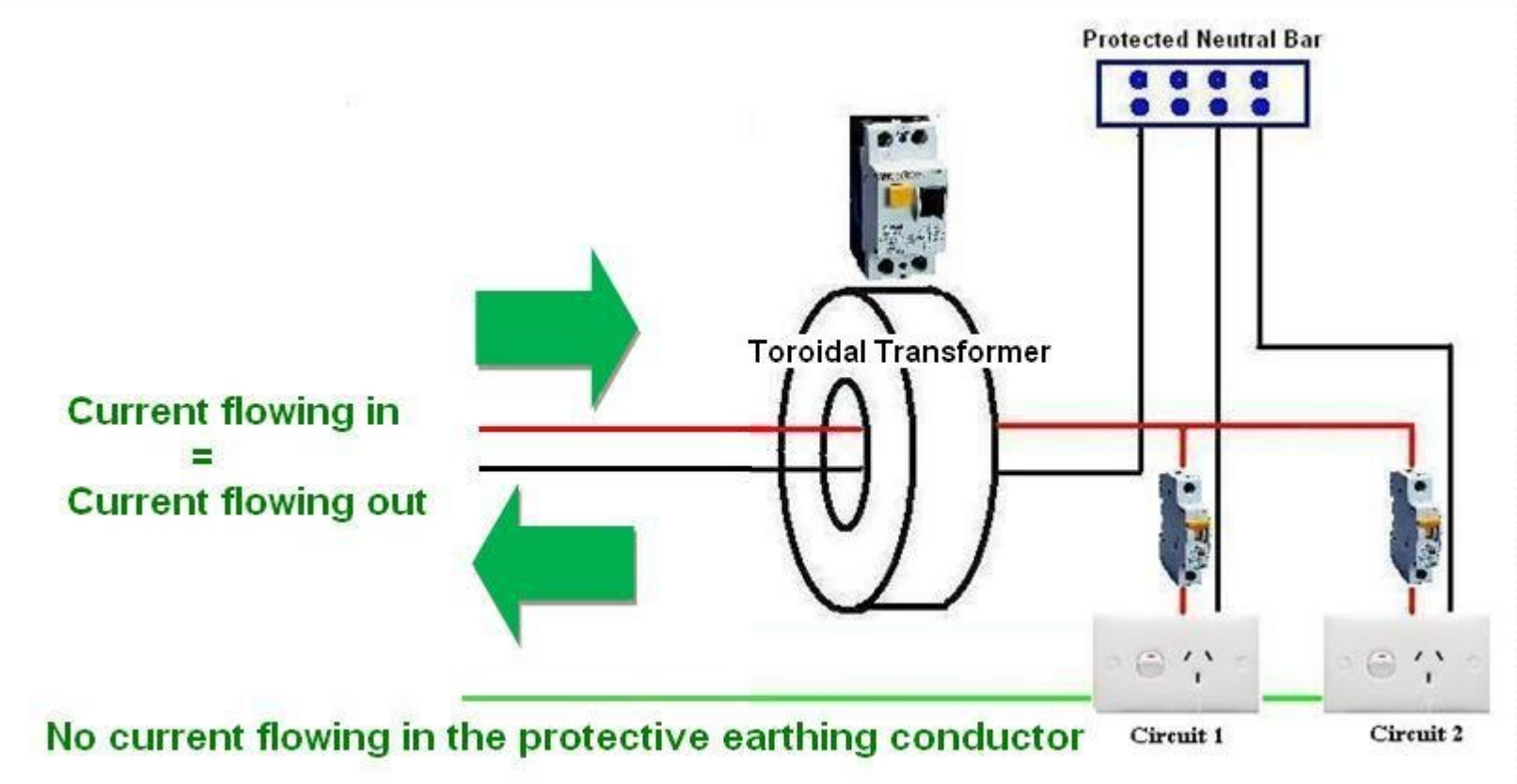
RCD Operation

- Constantly monitors the level of current in the active & neutral conductors which are normally balanced.
- If any current flows to earth via a fault, an imbalance is created & the RCD will activate.
- Automatically trips when sufficient current (e.g. 30mA) flows in the Earth path.
- A circuit breaker (e.g. I>40A).

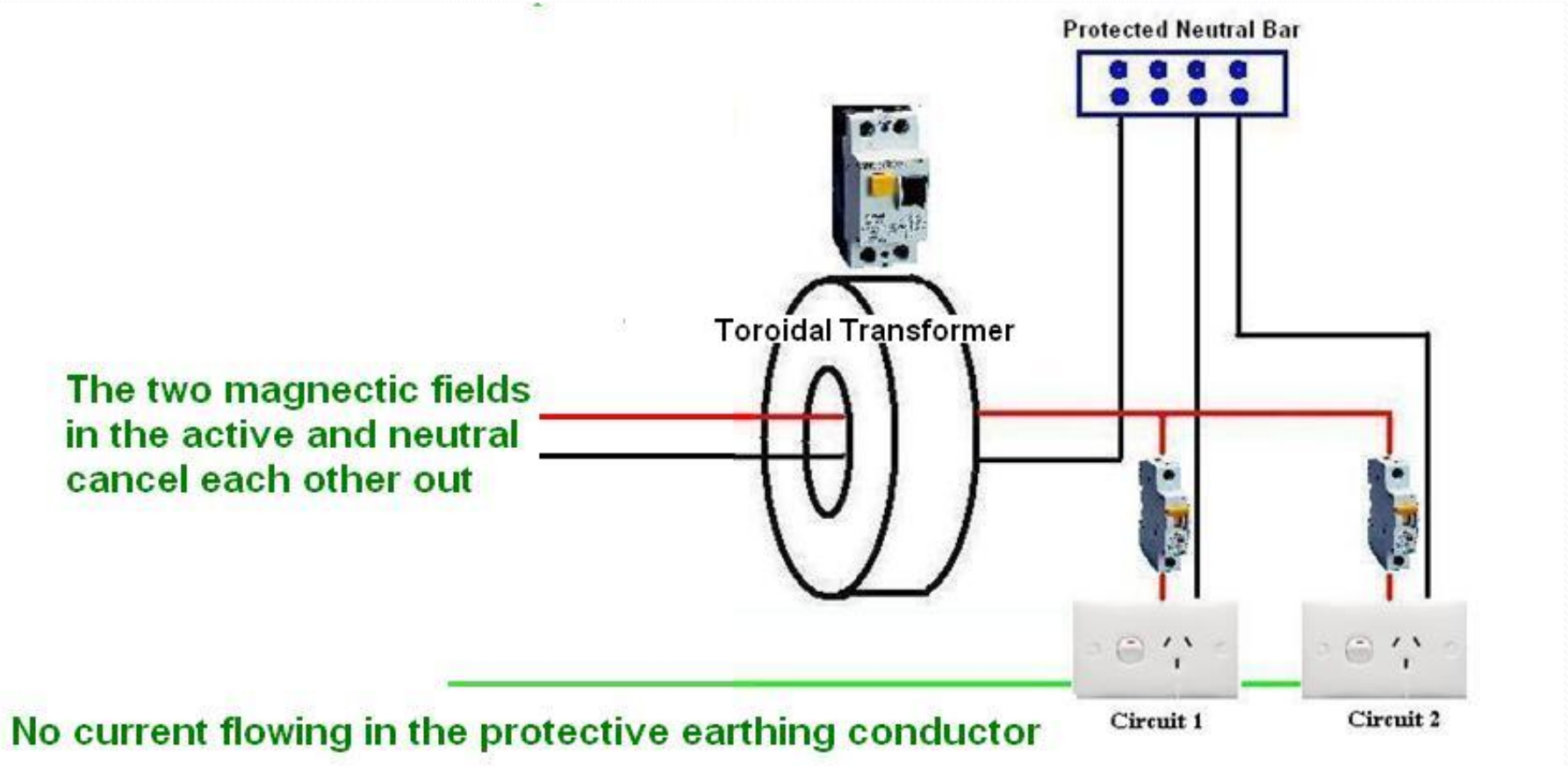



RCD Symbol
Test Button
ACTIVE
A
A
Active current
240 V AC
INTERNAL TRIPPING UNIT
Sensing winding
Load
Earth Leakage Current
NEUTRAL
N
N
Neutral current
MAGNETIC CORE
RESIDUAL CURRENT DEVICE

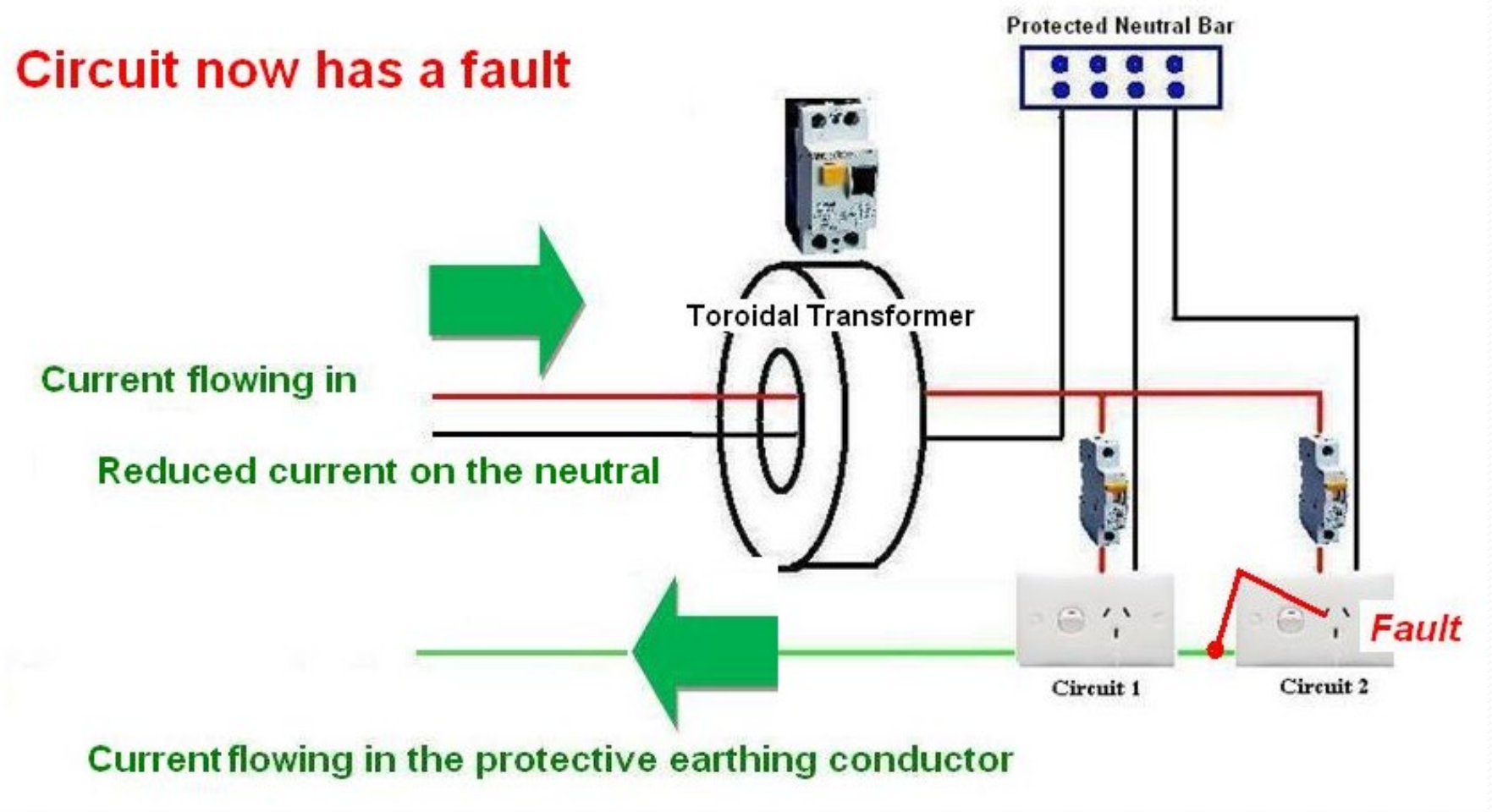
The RCD works by constantly monitoring and comparing the current flow in both the Active and Neutral circuits of an electrical installation.



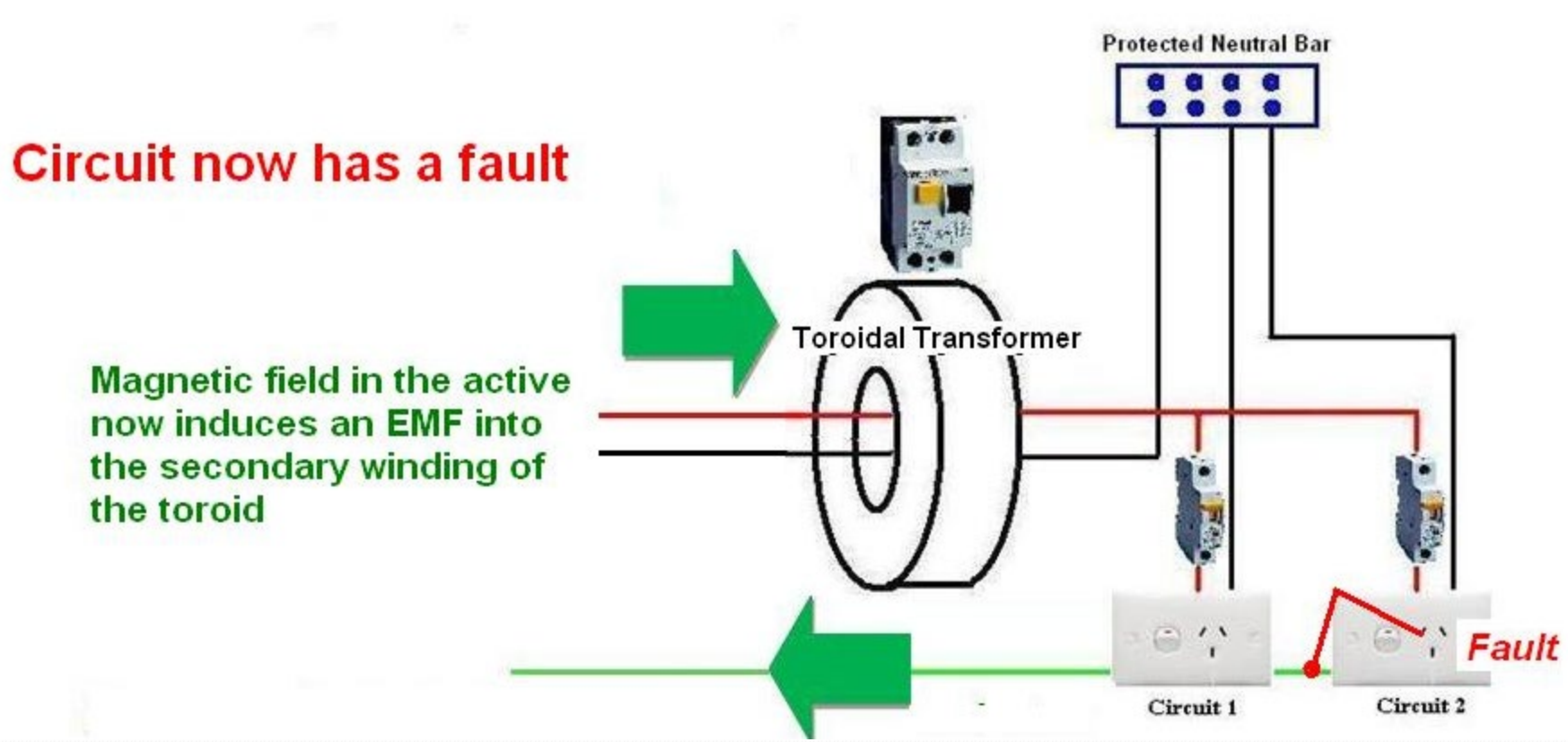
During normal operation, these Active and Neutral currents are in balance.



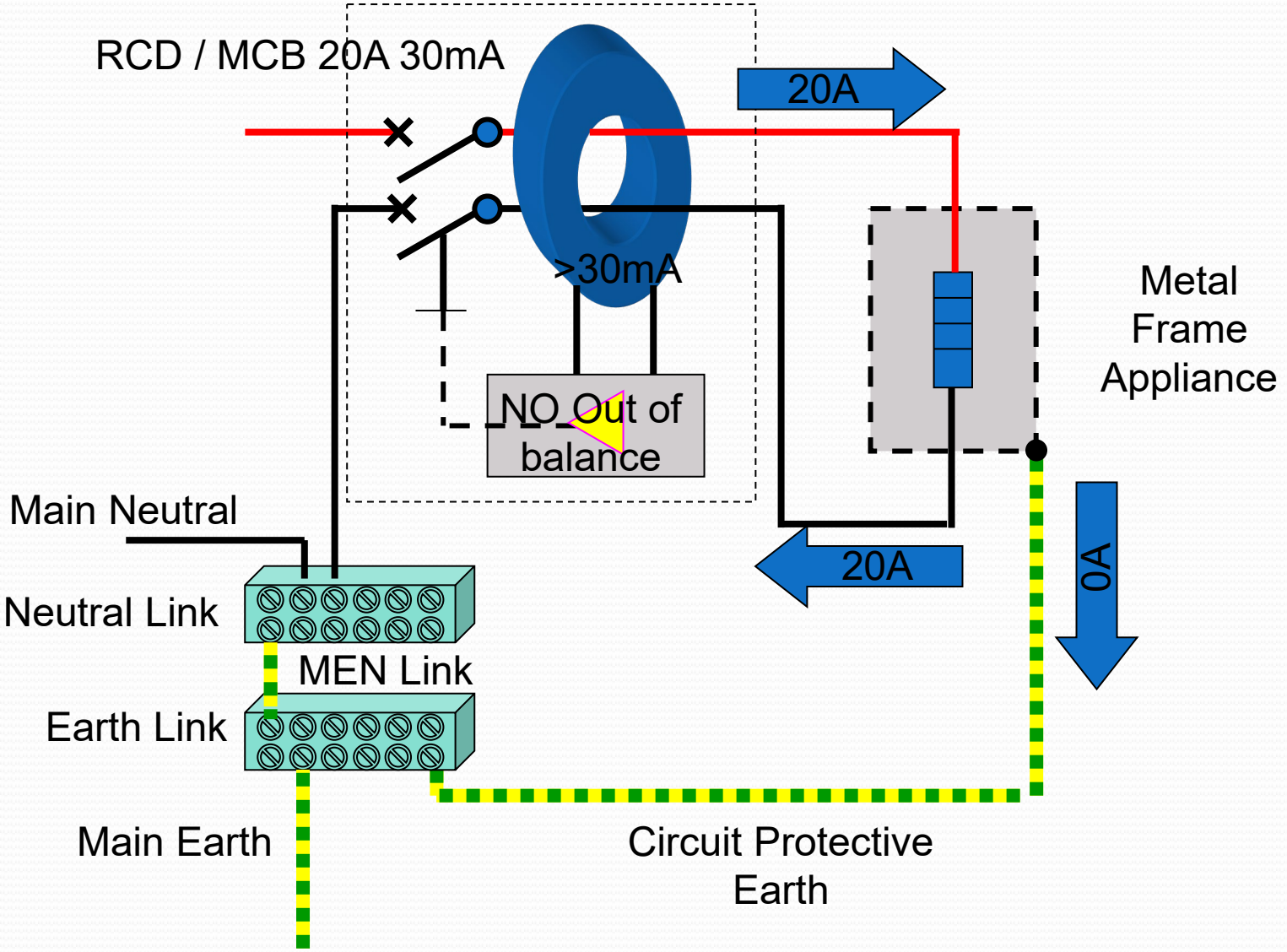
However, should any current flow to earth, an imbalance is created in these circuits.



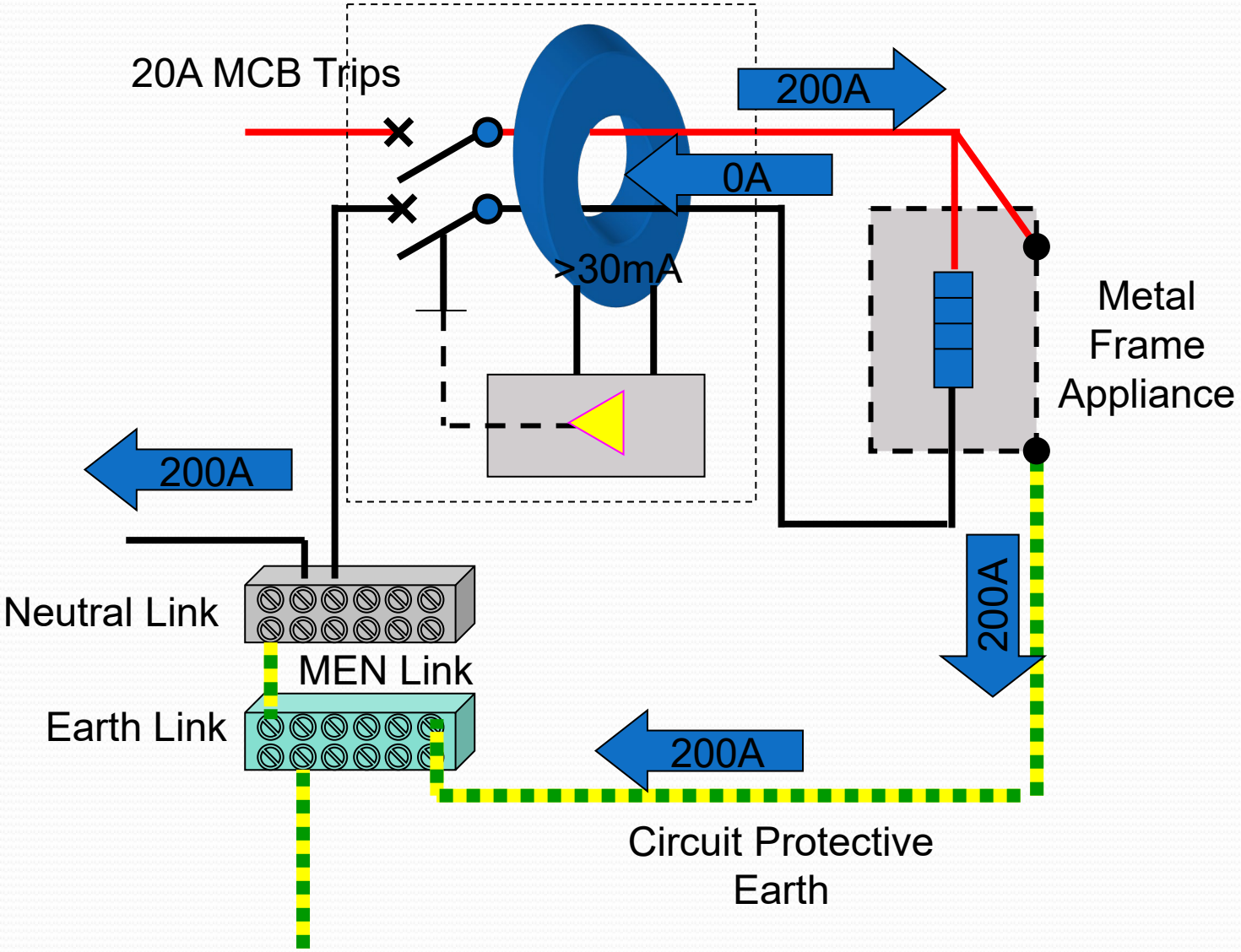
If this imbalance is sufficient, the RCD will cut the electrical supply.



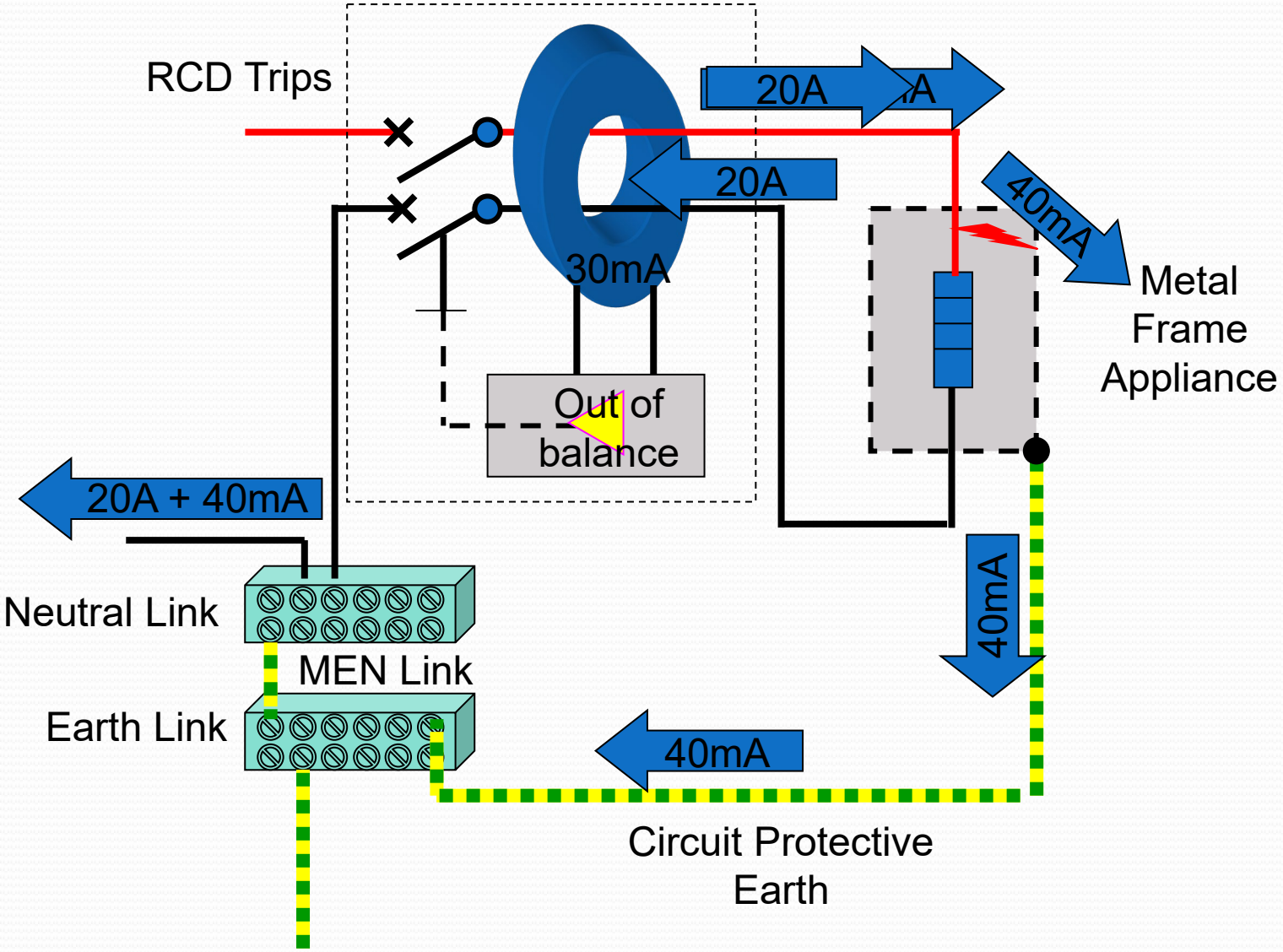
NO Fault


RCD / MCB 20A 30mA
20A
>30mA
NO Out of balance
Metal Frame Appliance
Main Neutral
20A
0A
Neutral Link
MEN Link
Earth Link
Main Earth
Circuit Protective Earth

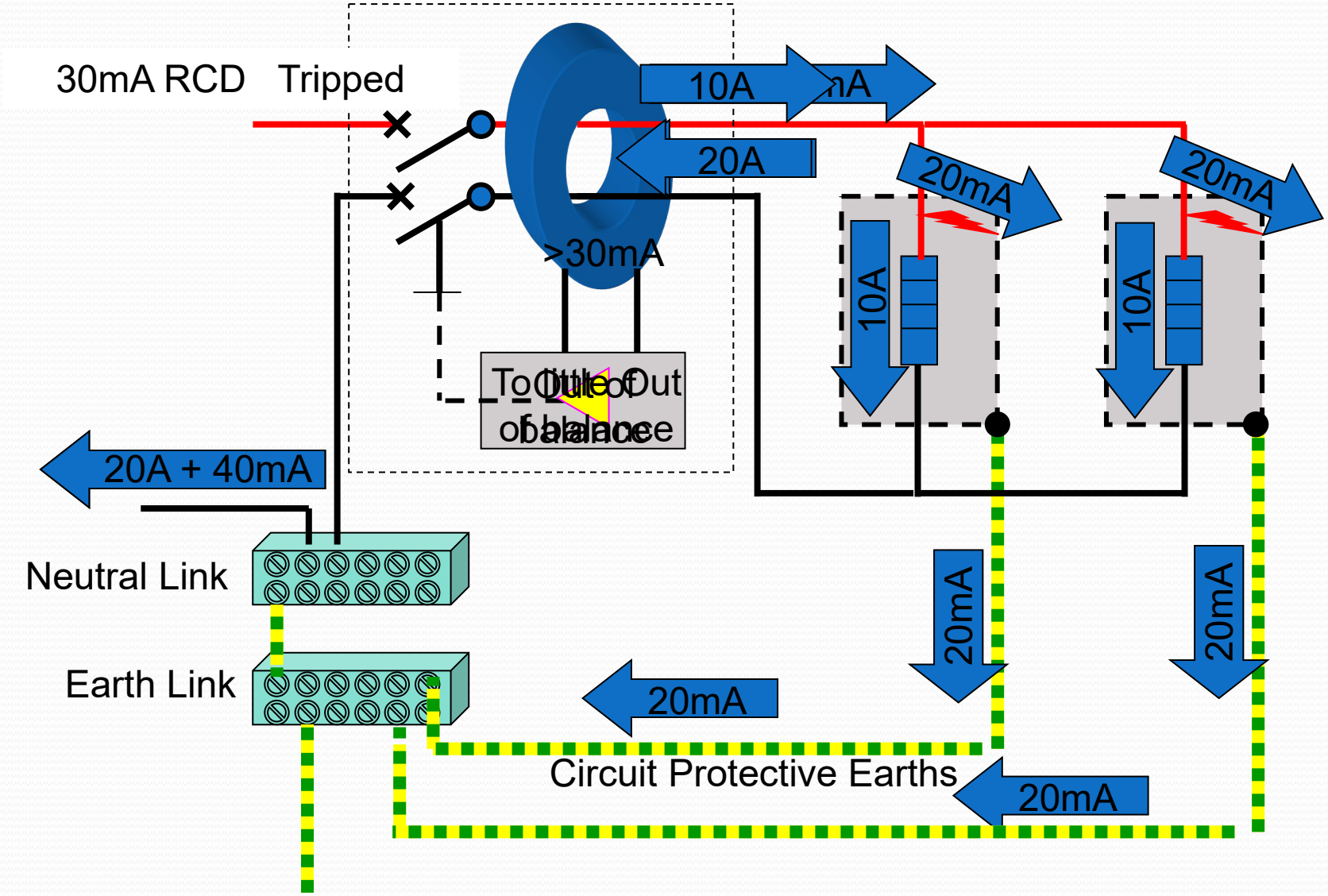
Low Resistance Short To Earth



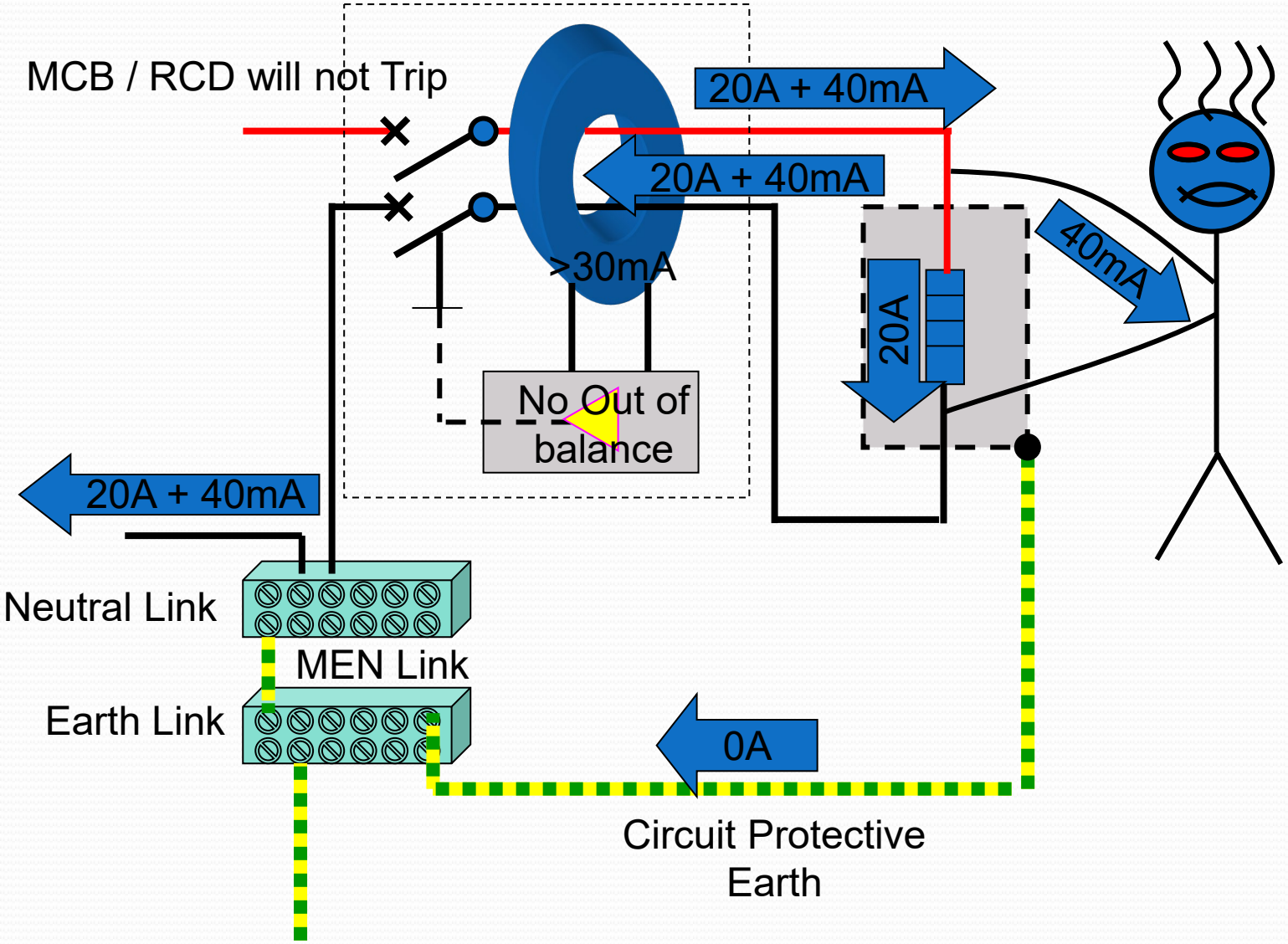
High Resistance Leakage To Earth



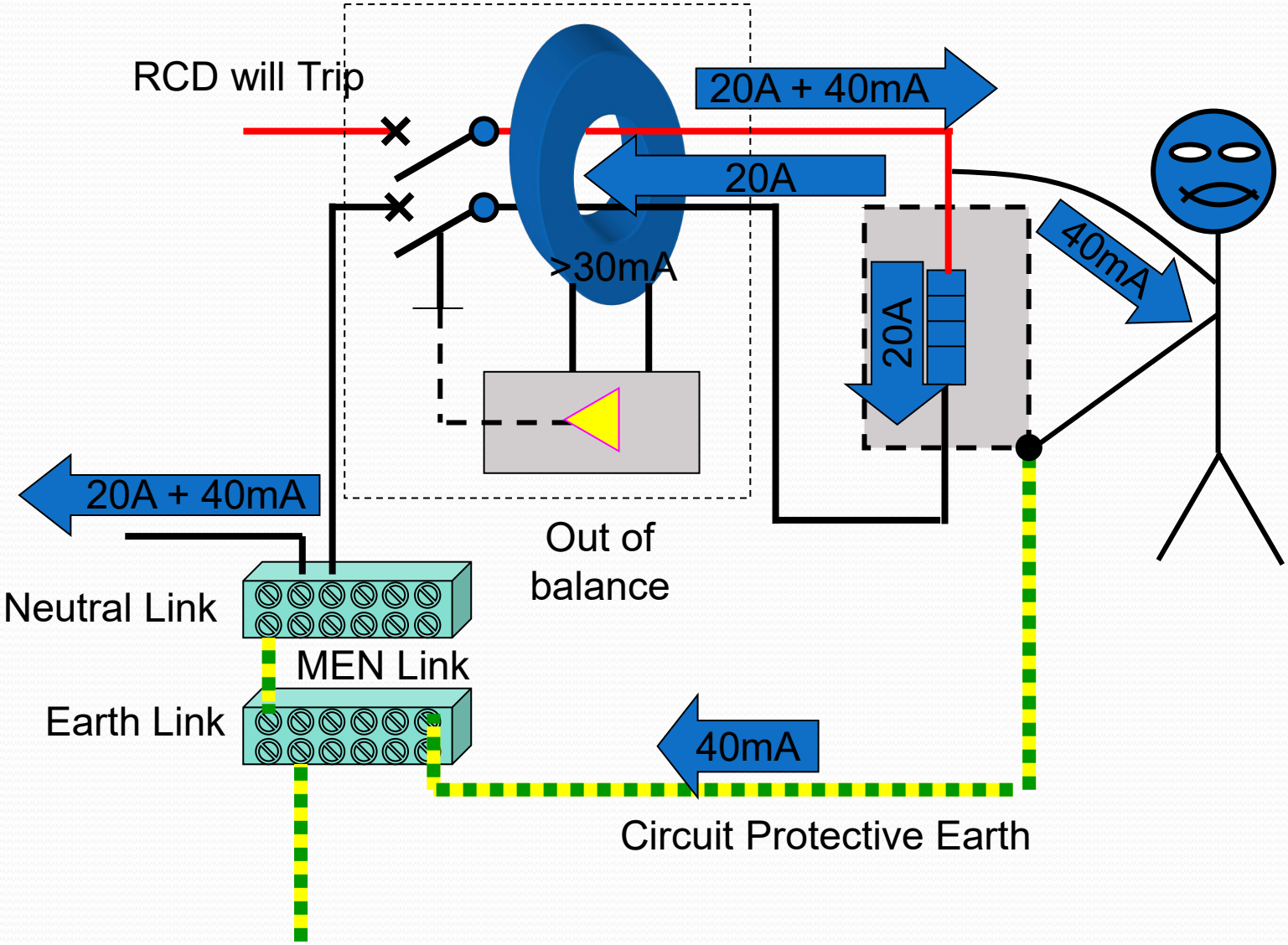
Cumulative Leakage To Earth

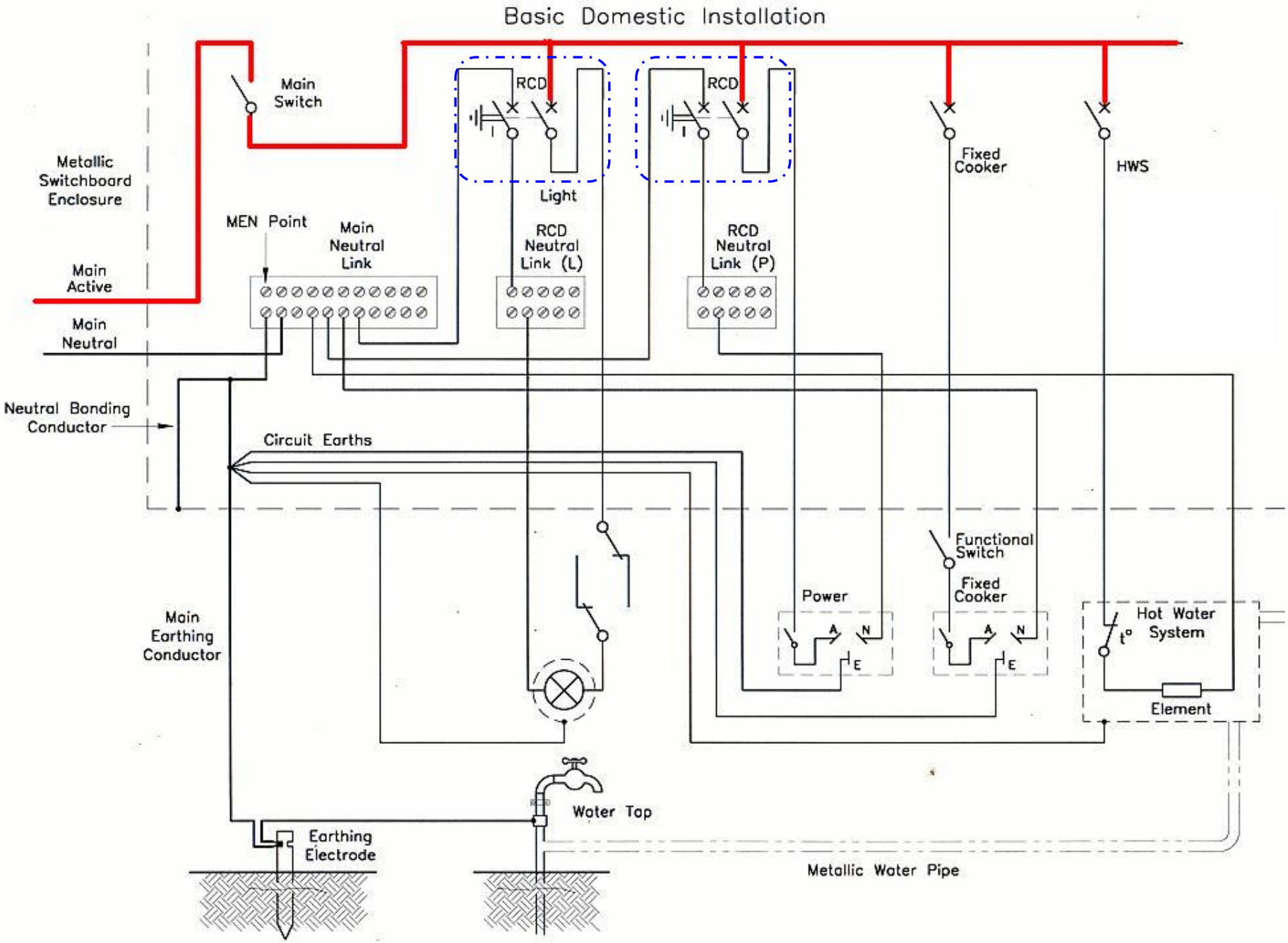


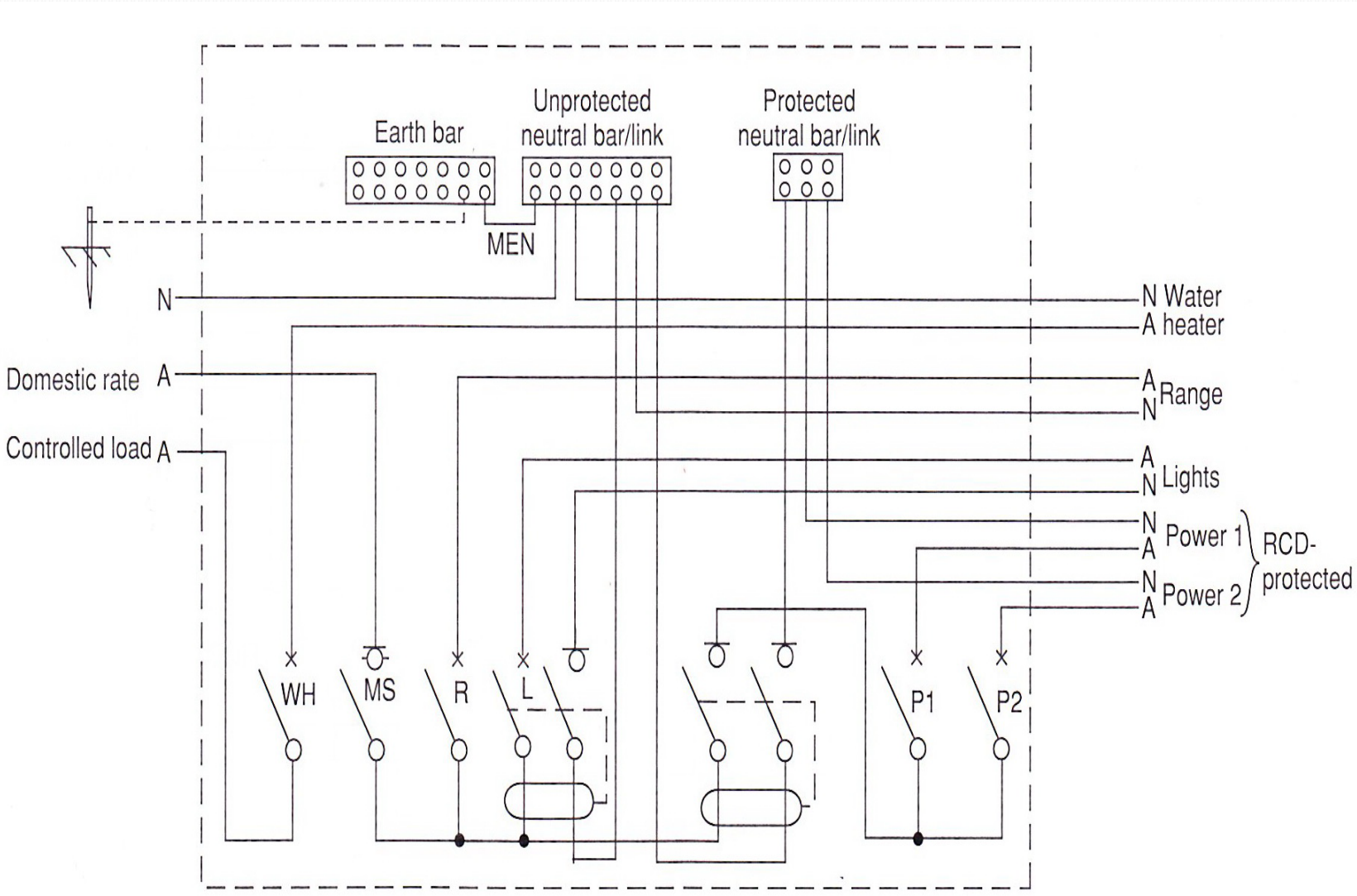
Human Contact No Protection Active to Neutral

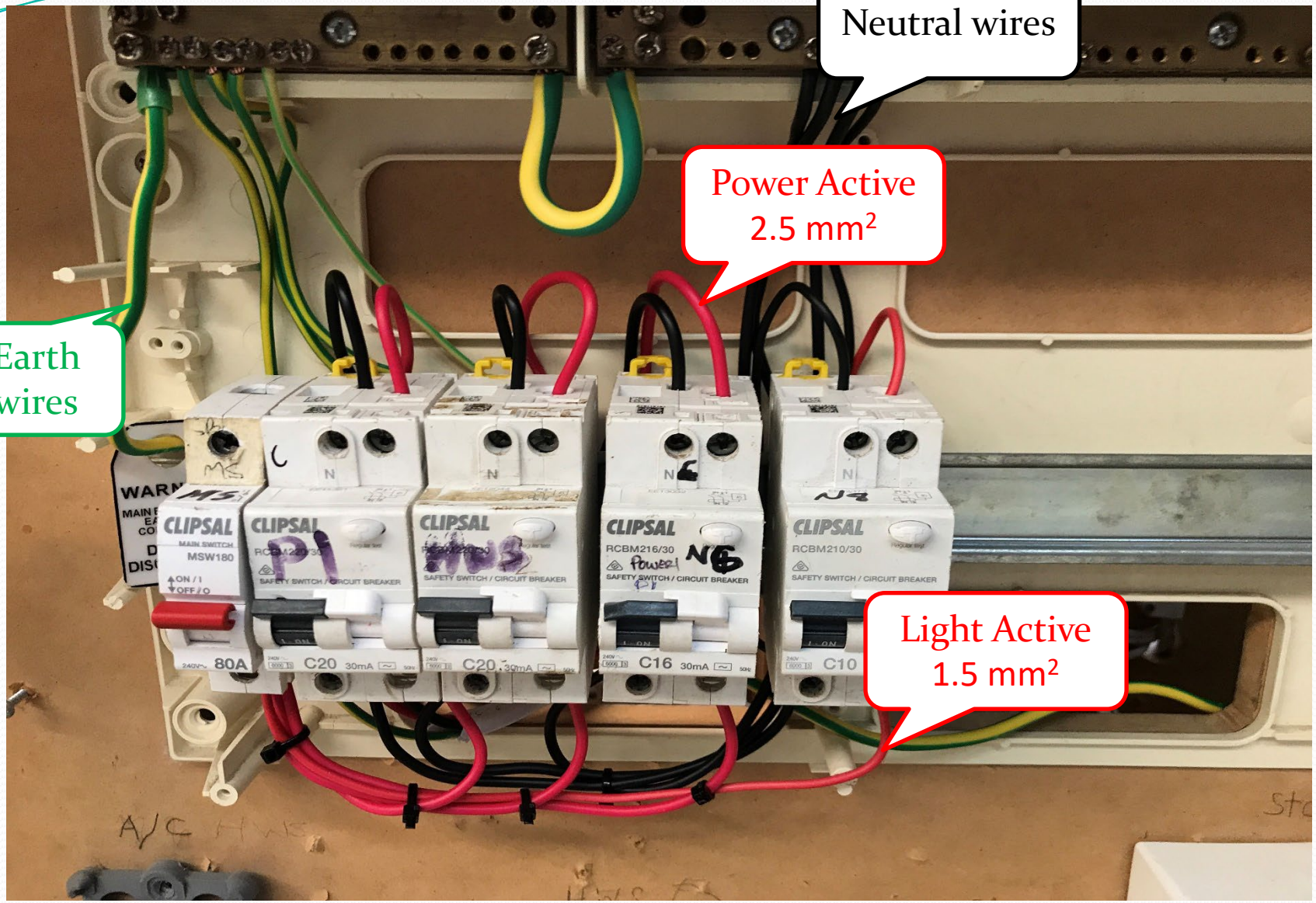


Human Contact Some Protection Active to Earth




Basic Domestic Installation
Main Switch
RCD
RCD
Fixed Cooker
HWS
Metallic Switchboard Enclosure
Light
MEN Point
Main Neutral Link
RCD Neutral Link (L)
RCD Neutral Link (P)
Main Active
Main Neutral
Neutral Bonding Conductor
Circuit Earths
Functional Switch
Power
Fixed Cooker
Hot Water System
Main Earthing Conductor
A
N
E
Element
Water Tap
Earthing Electrode
Metallic Water Pipe


Earth bar
Unprotected neutral bar/link
Protected neutral bar/link
MEN
N
Domestic rate A
Controlled load A
N Water heater
A
A Range
N
A Lights
N
N
A Power 1
N
A Power 2
RCD-protected
WH
MS
R
L
P1
P2


Neutral wires
Power Active
2.5 mm²
Earth
wires
Light Active
1.5 mm²
CLIPSAL
MSW180
80A
CLIPSAL
C20 30mA
CLIPSAL
C20 30mA
CLIPSAL
RCBM216/30
C16 30mA
CLIPSAL
RCBM210/30
C10

The AS/NZS3000:2007 defines an RCD as:

1.4.80 Residual current device (RCD)
A device intended to isolate supply to protected circuits, socket outlets or electrical equipment in the event of a current flow to earth that exceeds a predetermined value.

Type I – 10mA
Type II – 30 mA The most commonly used fro personal protection
Type III – 30 to 300 mA
Type IV – 30 to 2000 mA

Make sure that you are familiar with all aspects of the requirements of the AS/NZS3000:2007

1.5.6
Additional protection by the use of RCDs

2.6
ADDITIONAL PROTECTION BY RESIDUAL CURRENT DEVICES

8.3.10
Operation of RCDs

Testing RCDs

The objective is to test whether:
a) The RCD is actually providing protection on the required circuits
b) The RCD operates with a nominal residual current of 30mA flowing in the protected circuits
c) The test function of the RCD is operating

The simplest method of testing an RCD once installed is to use an RCD tester, preferably one that gives an indication of the trip time of the RCD, such as a 486D or 486CD

Testing with a 486CD in accordance with AS 3190 should determine:

1) RCD should not trip at 50% or less of rated value

2) Type I - 10mA RCD should trip at less than 40mS

3) Type II - 30mA RCD should trip at the rated value in less than 300 milliseconds

Table 3.1 from AS/NZS 3760

TABLE 3 - Maximum tripping times

RCD type	Test current a.c. mA	Maximum tripping time ms
Type I	10	40
Type II	30	300

THE END