MEDECINS SANS FRONTIERES

ELECTRICITY SUPPORT

MSF CEFORLOG 2007

TABLE DES MATIÈRES

COMPARISON OF UK-US TERMINOLOGY

UK	US
2-way lighting, switch	3-way lighting, switch
cooker	range
distribution board	distribution panel, breaker panel
earth, earthing	ground, grounding
fitting	fixture
residual current device (RCD)	ground fault circuit interrupter (GFCI)
skirting board	baseboard
strapper	traveler

INTRODUCTION

The goal of this document is to give MSF field logisticians the knowledge they need to manage electrical installations. This is not intended as a treatise on electricity, but simply as a review of a few basic principles to help in the set-up and maintenance of installations that are as safe as possible for both technicians and users.

Aimed at a very broad audience with widely different expertise in this area, this support document will start by reviewing electricity basics, then introduce circuitry for electrical outlets and lighting. It will then discuss electricity's inherent risks, the available safeguards, and how to diagnose failures in electrical installations. One chapter gives a brief look at three-phase power distribution. Protection and current conversion devices are then presented in detail, as are battery basics and sizing. We end with an examination of MSF solar installations and generator sets.

NOTE: throughout the document, this symbol will indicate the most important points or information.

Reference documents:

- MSF order forms
- Massis, *Aide a l'organisation logistique d'une mission*
- *Batteries MSF* guide

Illustration sources:

- Eyrolles, *L'installation électrique*
- Eyrolles, *Dépannages et rénovations électriques*
- Eyrolles, *Les cahiers du bricolage*
- Editions SAEP, Collection Pratique

Acknowledgments:
This document would not have been possible without the enthusiasm and experience of Raymond Damascène, Benoit Dal, Olivier Blanchet, Cédric Linossier, Gérald Massis (for MSF), Luc Vanacker (for Valcom) and Philippe Massieu from Girel. Educational coordination was provided by Richard Jabot.
Translated from the French by Nina Friedman

1. WHAT IS ELECTRICITY, ANYWAY?

Electricity is a form of energy that exists in nature (lightning, for example), but that is hard to store. We therefore must continually produce it from other forms of energy. On the other hand, it's clean, easy to transport, and directly usable.

1.1. HOW DOES IT WORK?

An electrical current is the free flow of electrons between two points in a conductor.

A free electron is an electron that is easily separated from the nucleus of the atom to which it belongs. Bodies that possess free electrons are called conductors (metals, for example, but also the human body and the earth). Those that don't have free electrons are called insulators (e.g. glass, plastic and wood).

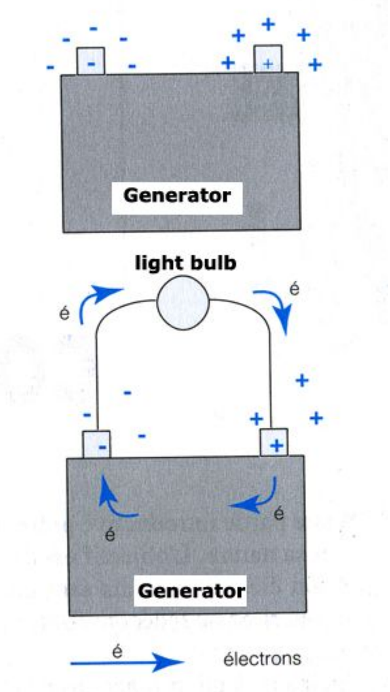
The energy of these free electrons in motion is what constitutes electrical energy.

If we "organize" this motion so that all the free electrons move in the same direction at the same time, we've created an electric current.

So electricity production consists of forcing the electrons to move together in a conducting material that facilitates the flow. We do this by creating an electron deficit on one side of the conductor, and a surplus on the other.

The device that produces this imbalance is called a generator. The terminal on the surplus side is marked +, that on the deficit side –.

When we connect a load to the generator's terminals, the generator pumps electrons: it absorbs the + charges and sends back the –. In the circuit, the electrons circulate from the – terminal to the + terminal.



1.2. EFFECTS

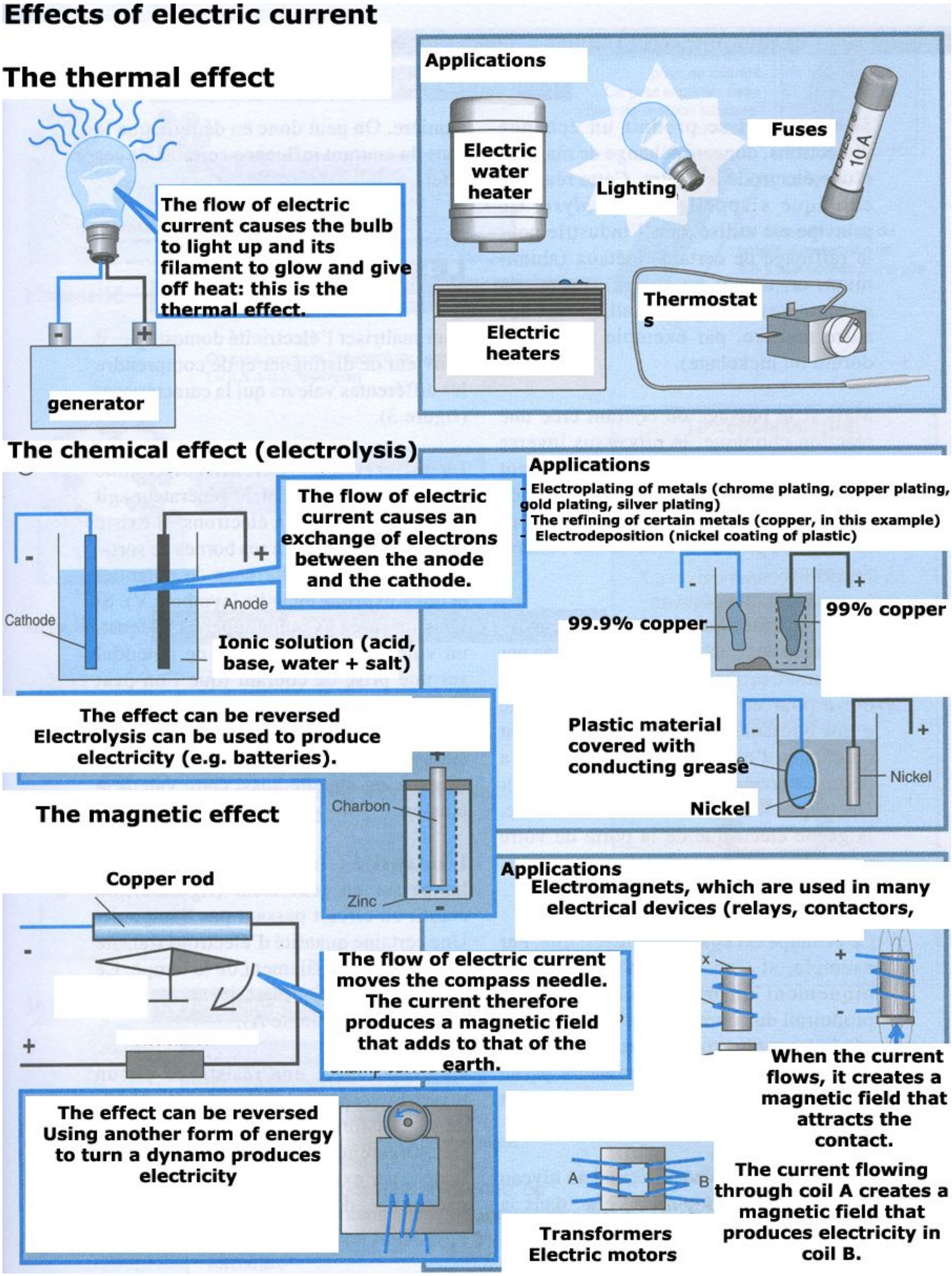
Electric current can have several chemical or physical effects, depending on the nature of the elements through which it passes.

- **the thermal effect:** when a current passes through a material with electrical resistivity, electrical energy is converted into thermal (heat) energy.
  Applications: lighting, electric heating.

- **the chemical effect:** when a current is passed between two electrodes in an ionic solution, it causes an exchange of electrons, and thus matter, between the two electrodes. This is electrolysis: the current caused a chemical reaction.
  Applications: metal refining, electroplating.
  The effect can be reversed: by performing electrolysis in a container, a chemical reaction can create electrical current.
  Applications: batteries, storage cells.

- **the magnetic effect:** electric current passing through a copper rod produces a magnetic

field.
Applications: electric motors, transformers, electromagnets.
Here again, the effect can be reversed: turning an electric motor mechanically produces current.
Applications: electric generators, bicycle dynamos.



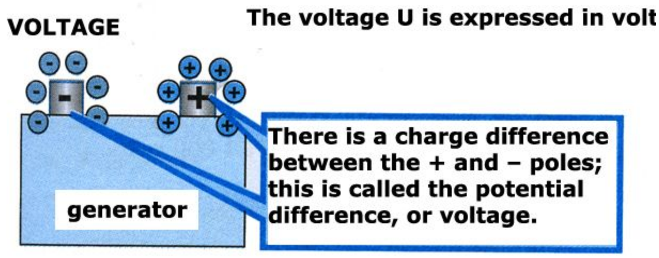
2. VALUES

In order to master electricity, you must be able to understand and differentiate between the values that characterize it.

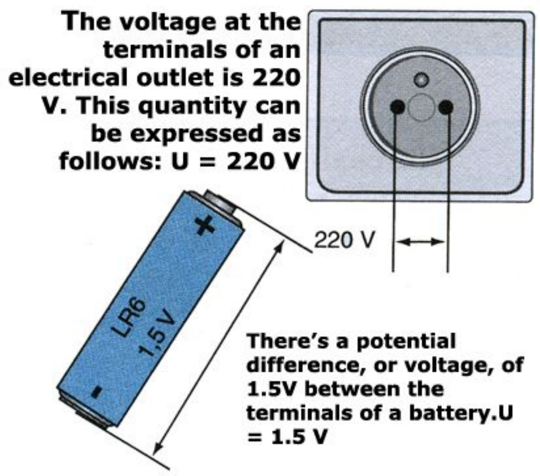
2.1. THE POTENTIAL DIFFERENCE (VOLTAGE)

As mentioned earlier, a generator acts as an electron pump. Between its terminals there's a trough called the potential difference, or voltage, which is expressed in volts (V).

THE VOLTAGE IS DETERMINED BY THE DISTRIBUTION NETWORK

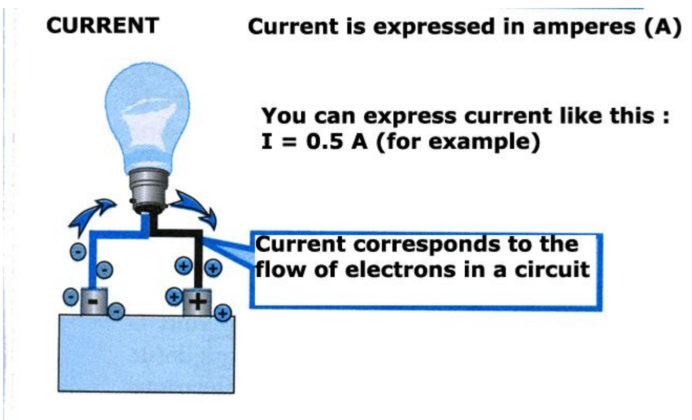


For example, 220 V between the terminals of an electrical outlet, or 1.5V between the terminals of a battery.



2.2. CURRENT

When you connect a light bulb to a generator, a certain quantity of electrons passes through the wires and the filament of the bulb. This electron flow corresponds to the current, expressed in amperes (A).



THE CURRENT IS A FUNCTION OF: **THE POWER P,**
THE VOLTAGE U,
AND THE RESISTANCE R.

2.3. RESISTANCE

A resistor is any material that allows electrical energy to be converted to thermal energy.

Resistance is expressed in ohms (Ω).

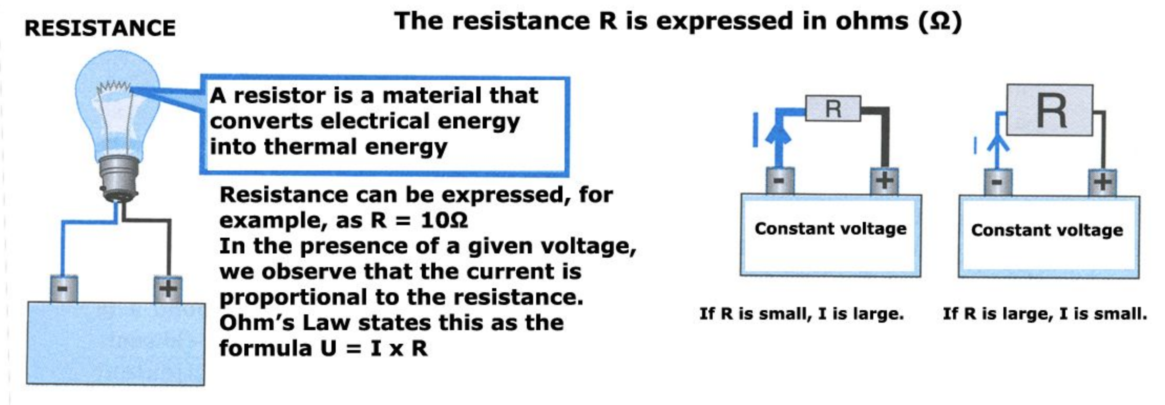
For a given voltage, we observe that the current is proportional to the resistance. This proportionality, expressed as a mathematical relationship, is known as Ohm's Law:

U = I x R
Voltage = Current x Resistance

From this we deduce that for a constant voltage, increasing the resistance will reduce the current. Conversely, the current will increase if the resistance is lowered.

Also, at constant resistance, if the voltage increases, so will the current.

Ohm's Law is valid only for pure resistances, i.e., for devices that convert electrical energy into purely thermal energy . With motors, for example, this isn't the case.



RESISTANCE IS DETERMINED BY THE LOAD

Example: For wire conductors, a larger cross section offers less resistance to current flow and results in a smaller voltage loss. On the other hand, resistance is directly proportional to the length of the wire.

To minimize voltage loss, current needs the shortest possible wire with a large cross-section. See the "Conductors" sections.

Note also that the kind of wire (copper, iron, etc.) also affects a cable's resistance.

When the resistance in an electrical circuit is near zero, and the current is therefore extremely large, we say that there's a **SHORT-CIRCUIT**.

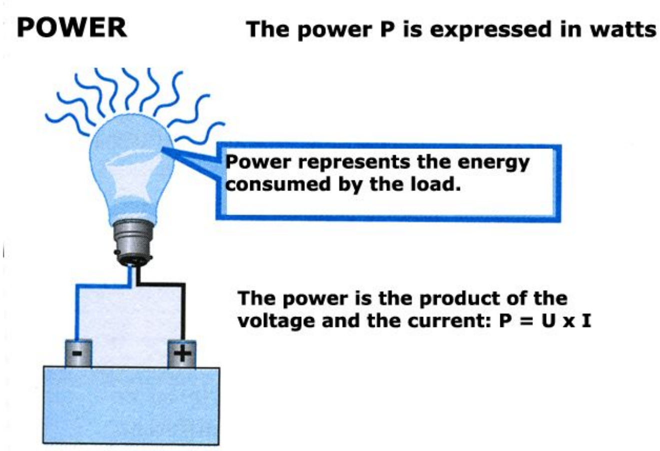
2.4. POWER

Power represents the amount of energy consumed by a device connected to the circuit. It is calculated by multiplying the voltage by the current, and is expressed in watts (W).

P = U x I
Power = Voltage x Current

From this we see that the more powerful the load, the more current it draws.

POWER IS DETERMINED BY THE LOAD



Example: A 50W light bulb plugged into a 220V outlet draws a current of 50/220 = 0.23A.
A 100W light bulb plugged into a 220V outlet draws a current of 100/220= 0.46A.

2.5. ENERGY CONSUMPTION

This is calculated by multiplying the power of a device by the duration of its use, expressed in hours. This is the amount of electricity produced or consumed during a given time period. It’s expressed in kilowatt-hours (kWh).

Example: A 100W light that’s left on for 3 hours will consume 300Wh, or 0.3kWh.

This is the unit of consumption that adds up on the electric meter to determine your electricity bill.

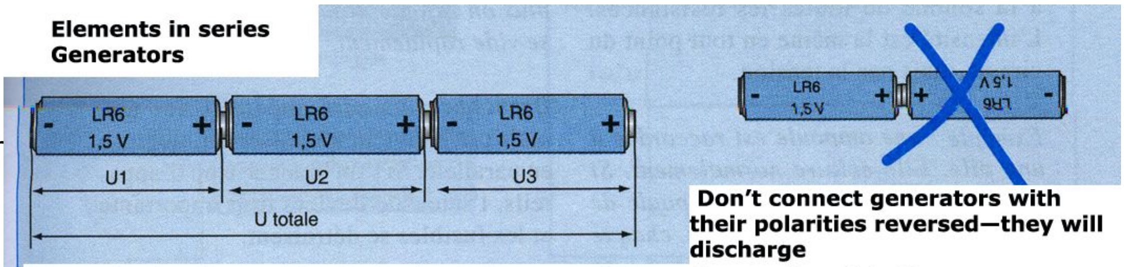
3. GROUPING COMPONENTS

There are two basic ways of connecting circuit components— in series or in parallel.

3.1. COMPONENTS IN SERIES

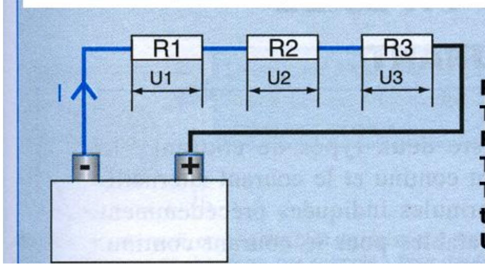
Components are said to be in series when they are placed one after the other.

Elements in series
Generators



Don't connect generators with their polarities reversed—they will discharge

The output voltage of the batteries is the sum of the voltages of each battery.
$U_{total} = U1 + U2 + U3$
In the example above, $U_{total} = 1.5 + 1.5 + 1.5 = 4.5V$



Les résistances

Resistors
The total resistance is the sum of all the resistances
$R_{total} = R1 + R2 + R3$
The current is the same everywhere in the circuit.
The voltage is different across each resistor, but their sum equals the voltage of the generator.
$U1 + U2 + U3 = U_{generator}$

For generators connected in series, the total output voltage is the sum of the voltages of each generator.

For resistors connected in series, the total resistance is also equal to the sum of all resistances. The current is the same everywhere in the circuit.

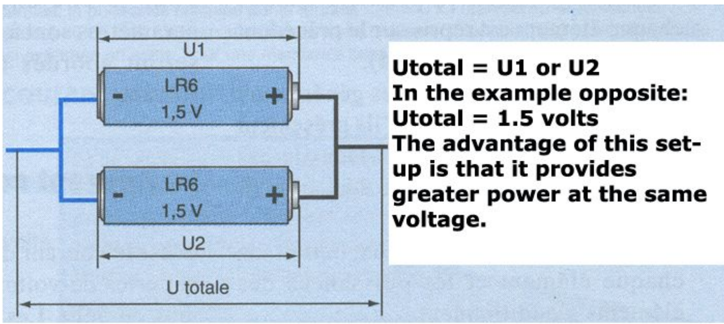
3.2. COMPONENTS IN PARALLEL

A set-up is said to be "in parallel" when each element is connected to the previous one by a shunt.

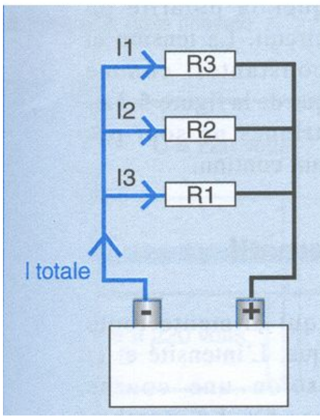
Components in parallel

Generators

Caution: this set-up only works with generators of equal voltage. Otherwise, one will discharge into the other.



$U_{total} = U1$ or $U2$
In the example opposite:
$U_{total} = 1.5$ volts
The advantage of this set-up is that it provides greater power at the same voltage.



Resistors

The equivalent resistance of this group connected in parallel is given by the following formula:

The voltage is the same across all the resistors.
The current is proportional to each resistance
$I_{total} = I1 + I2 + I3$
The more resistors are connected in parallel, the greater the current. This is what happens when too many devices are plugged into the same outlet.
8. Example: $R1 = 2\Omega$, $R2 = 3\Omega$ and $R3 = 5\Omega$
$1/R_{eq} = \frac{1}{2} + 1/3 + 1/5$
$1/R_{eq} = 31/30$
$R_{eq} = 30/31$
$R_{eq} = 0.96\Omega$

Generators can be connected in parallel, provided their characteristics match. Otherwise, the strongest will discharge into the weakest.

The voltage is the same across each component.

For resistors in parallel, the voltage is identical across each one. The total current is equal to the sum of the currents flowing through each resistor.

The total resistance is less than that of the smallest resistor.

When several devices are plugged into the same outlet they are, in effect, connected in parallel. As each new device is plugged in, the total resistance of the circuit is reduced and the current increases...until the fuses blow.

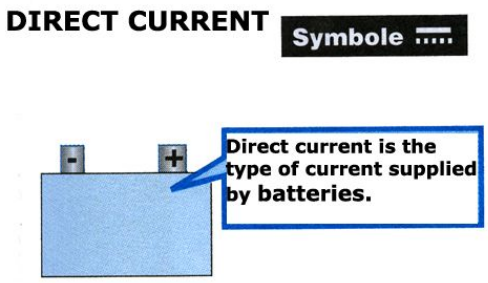
4. TYPES OF CURRENT

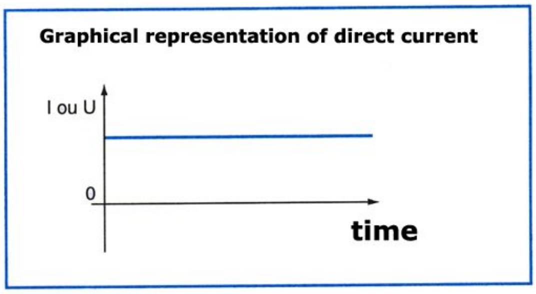
There are two types of current: direct and alternating.

4.1. DIRECT CURRENT (DC)

Here the electrons always flow in the same direction, from the side with a deficit to the side with a surplus.

This is the kind of current supplied via the chemical effect by portable and car batteries, via the photovoltaic effect by solar panels or vthe transformation of alternating current. The terminals are marked + and – to show the polarity of the circuit or generator. The voltage and current are constant in time.





Advantages: It can be stored and it is possible to add the sources in parallel or series.

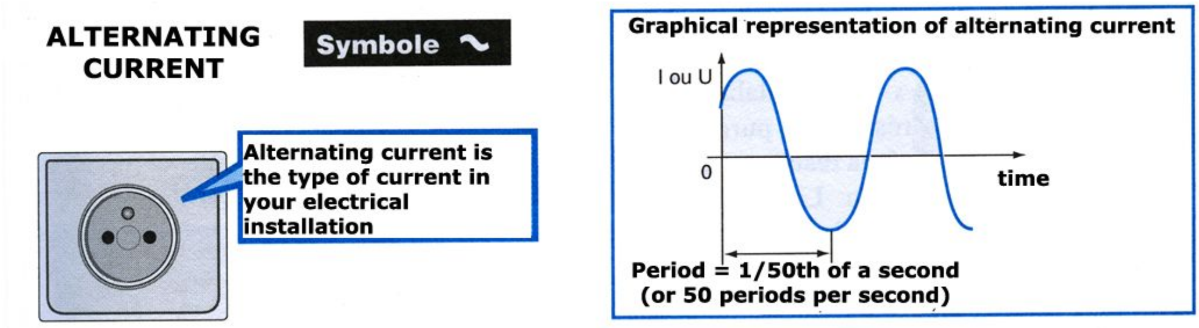
Disadvantages: In reality, the use of the batteries limits the voltage to a few volts (up to 24 volts in some vehicles). Those low voltages prevent the transportation of this type of current.

4.2. ALTERNATING CURRENT (AC)

In alternating current, the electrons move alternately in one direction, then the other, at a given frequency. There is no positive or negative terminal, since the current continually alternates: we don't speak of + or – in AC, but rather of "phase" and "neutral."

This is the type of current supplied by electric utility companies. Voltage and current follow a sinusoidal curve. While voltage and current continually vary between a maximum and minimum value, measurement masks this variation and shows a stable average value—such as 220V.

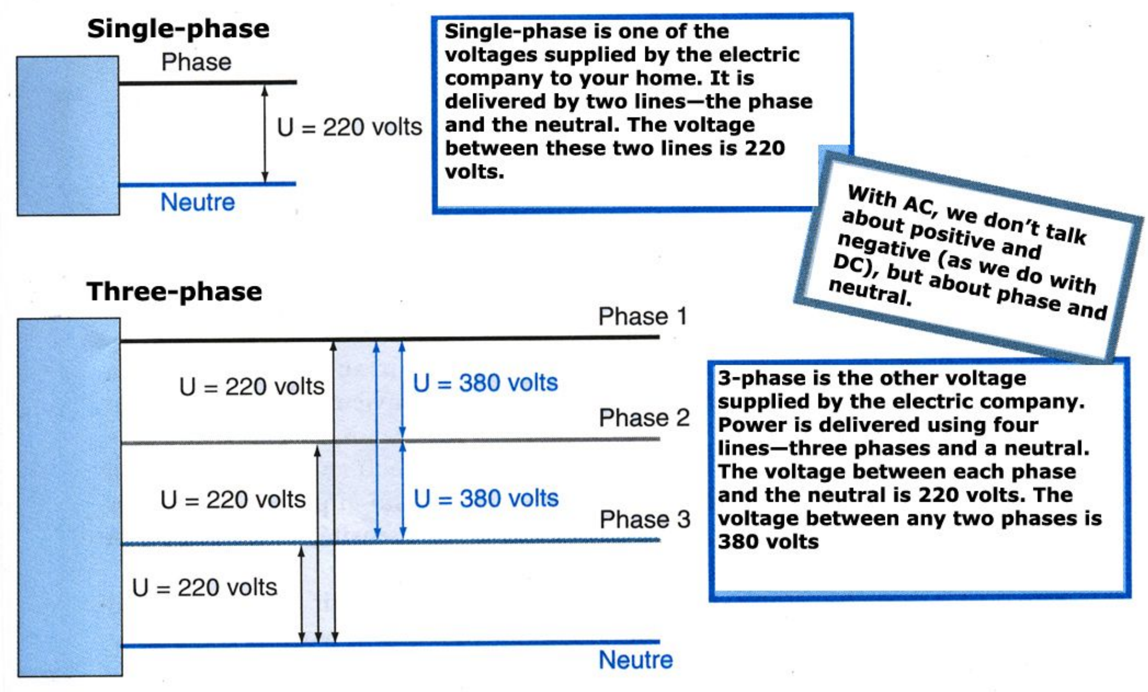
The frequency is defined as number of sinusoidal oscillations per second:
50 oscillations per second in France and in Europe (50Hz),
60 oscillations per second in the US (60Hz).



Advantages: Can be transported over long distances without too much loss using high tension lines. It is easy to produce.

Disadvantages: It cannot be stored and it is not possible to add the sources.

There are two types of alternating current: single-phase and 3-phase.

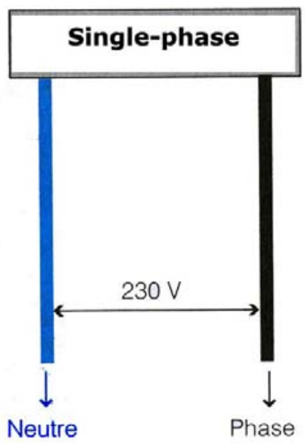


- Single-phase:

This the most common type of current. It's produced and distributed by the public network, or made using a single-phase generator.

Supply is via two lines (phase and neutral), usually with a 230V voltage difference between them. In some countries you'll come across 110V (the US, for example).

Plugs can be inserted in either direction.

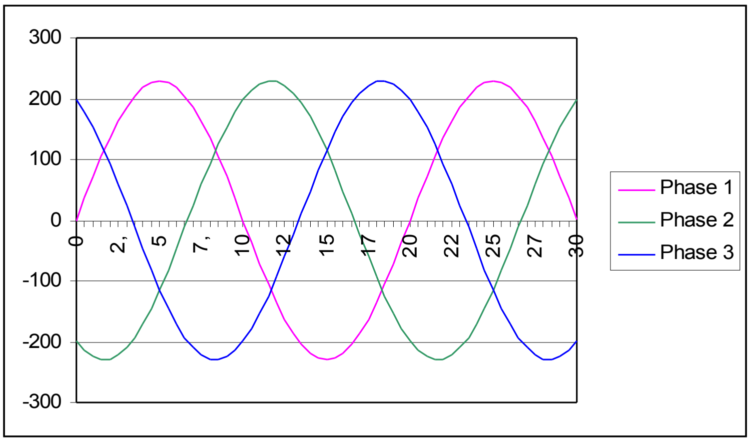


- Three-phase:

This current is used ass soon as the need power become important (practically between 6 and 12 kVA). It's the common current for electricity companies, before domestic supply, and we can also produce it with a three phase generator.

Three phase current is the combination of three single phase currents. As neutral is always very close to 0V, the same wire will be use for the return of all the phases. But for for each current we will have a separate phase wire. In a three phase wiring we will have 3 phases + 1 neutral (and 1 earth).

Anytime, if the current is perfectly balanced between phases (exactly the same voltage and same intensity in all phases), sum of voltages and sum of intensities are equal to zero, cf drawing below:Voltage (V) over time (ms), of the three phases.

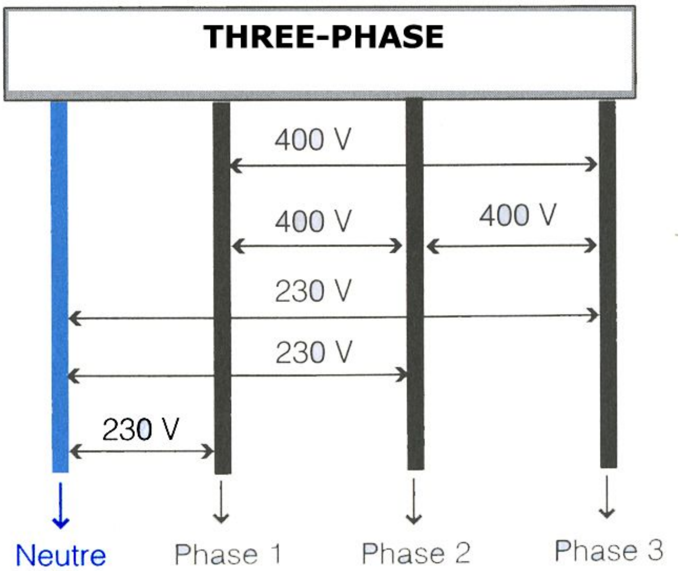


To carry a given power, with 3 single phase cables (grounded), we will have 9 wires. To carry the same power in a three phase cable, we will have only 5 wires (3 phase, 1 neutral, 1 ground). This is a significant saving.

Here lies the main interest of the three phase current : we save wires, not only in cables, but also in apparatus using or producing electricity: three phase motor or alternator will be smaller than the same power single phase one.

While you can't run a 3-phase, 380V device on a single-phase 220V system, the reverse is possible. The voltage between the neutral and any of the 3 phases of a 380V three-phase power supply is 220V. This operation requires certain precautions, which will be discussed in detail later on:

- identification of the neutral
- phase balancing
- power regulation



Practically, we will keep in mind the following :

- Three phase current allows saving compare to single phase (for the same power)
- A good balance between phase will reduce almost to 0 current in neutral wire
- Each phase being designed for 1/3 of total power, even if we divide a three phase wiring into 3 single phase ones, we cannot have, on each of these single phase circuit, 1/3 (maximum) of the total power available in three phase. (ie: for a three phase circuit of 60 kVA, we will have a maximum of 20 kVA per phase, even if some phase are not fully used).
- Three phase wiring being often of high power, with sometime complex phenomena's (voltage drops, induction), et specific material, it will require involvement of a specialist for any action out of the use of MSF standard material.

5. BASIC MEASUREMENTS

5.1. MEASUREMENT DEVICES

5.1.1. The analog multimeter:

This tests voltage, current, resistance, and continuity. Measurements are read from the needle's position on the analog display.

Current is measured by connecting the tester in series.

It's inadvisable to use these for measuring large currents (over 10A).

There is no MSF model.

5.1.2. The digital multimeter:

This, too, measures voltage, current, resistance, and continuity.

The readings show up on a liquid crystal display. They are accurate and give a direct readout of values.

For currents under 10A, measurements are done with the tester in series, and the red lead inserted into the 10A jack. If the reading is too low, move the indicator to the mA, rather than the 10A, position.

MSF model: PELEMULT01-

MSF model: F711

5.1.3. - Current clamp:

Large currents can be measured simply by passing the clamp around the conductor carrying the current to be measured. Stripping the conductor isn't necessary, but you've got to be careful to take only one conductor at a time.

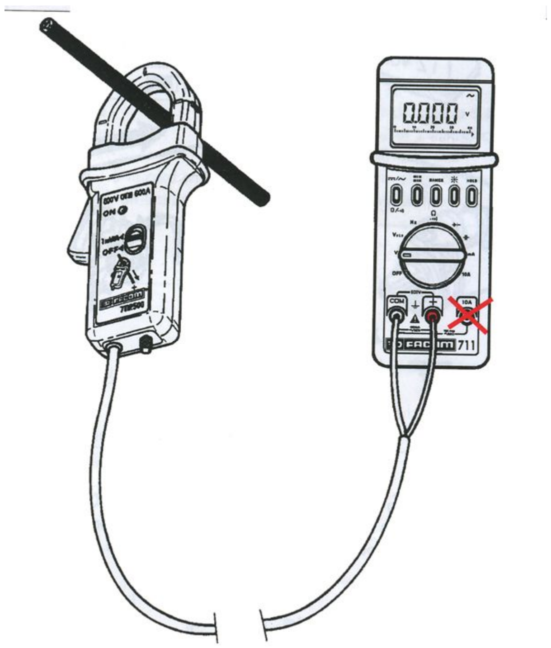
Some models also measure voltage and resistance.

Some multimeters offer an optional current clamp that connects to the test leads (see photo on the right).

Place the jaws of the clamp around the wire to be tested, the arrow on the clamp showing the conventional current direction.

These clamps work for both alternating (up to 400A) and direct (up to 600A) current.

MSF model: F711P.500



For AC, you get a direct reading with the function switch in the voltage ("V") position and the scale set at 1mV/A.

For DC, use the same position and scale, but set the display to 0mV using the little knob found at the bottom of the clamp.

The new MSF model is the «Métrix MX355 », code PELEZBD016 (see photo on the right) a multimeter with integrated current clamps. For direct and alternative currents, its range of measures go up to 600V for voltage and 400A for current.

5.1.4. - The voltage detector:

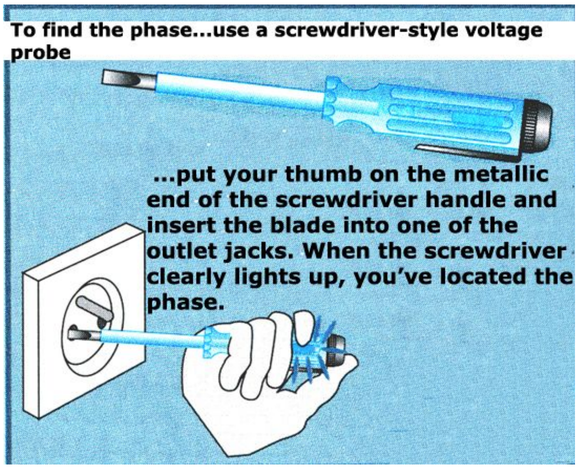
this allows you to be **absolutely sure** that there's no voltage in the system.

MSF model:

5.1.5. - The screwdriver-style voltage probe:

This is used to distinguish between phase and neutral: it lights up when in contact with a phase jack, and shouldn't light up when touching the neutral jack.

NOTE: there are AC and DC screwdriver-style probes.



5.1.6. The test battery:

Should only be used for troubleshooting.

Used to check current flow in a wire or electrical device when a multimeter isn't available. Indicates that a wire is intact, that a switch is working, or that a fuse is functional.

5.1.7. The test lamp:

Should only be used for troubleshooting.

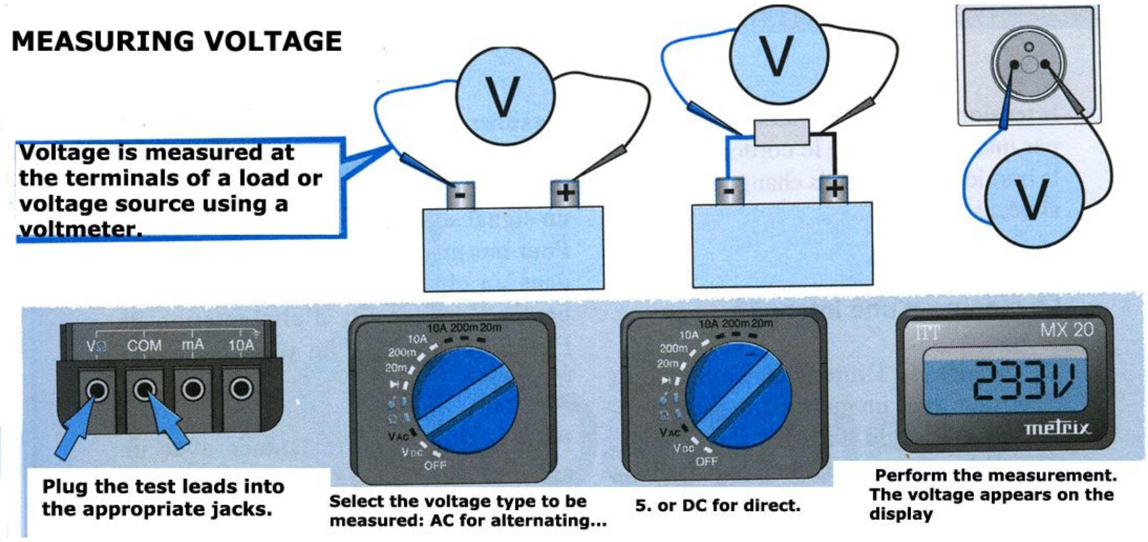
Allows you to verify that an outlet is working, or to identify the conducting wires in a three-wire system.

5.2. MEASURING VOLTAGE: IN A LIVE CIRCUIT

5.2.1. Using the multimeter:

Plug the leads into the appropriate jacks: the black lead into "COM" and the red into "VΩ."

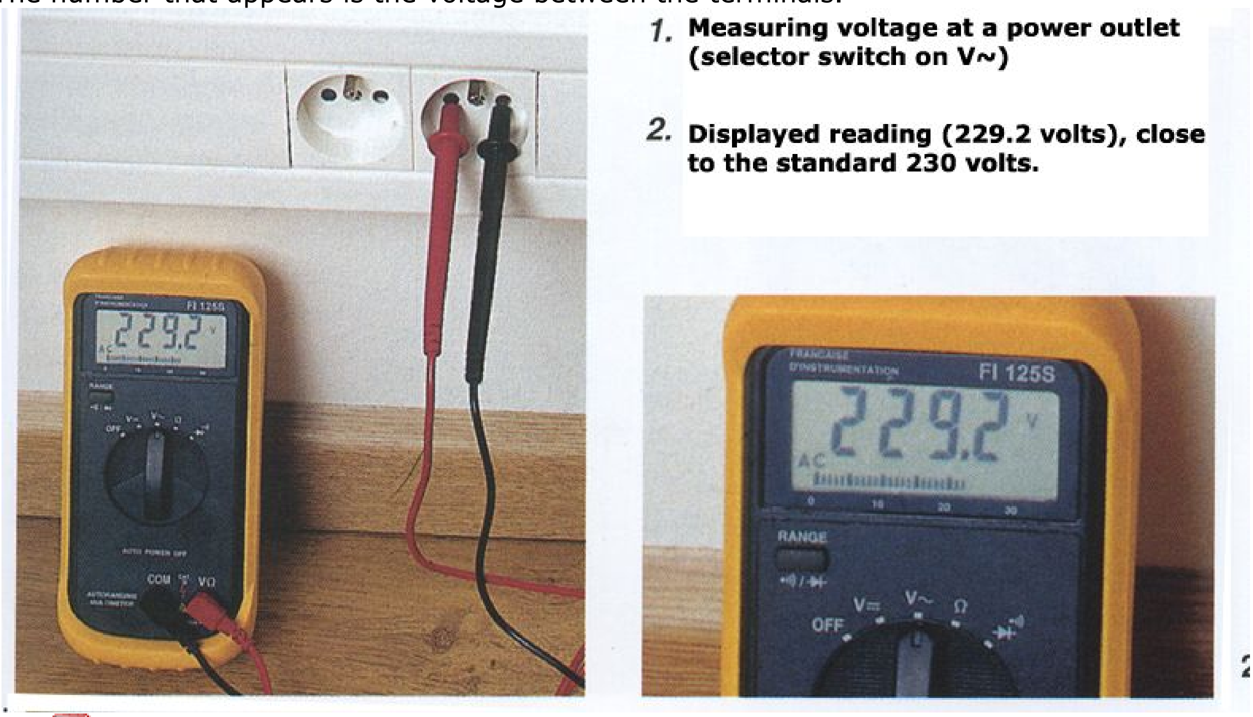
MEASURING VOLTAGE



Choose alternating (V_{AC}) or direct (V_{DC}), depending on your needs. Attempting to measure voltage with the lead plugged into the mA or 10A jack can blow the tester's fuse.

Place the test probes in parallel with the terminals of the device to be measured (i.e., red lead to + and black lead to –, for DC) or between the phase and neutral of an outlet (for AC).

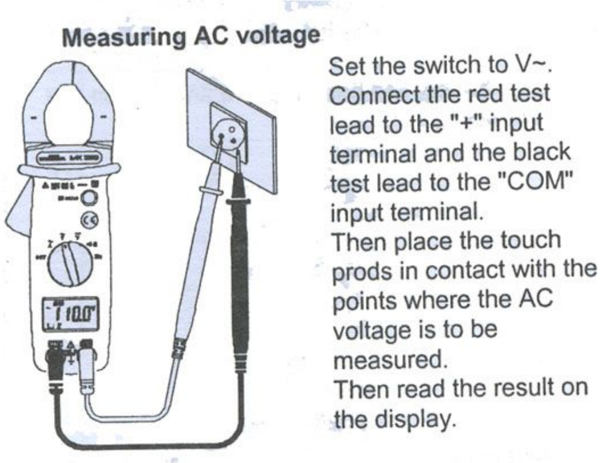
The number that appears is the voltage between the terminals.

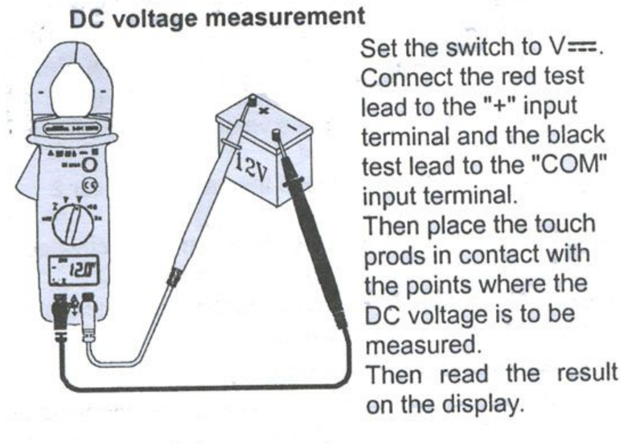


NOTE: when using an analog multimeter, if you don't know the order of magnitude of the voltage being measured, always start with the test lead in the jack for the highest range (e.g. 1000V) and work your way down, if necessary.

WARNING: Select the correct voltage type: if the selector switch is in the DC position (V_{DC}) when you measure an AC outlet, the display will read 0 volts instead of the actual 230 VAC.

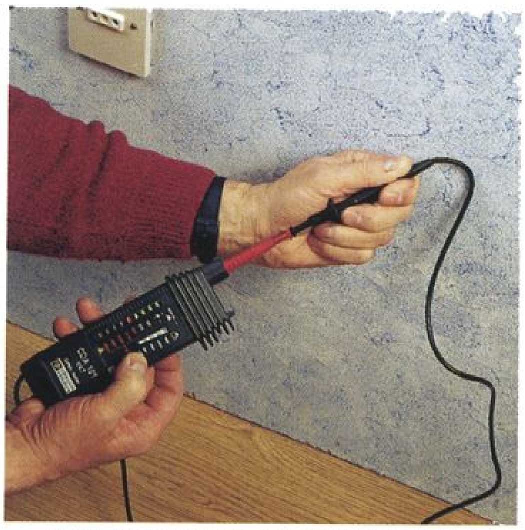
5.2.2. With the MSF standard tool (PELEZBD016 Metrix MX355) :





5.3. TESTING FOR THE ABSENCE OF VOLTAGE

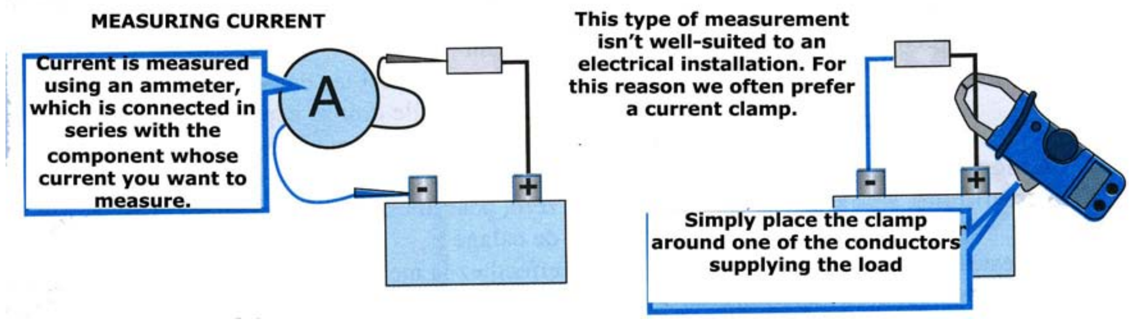
This is done with a voltage detector, rather than a voltmeter:
Start by verifying that the voltage detector is working properly: the LEDs light up.
Then test for the absence of voltage at the outlet terminals, for example: the LEDs fail to light up.



Verifying that the voltage detector is working : LEDs light up

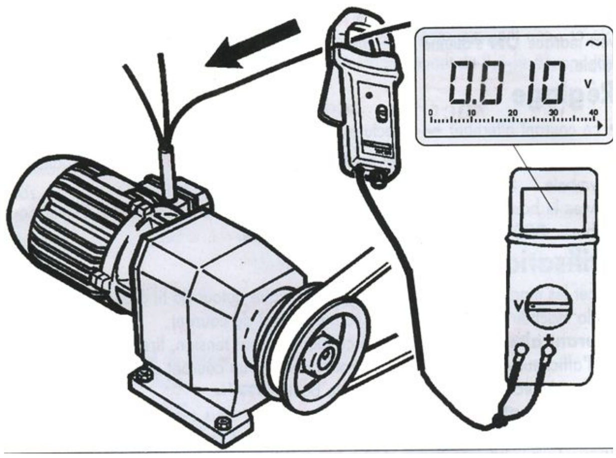
Verifying that there is no voltage at the outlet : LEDs don't light up

5.4. MEASURING CURRENT: IN A LIVE CIRCUIT

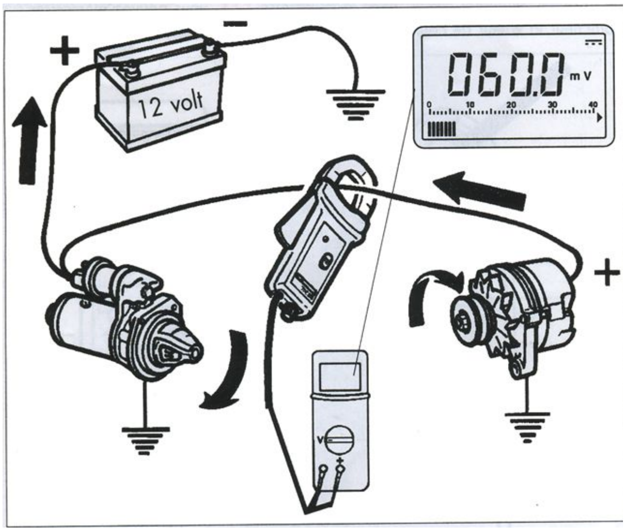


For safety reasons we recommend measuring current with a current clamp.

A multimeter must be in series with the element being measured. This requires interrupting the circuit—a dangerous procedure.



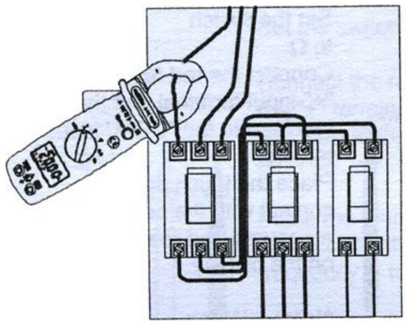
Measuring alternating current



Measuring direct current

With the MSF standard tool (PELEZBD016 Metrix MX355) :

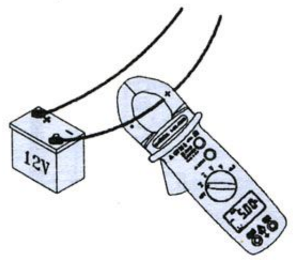
4.3. Measuring AC current



Set the switch to A~.
Open the clamp by pressing the trigger.
Place the clamp around the conductor to be measured and release the trigger; check that the clamp is closed properly. Read the result of the measurement on the display.

Note: For safety reasons, disconnect the measuring leads before performing this operation. The clamp must be positioned around a single conductor in a circuit, with the risk of rendering the measurement incorrect. The best measurement is obtained with the conductor centred in the middle of the jaws.

4.4. Measuring DC current
(MX 355)

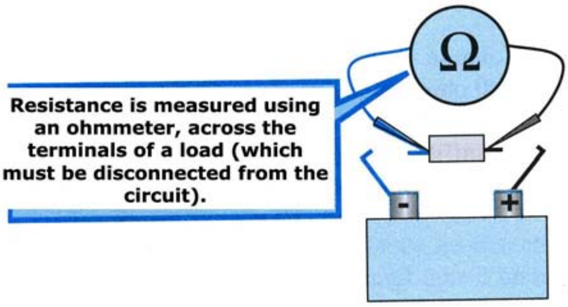


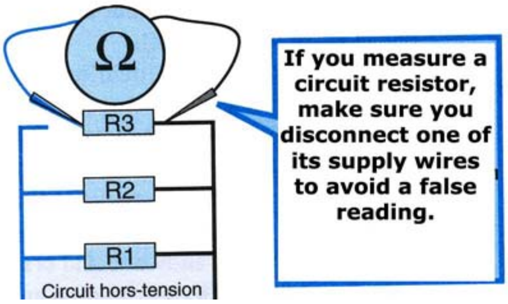
Before measuring currents higher than 40 A, set the scale to 400 A by pressing the **RANGE** button. Then reset to zero (see § 3.2)

Open the jaws of the clamp by pressing the trigger and insert the cable to be measured between them. Close the clamp and read the result of the measurement on the display.

Note: For safety reasons, disconnect the measuring leads before performing this operation. If reading is difficult, press the **HOLD** button and read the result afterwards.

5.5. MEASURING RESISTANCE: IN A DE-ENERGIZED CIRCUIT





This is performed at the terminals of a device which is de-energized. Otherwise, you risk destroying the testing device.

To measure the resistance of a circuit element, make sure you disconnect one of its supply wires.

Plug the test leads into the appropriate jacks: the black into "COM" and the red into "VΩ."

Turn the selector switch to Ω, which is the multimeter's ohmmeter position. Readings are taken directly from the display.

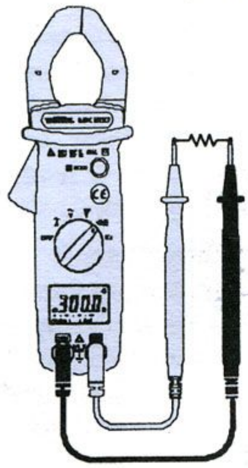
An example:

Infinite resistance: Blown fuse

Very low resistance: Intact fuse

With the MSF standard tool (PELEZBD016 Metrix MX355) :

Measuring resistance



Set the switch to Ω.
Connect the red test lead to the "+" input terminal and the black test lead to the "COM" input terminal.
Place the touch prods in contact with the points to be measured and read the result on the display.

Note: When performing a measurement on a circuit, make sure that it is not live and that the capacitors have been discharged.

For an analog multimeter:

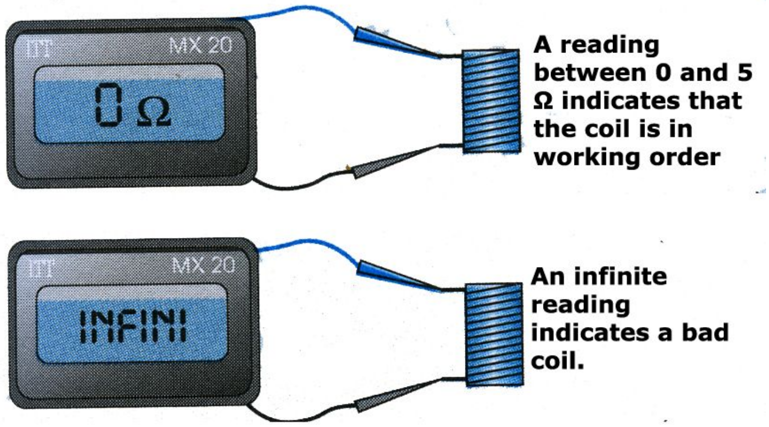
- plug the test leads into the appropriate jacks:
- turn the selector switch to Ω,
- touch the two probes together; the needle should move toward 0 ohms.
- Perform the measurement by placing the probes across the resistance you want to measure.

5.6. TESTING CONTINUITY: IN A DE-ENERGIZED CIRCUIT

This verifies that the conductor—e.g. fuse or power cord—is intact.

Testing continuity

This allows you to check for an open circuit (in a coil or power cord). It can also be done using an ohmmeter.



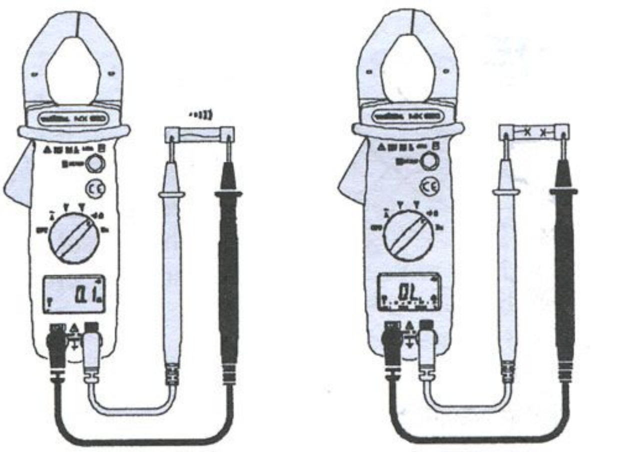
The multimeter's continuity function, indicated by an audible signal, is used in a de-energized circuit.

A 0Ω reading indicates that current can pass and that the circuit is closed; the buzzer will also sound. A reading of infinity and the lack of a buzzer sound indicate an open circuit.

With the MSF standard tool (PELEZBD016 Metrix MX355) :

Continuity test with buzzer

Set the switch to •))) Ω.
Connect the red test lead to the "+" terminal and the black test lead to the "COM" terminal.
Place the touch prods in contact with the circuit to be tested.
If the resistance is lower than 40 Ω, the buzzer sounds continuously.



6. CONDUCTORS

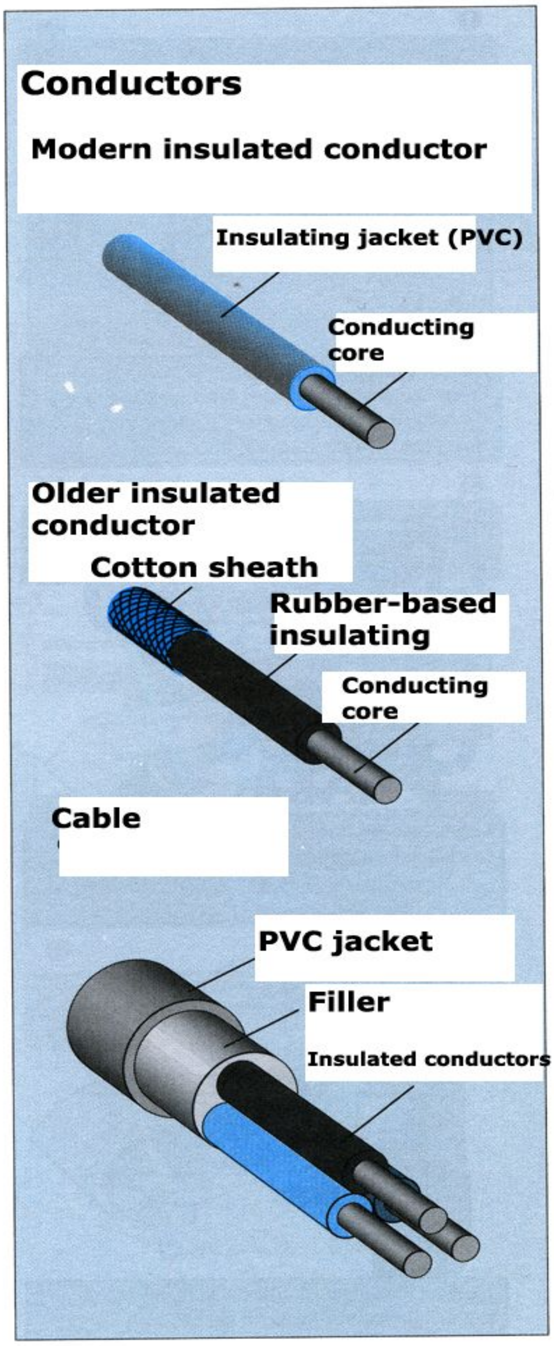
Used to transport electricity, conductors are considered active components of the electrical circuit.

6.1. TYPES

conductors can be divided into several basic types.

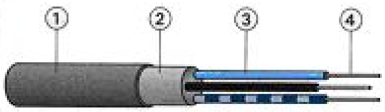
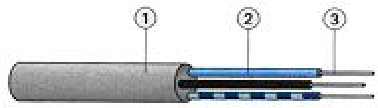
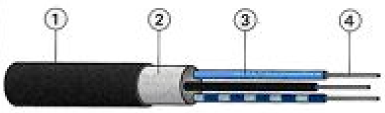
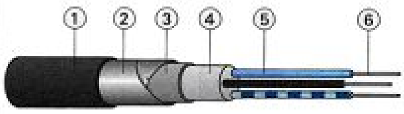
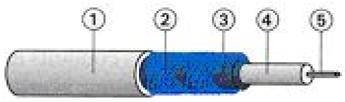
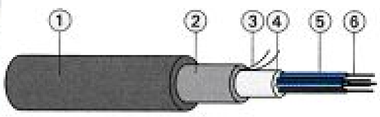
- insulated wires:
  Comprised of a conducting core and its insulating jacket. The core is usually copper. It can be solid (rigid conductor) or made up of multiple strands (flexible conductor). The cross-section is standardized according to the power of the circuit. See the table below.

  Insulation for newer conductors is usually PVC, while older wires use rubber and cotton.



- Cables: A cable is a cluster of several insulated wires of identical cross-section, with additional protective jackets. The sheath is also PVC. See the table below.

Domestic wires and cables

Type	Schéma	construction	cross-section
H 07V-U H 07V-R H 07V-K		1. PVC insulation 2. U: rigid copper core R: rigid copper stranded core K: flexible copper core	U: 1.5 to 4 mm2 R: 6 to 300 mm2 K: 0.75 to 95 mm2
A 05VV-U A 05VV-R ou FR-N 05VV-U FR-N 05VV-R		1. PVC jacket 2. filler 3. PVC insulation 4. U: rigid copper core R: rigid stranded core	8. U: 1.5 to 4 mm2 R: 4 to 16 mm2 2 to 5 cores
H 05VV-F A 05VV-F		1. PVC sheath 2. PVC insulation 3. flexible copper core	10. U: 0.5 to 6 mm2 2 to 5 cores
U 1000 R 2V		1. PVC sheath 2. elastoplastic filler sheath 3. XLPE insulation 4. U: rigid copper core	12. 1.5 to 240 mm2 1 to 5 cores
U 1000 RVFV		1. PVC sheath 2. armour (double steel tape) 3. moisture-proof PVC sheath 4. elastoplastic filler 5. PVC insulation 6. copper core	14. 1.5 to 120 mm2 2 to 5 cores
COAXIAL		1. PVC sheath 2. copper braid 3. copper tape 4. insulation 5. copper core	16. For cable antenna television circuits
CABLE PTT 278 SYS SYT		1. PVC sheath 2. moisture barrier 3. drain wire and ripcord 4. water-repellent tape 5. polyethylene insulation 6. copper core	18. 0.6 mm2 1 to 56 pairs Type 4 pairs for domestic telephone installations

6.2. COLOUR CODE

Conductors must conform to a standard colour code: Yellow/green: earth,
Light blue: neutral
Red, black, brown, all other colours: phase

CAUTION: don't trust the colours in older installations. A phase might be yellow and green, for example.

6.3. THE INSTALLATION

Wiring might be surface-mounted, i.e. exposed, or concealed within walls. We prefer the first method for our missions.

Surface mounted conductors can be attached directly to the walls, run through plastic conduits, or covered with moulding, with a preference for the first two.

- Direct attachment to the wall:

  A few rules to follow:

  Preferred cables: FR-N 05 VV-U, A05 VV-F, U 1000 R2V

  Bending radii:

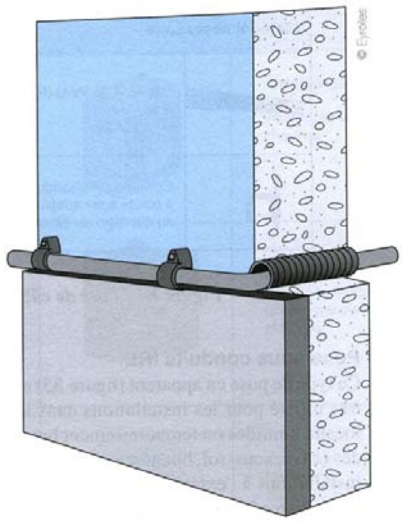
Rules for installing exposed cables		
Cable type	Maximum distance between attachment points	Minimum bending radius
Unarmoured cable	0.40 m	6 times the diameter
Armoured cable	0.75 m	8 times the diameter

Attach unarmoured cable with plastic staples of the appropriate diameter, 1 metre apart for vertical runs and 0.45 m apart for horizontal runs.

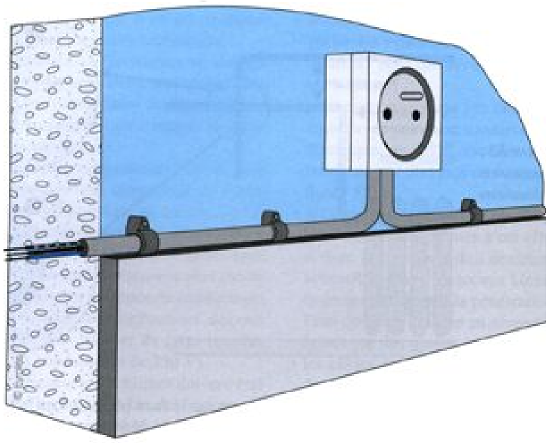
Connections must be in specially provided boxes, with an accessible cover.

Avoid using twisted or flat cables when attaching directly to the wall.

Passage through a wall inside a sheath:

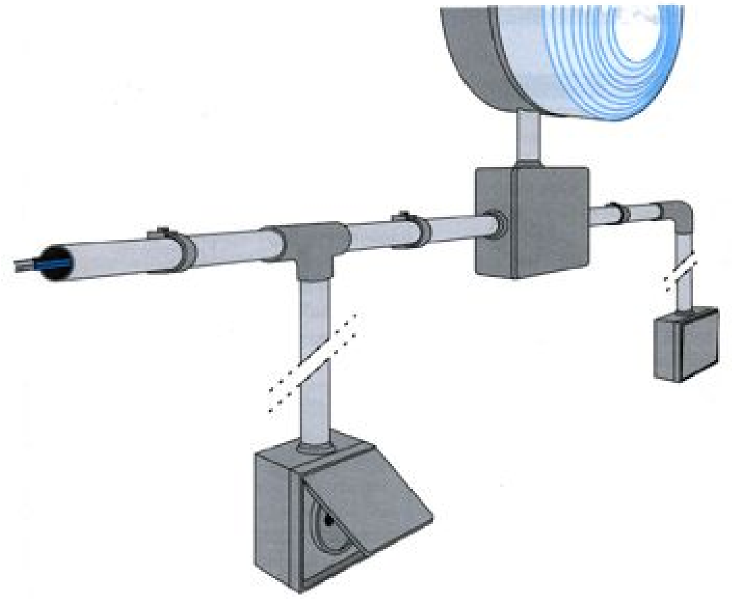


Routing along the top of skirting boards



Installation within conduit:

A few rules to follow:



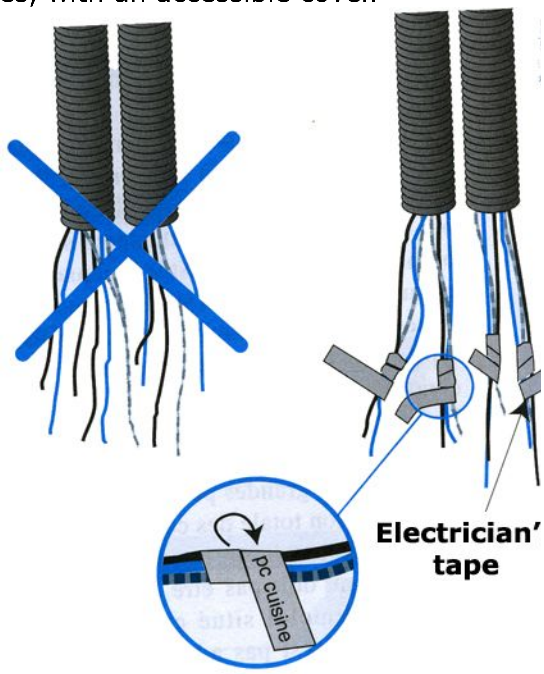
Preferred cables: H 07V-U-R-K, U 1000 R2V

Respect the one third rule: the total cross-section of the conductors should not exceed 1/3 of the conduit's inside cross-section.

Attach with supports of the appropriate diameter, 0.8 m apart.

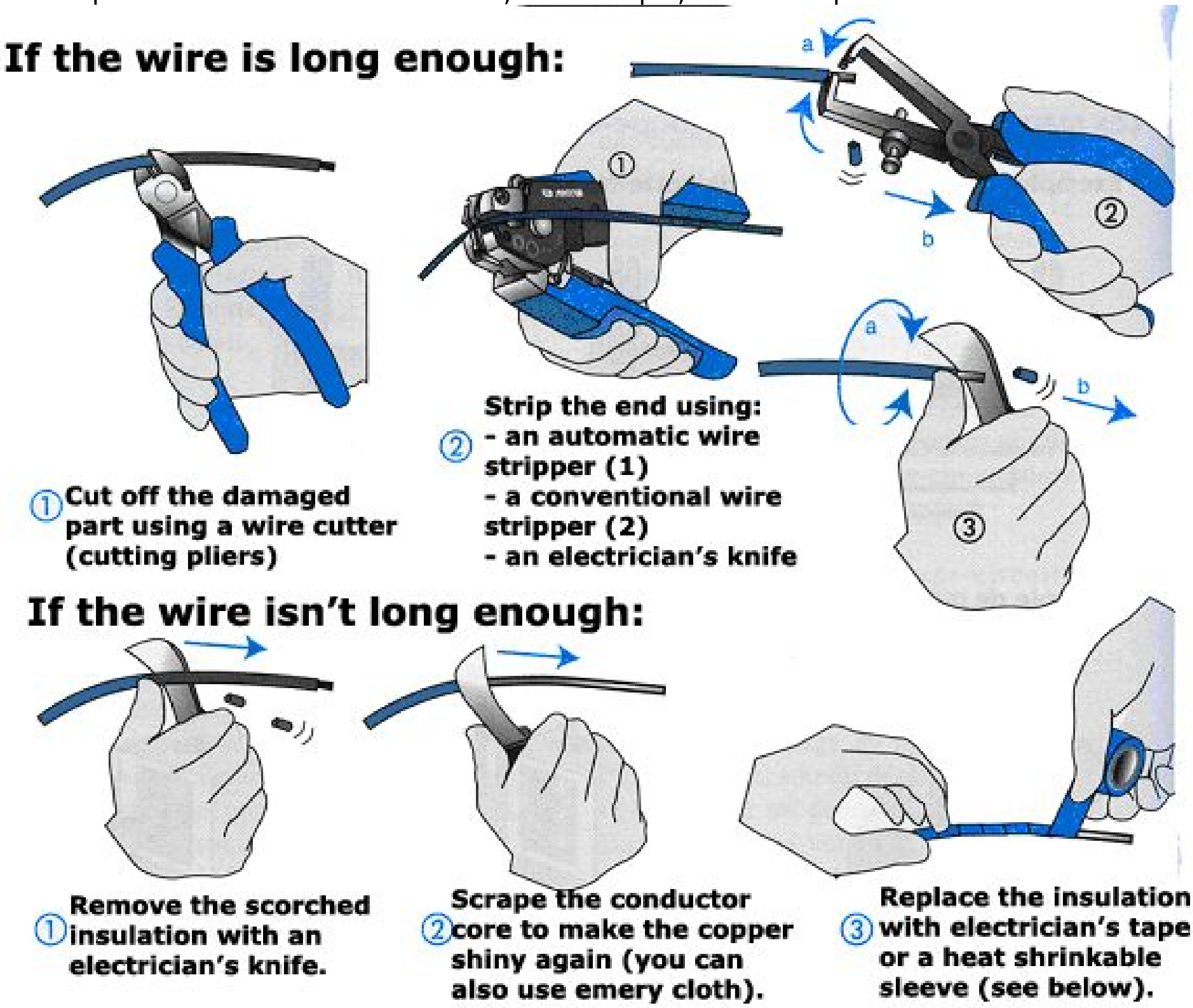
Connections must be in specially provided boxes, with an accessible cover.

Labelling: label each line with electrical tape, leaving a 4 - 5 cm tail with the line's destination written on it.



6.4. REPAIRS

To repair a wire that has overheated, for example, follow the procedure below:



6.5. THE POWER/CROSS-SECTION RELATIONSHIP

Copper electrical wire of a given cross-section has is a maximum amperage and a maximum electrical power:

Wire cross-section (mm^2)	**Power (W)**	**Fuse amperage (A)**	**Circuit breaker amperage (A)**
1.5mm²	2200 W	10 A	16 A
2.5mm²	4600 W	20 A	25 A
4mm²	5750 W	25 A	32 A
6 mm²	7000 W	32 A	40 A
10 mm²	9000 W	38 A	60 A

The amperage is the maximum allowable current for the installed protection device.
For more detail, see the "Current ratings of protection devices for various circuit types" section.

6.6. POWER/CROSS-SECTION/DISTANCE TABLE

Cable manufacturers specify the maximum currents their cables can carry without damage from overheating.

These information is given in tables or abacus for direct and alternate current but it can also be calculated by using the followin formula::

$$\text{max length (m)} = \frac{\text{Voltage (V)} \times \text{Section (mm}^2) \times 46{,}5 \times \text{Voltage loss (\%)}}{180 \times \text{Current (A)}}$$

Usually, we can tolerate a voltage loss up to 3% (between entry voltage and output voltage) with single-phase and with Direct current and up to 5% with tri-phase.

Example: Cables from solar panels to battery

peak power current: 24A, voltage: 12V, Maximum voltage loss: 3% , length: 10 m,

2 types of cables are available: 25 & 35 mm².

$$\text{max length (25mm}^2) = \frac{12 \times 25 \times 46{,}5 \times 3}{180 \times 24} = \underline{9{,}68\text{m}}$$

$$\text{max length (35mm}^2) = \frac{12 \times 35 \times 46{,}5 \times 3}{180 \times 20} = \underline{13{,}56\text{m}}$$

We will prefer to choose the 2x35mm² cable

6.6.1. Alternating current

- Table

This table gives the required cross-section as a function of length, voltage, and current. Lengths are in metres, and are calculated assuming a voltage drop of 3% for single-phase and 5% for 3-phase power.

230 VOLTS – MONOPHASÉ – COS Ø = 1

Puissance en kW	Intensité en A	Sections en mm² 1,5	2,5	4	6	10	16	25	35	50	70	95	120	150	185	240
0,5	2,3	100	165	265	395											
1	4,6	50	84	135	200	335	510									
1,5	6,8	33	57	90	170	225	355	565								
2	9	25	43	68	100	170	265	430	595							
2,5	11,5	20	34	54	80	135	210	340	470	630						
3	13,5	17	29	45	66	110	180	285	395	520						
3,5	16	14	24	39	56	96	155	245	335	450						
4	18		21	34	49	84	135	210	295	395	500					
4,5	20		19	30	44	75	120	190	260	350	515					
5	23			27	39	66	105	170	235	315	460	620				
6	27			23	32	56	90	140	195	260	385	510				
7	32				28	48	76	120	170	225	230	460	570			
8	36					42	67	105	145	195	290	400	500	620		
9	41					38	60	94	130	175	255	355	440	550		
10	45					34	54	84	120	155	230	320	400	495	615	
12	55						45	70	98	130	190	265	330	410	510	
14	64						38	60	84	110	165	220	285	350	435	560
16	73							53	74	99	145	200	250	305	380	500
18	82							47	65	88	125	175	220	270	340	440
20	91								59	79	115	160	200	245	310	400
25	114									64	98	130	150	195	245	315
30	136										77	105	135	165	205	265
35	159	Longueurs en metres		**Length in meter**								90	115	140	175	225
40	182											80	100	125	155	200
45	205												89	110	135	175
50	227													98	120	160
60	273														100	140
70	318															115

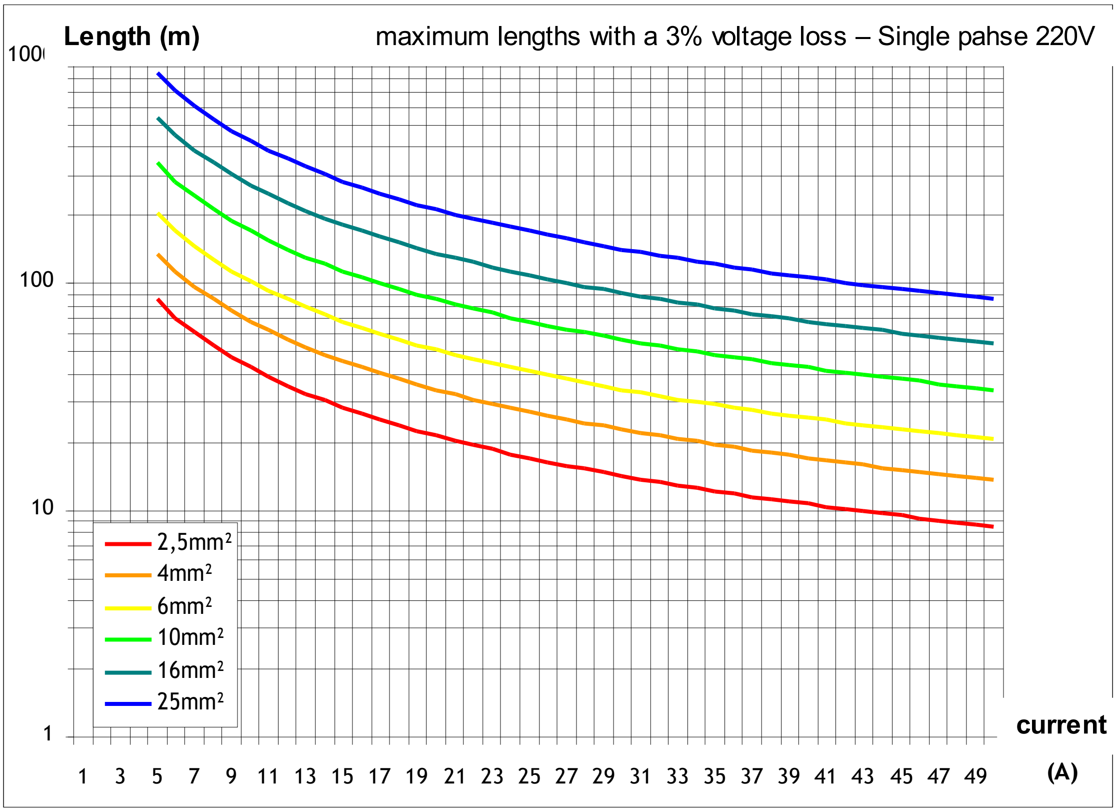
Example: To carry a current of 15 amps over 100 metres, you'll need to use 10 mm2 cable

400 VOLTS – TRIPHASÉ – COS Ø = 0,8

Puissance en kW	Intensité en A	Section en mm² 1,5	2,5	4	6	10	16	25	35	50	70	95	120	150	185	240
2,5	5	190	325	510	745											
3	6	160	270	420	620											
3,5	7	135	230	365	540	895										
4	8	120	200	320	470	785										
4,5	9	105	180	285	420	700										
5	10	96	165	255	375	630	970									
6	12	79	135	210	315	525	810									
7	14	68	115	180	270	455	700									
8	16	60	105	160	240	400	610	940								
9	18	51	92	145	215	355	550	850								
10	19		84	120	190	320	500	780								
12	23		69	110	160	265	415	640	880							
14	27			94	140	230	355	550	750							
16	31			81	120	200	315	485	655	860						
18	35				110	180	280	430	580	770						
20	38				98	160	255	390	520	690						
25	48					130	206	315	420	555	760					
30	57						170	260	355	465	640	840				
35	67						145	225	300	400	550	710				
40	76							195	260	350	490	640	745			
45	86							175	235	310	430	565	670	770		
50	95							160	215	285	385	510	600	695		
60	114								180	235	320	420	500	590	680	
70	133									200	275	365	430	495	580	
80	152	Longueurs en metres **Length in meter**									240	315	375	430	510	605
90	171										215	280	335	385	445	535
100	190											250	300	350	405	480
120	228												250	290	340	400
140	266													250	290	345
160	304														255	300
180	342															265

Maximum length for a 5% voltage drop. These lengths are also valid for a starting current of 2In with a 10% voltage. Example: To supply an 18kW cosØ=0.8 motor with a 100m cable, you need to use a 6 mm2 cable.

- abacus:



6.6.2. direct current

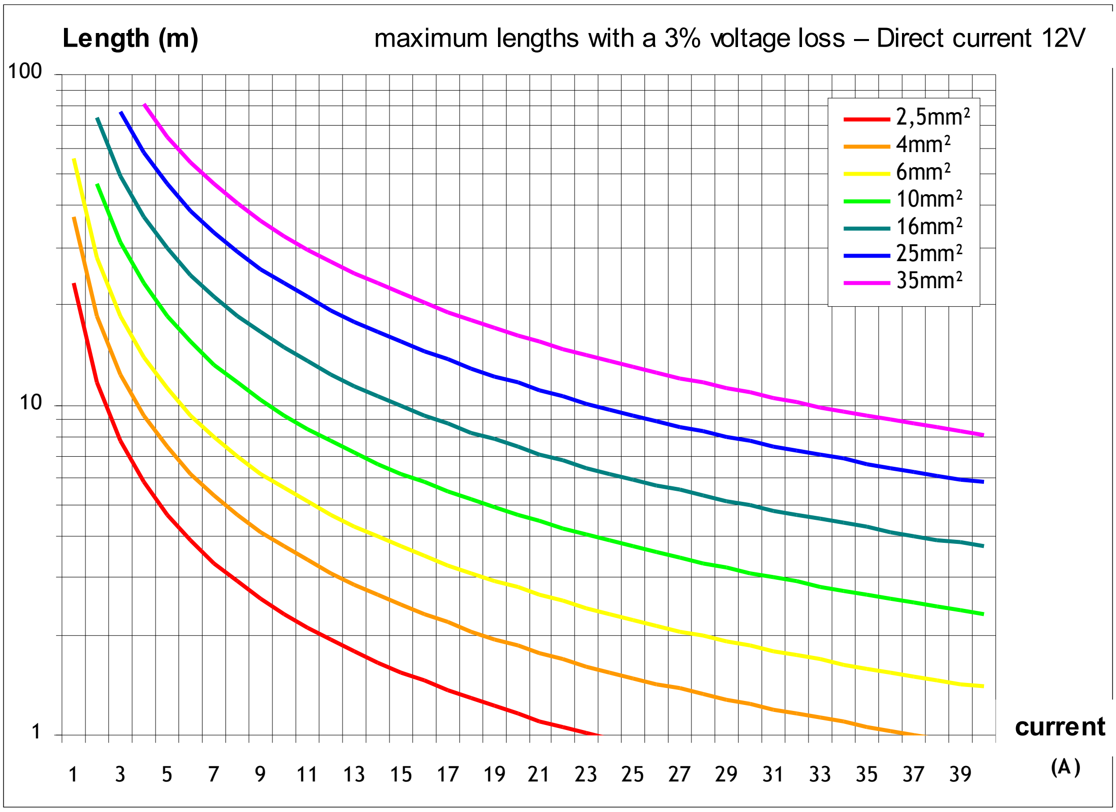
- Table

For 12V DC, refer to the following table:

Table: Maximum wire length in metres for 12V

Wire cross-section (en mm2)	CURRENT								
	1A	2A	3A	4A	5A	6A	8A	10A	14A
1,5	22	11	7	6	4	4	3	2	2
2,5	38	19	13	9	8	6	5	4	3
4	60	30	20	15	12	10	8	6	4
6	88	44	29	22	18	15	11	9	6
10	150	75	50	38	30	25	19	15	11

- abacus:

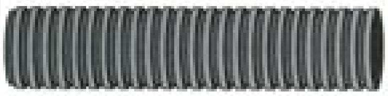
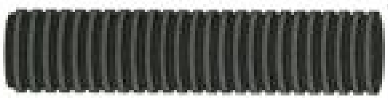
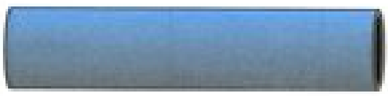
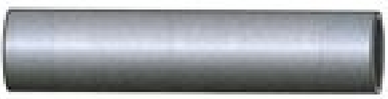
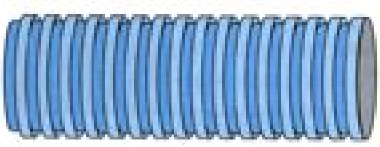


7. CONDUITS

Conduits are water- and airtight (keeping out moisture and dust), offer mechanical resistance (against impact and crushing), and are flame-resistant. They protect conductors in both surface-mounted and within-wall installations.

7.1. TYPES

There are several types:

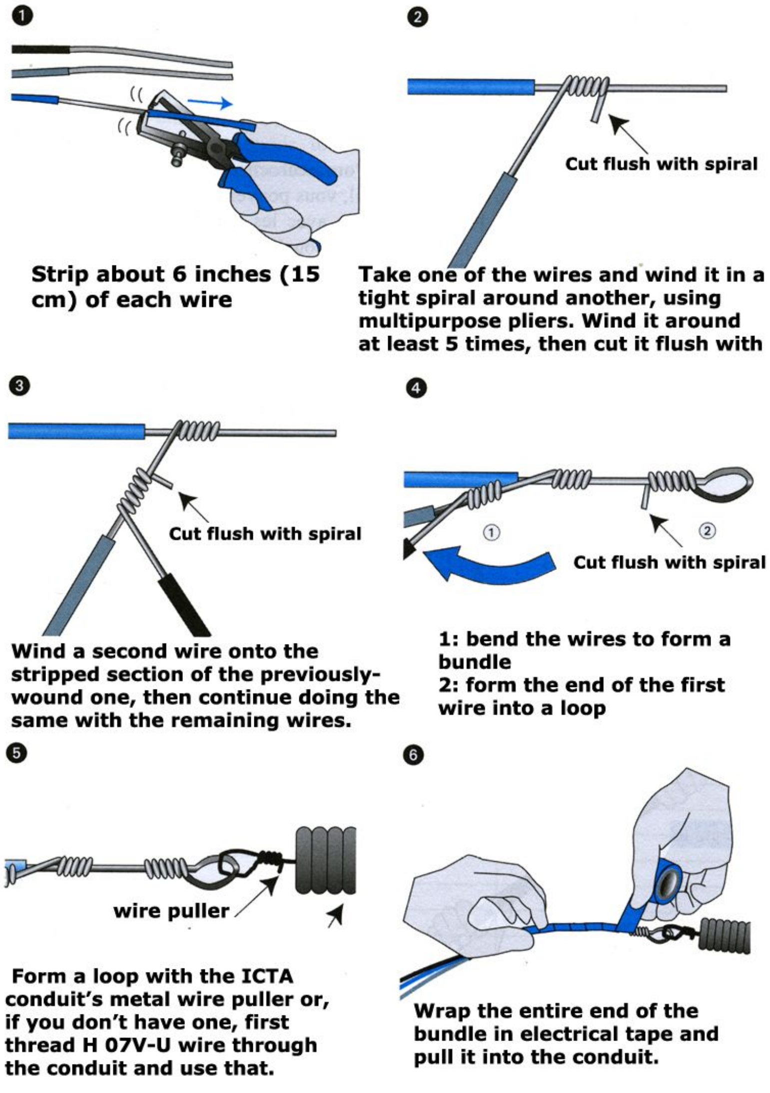
TUBES ET CONDUITS				
Type	**Schéma**	**Caractéristiques**	**Diamètre (mm)**	**Utilisation**
ICA **3321** (anciennement ICO)		Insulating Bendable Corrugated IP 44 Flame-retardant Colour: grey	16 20 25 32 40 50 63	Surface Concealed (walls)
ICTA **3422** (anciennement ICT)		Insulating Bendable Transversely elastic Corrugated IP 44 Flame retardant Colours : grey, black, blue, green	Idem	Universal: - surface - concealed - encased in concrete
ICTL **3421** (anciennement ICD)		Insulating Bendable Transversely elastic Smooth Colour: grey Flame retardant	Idem	Surface Concealed (walls, floors) Rarely used
ICTL **orange** (anciennement ICD)		Insulating Bendable Transversely elastic Smooth Colour: orange Non-flame retardant	Idem	Prohibited in surface installations Encased in concrete (walls, floors) Rarely used
IRL **3321** (anciennement IRO)		Insulating Rigid Smooth IP 42 Colour: grey or white	Idem	Surface, usually Concealed (walls)
MRL **5557** (anciennement MRB)		Steel tubing (stainless or galvanized) Metallic Rigid Smooth	Idem	Surface, where there are serious mechanical constraints: parking garages, factories, agricultural uses
TPC (Tube pour Protection des Câbles)		Insulating, bendable, double-walled, corrugated exterior, smooth interior. IP 44 Red: electrical Green: telecommunications	40 50 63 75 90 110 125 160	Buried

For our missions, the main types are IRL 3321 (insulating, rigid, smooth) and ICTA 3422 (insulating, bendable, corrugated):

7.2. RUNNING CONDUCTORS THROUGH CONDUITS

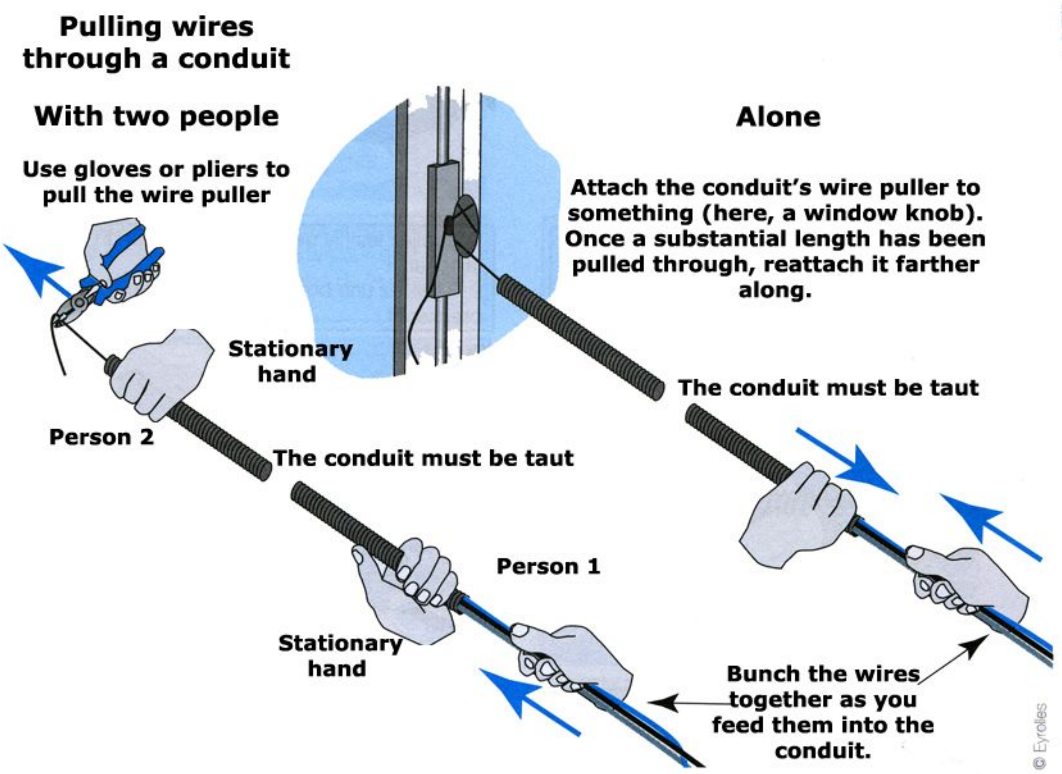
It's essential that wires and cables can be easily pulled through or out once conduits and their accessories have been installed. To make sure this is the case, follow the one-third rule: the total cross-section of the cables must not exceed 1/3 of the conduit's inside cross-section.

Preparing conductors before feeding them into the conduit:



For stubborn conduit, use talc.

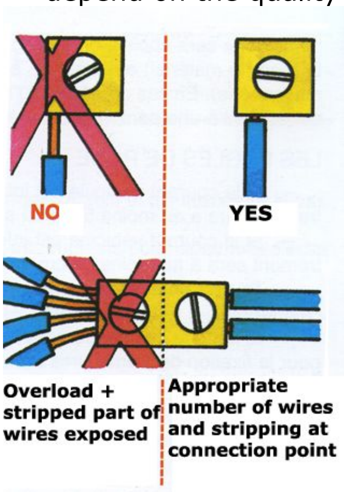
How to pull wires through conduit, when you have one or two people:

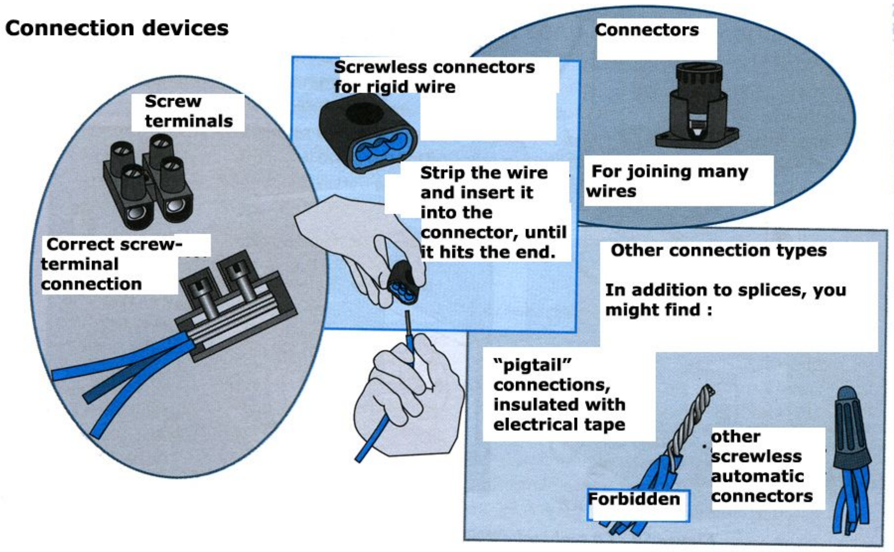


8. CONNECTIONS

Appropriate devices—such as screw-terminal connectors, screwless terminal blocks, and junction boxes—must be used when wiring connections.

CAUTION: the reliability of the installation, as well as its safety (from risk of fire), will depend on the quality of the connections.





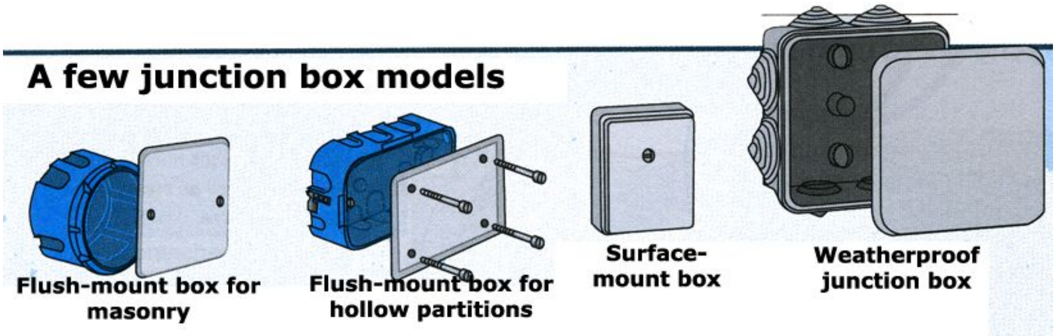
With connectors, a double connection is more reliable. Therefore, whenever possible:

- strip the wire so that the exposed portion is slightly shorter than the connector,
- Thread all wires to be connected from the same side,
- Tighten the two screws onto the wires.

8.1. JUNCTION BOXES

Use these if possible.

These are meant to house conductor connections for shunts and branch circuits. There are boxes, often made of plastic, for surface connections. Inside, connections are wired using screw- or clamp-type terminals.



Cover plates must remain accessible.

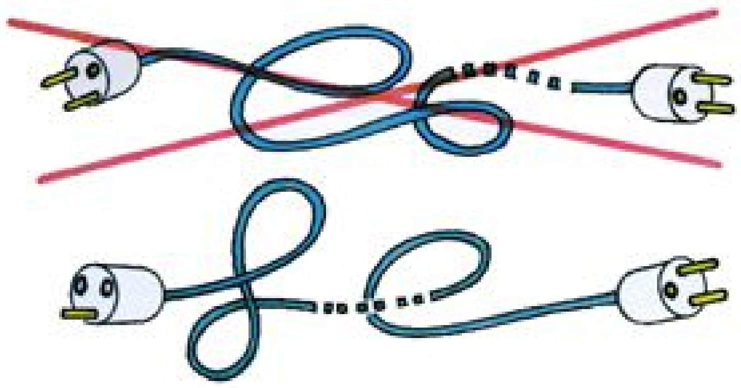
8.2. STRIPPING A WIRE

CAUTION: Take care not to score the copper core (for rigid wires), or cut any of the thin strands (for flexible wire), as this will reduce the effective cross-section of the conductor and thus its ability to safely power the same appliances.
For example, a 2.5 mm^2 wire that could formerly supply a 4600W device will only be capable of handling 2200W if its cross-section is inadvertently reduced to 1.5 mm^2 by cutting.

9. CORDS

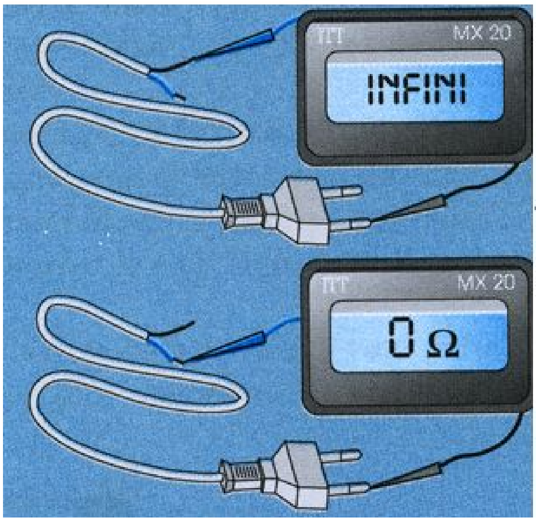
Called extension cords, these are made with type H05VV-F 2 x 1mm^2 or with H07VV-F 3G 1.5mm^2 cable.

CAUTION: a flexible cable should never have 2 identical plugs.



9.1. CONTINUITY TEST

To test a cord, use a multimeter in its ohmmeter or audible signal mode.



To test a cord, touch one of the test probes to one pin of the plug and look for the corresponding wire at the other end of the cord. You should get the readings opposite. Now test the other pin. An infinite reading between one of the pins and the ends of both wires means that one of the wires is bad.

Touch one test probe to one of the plug's pins, then touch the other probe, in turn, to each of the wires at the other end of the cord.

You should get one infinite reading and one zero reading (a beep for one wire, but not for the other). Two infinite readings means that a wire is bad. Repeat the operation with the second pin.

9.2. WHICH WIRE WITH WHICH WIRE?

Say you have a sheath with 4 electrical wires of the same colour. To find which ends belong to the same conductor, place one of the ohmmeter's test probes on one of the four wires at one end and then, at the other end, touch the other probe to first one, then the three other, wires.

You should get three infinite readings and one zero reading (a beep for one wire, but not for the other three). The two ends of the same wire give a zero reading.

Repeat for the other wires.

10. CABLE REELS

When using a cable reel with a high power load, always unwind the cable COMPLETELY.
If the reel isn't equipped with thermal overload protection—which is often the case—cable insulation can melt and cause a short-circuit, with the risk of a fire.

MSF model: three 16A 3-pin outlets, 40m cable (H07RN F3G2.5).
Maximum power, unwound: 3800W.
Maximum power wound: 1500W.
Code : KPROCABE50R

CIRCUITS

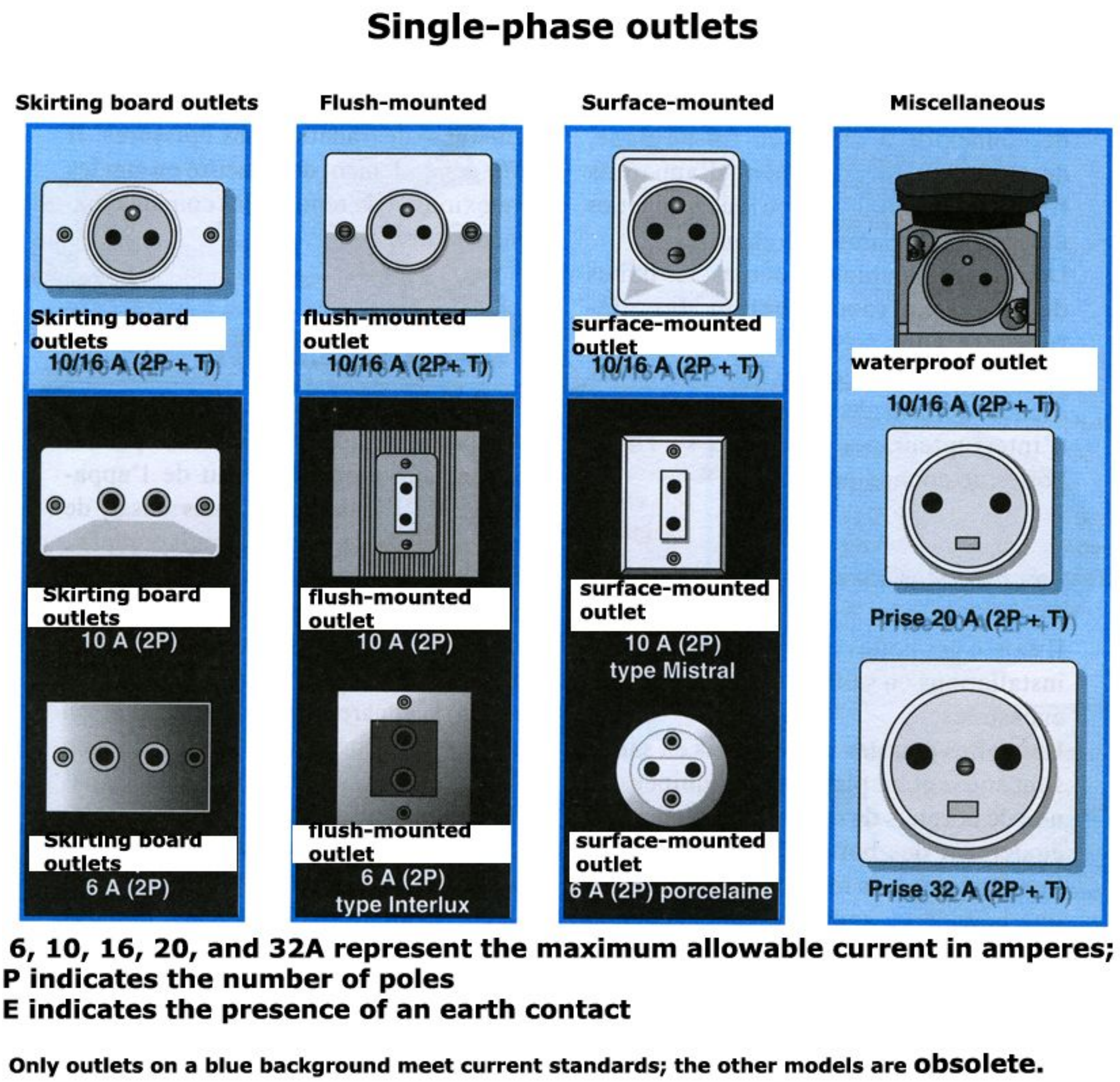
1. POWER OUTLET CIRCUITS

This chapter will deal only with single-phase outlet circuits. Three-phase outlets are discussed in the chapter on three-phase systems.
These circuits are designed for connecting appliances both with and without an earth.

1.1. OUTLET TYPES

For single-phase we find mainly 2-pole (2P, 2-pin) or 2-pole plus earth (2P+E, 3-pin) outlets.

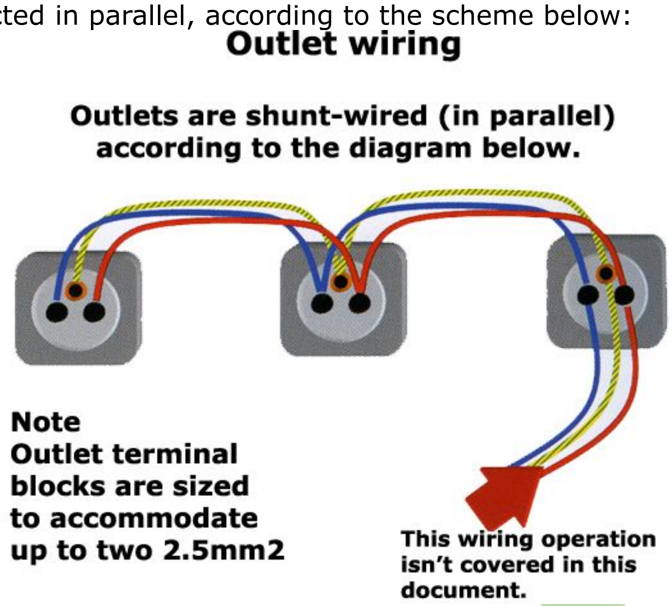
We use

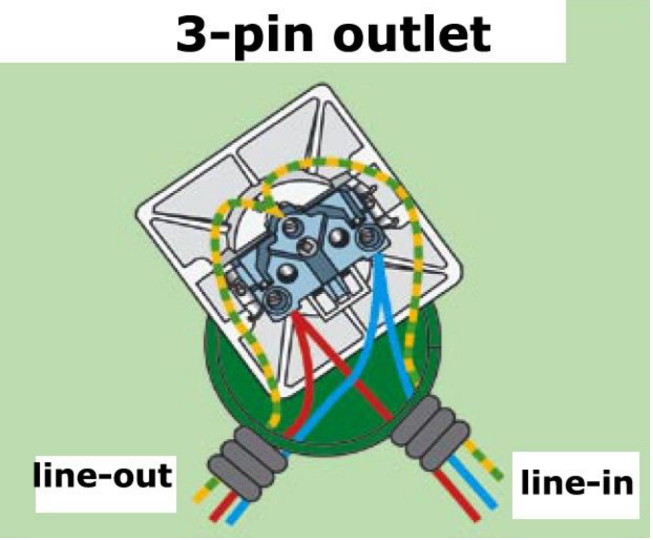


primarily 10/16A 3-pin, 20A 3-pin and 32A 3-pin outlets.
Older outlets come in a wide variety of models and shapes, from porcelain to plastic. These rarely have earth contacts and don't satisfy today's safety requirements.

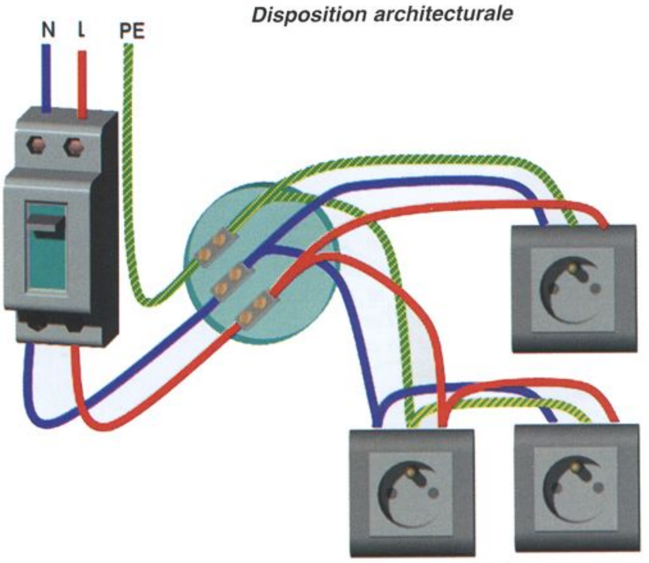
1.2. WIRING 16A OUTLETS

16 amp outlets are connected in parallel, according to the scheme below:



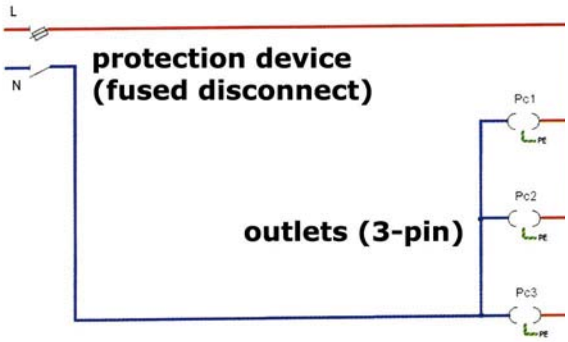


Or from a branch distribution box:

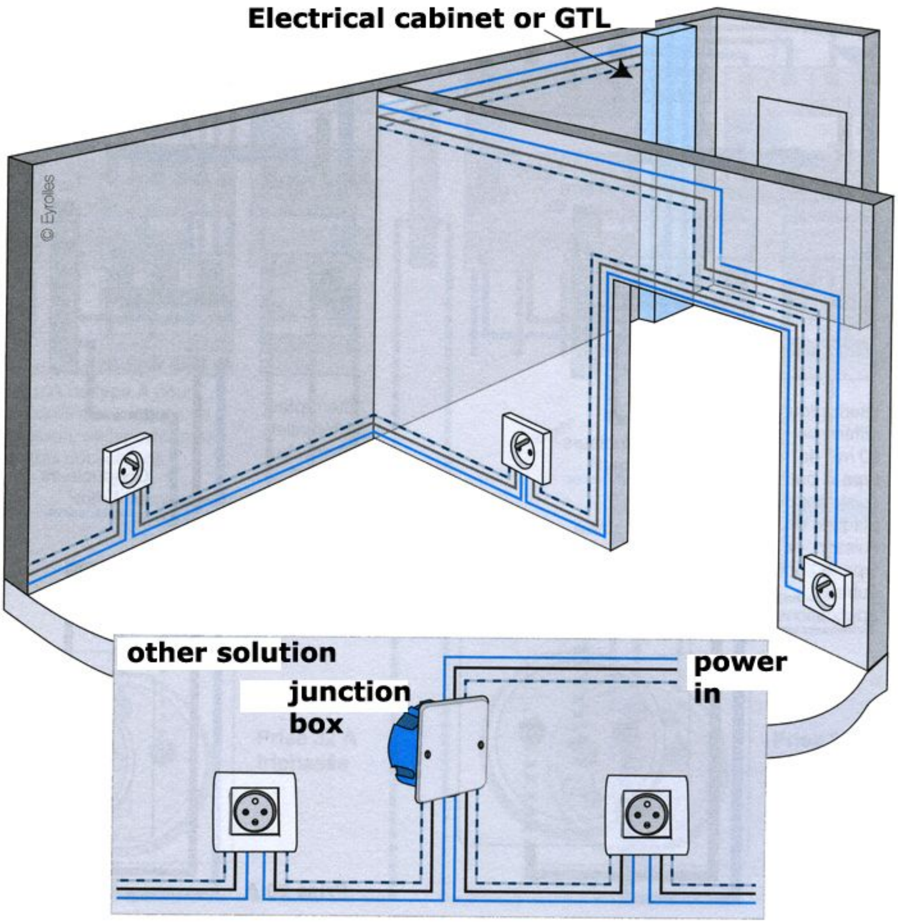


Phase and neutral go to the outlet.

The outlet terminal blocks can accommodate up to two 2.5mm^2 conductors.
Single-line diagram:

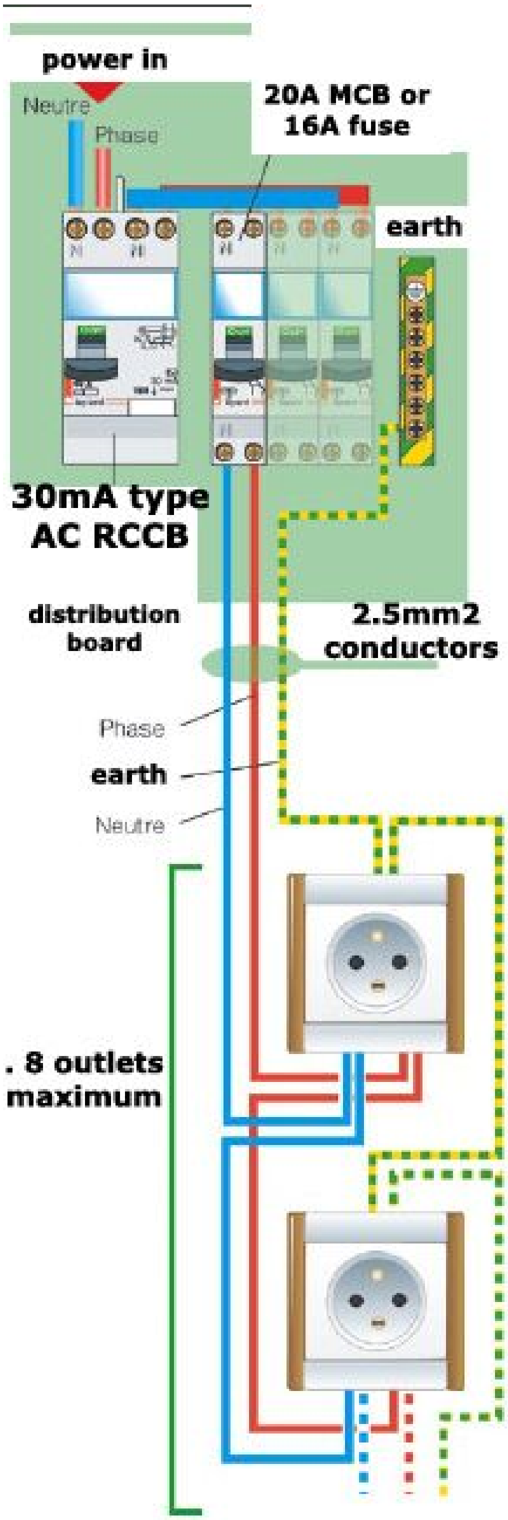


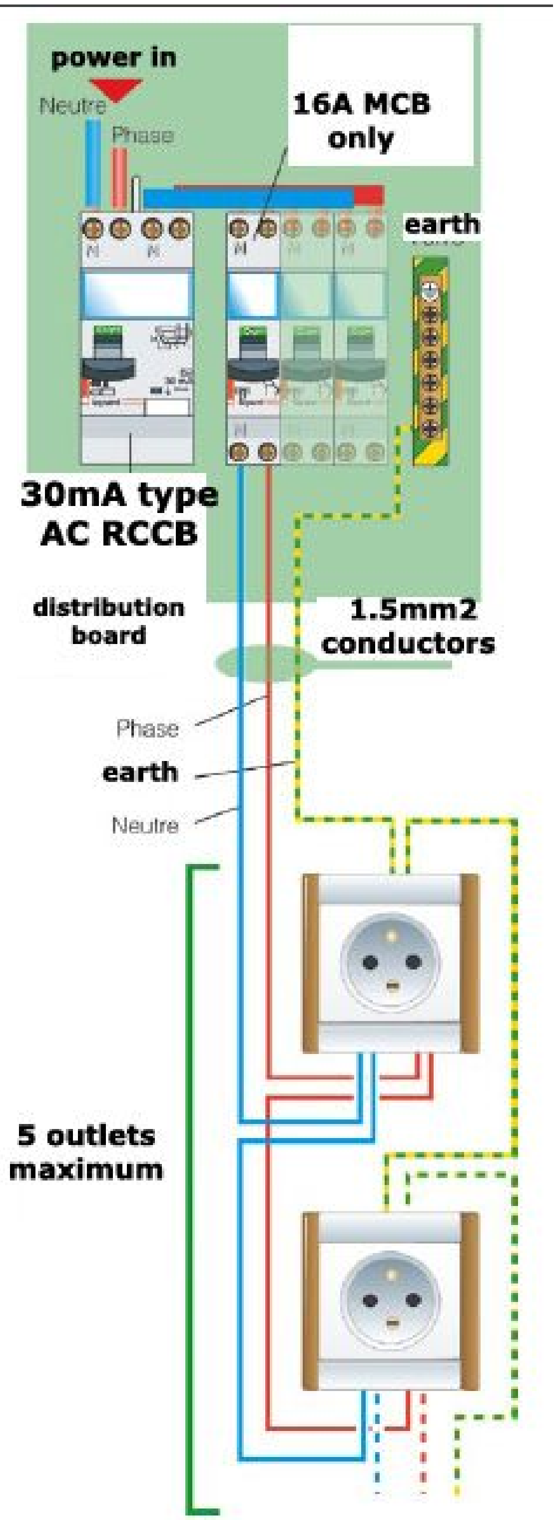
Multi-line diagram:



CAUTION:
The maximum number of outlets that can be wired in a 16A outlet circuit is limited, and depends on the cross-section of the cables (1.5 or 2.5mm^2):

Circuit type	Minimum copper wire cross-section	Rated current of protective device		Installation limits
16A outlets	2.5 mm^2	20A circuit breaker	16A fuse	Max. 8 outlets per circuit
	1.5 mm^2	16A circuit breaker	Fuse prohibited	Max. 5 outlets per circuit

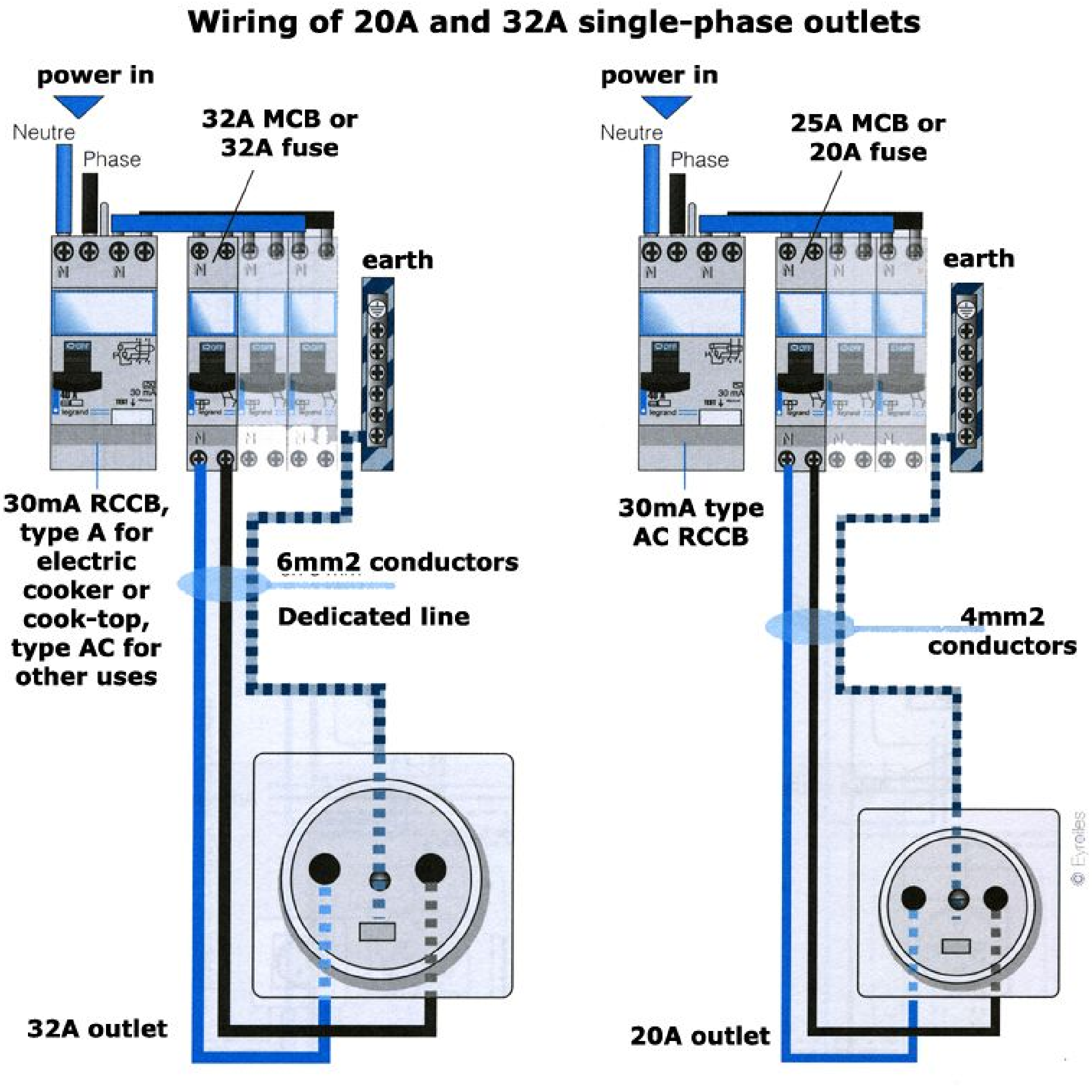




For more on protection devices, see the “Protection Devices” chapter.

1.3. WIRING 20A OR 32A SINGLE-PHASE OUTLETS

Only one 20A or 32An outlet should be wired per circuit.
For 20An outlets, use only 4mm² cable. For 32An outlets, use only 6mm² cable.

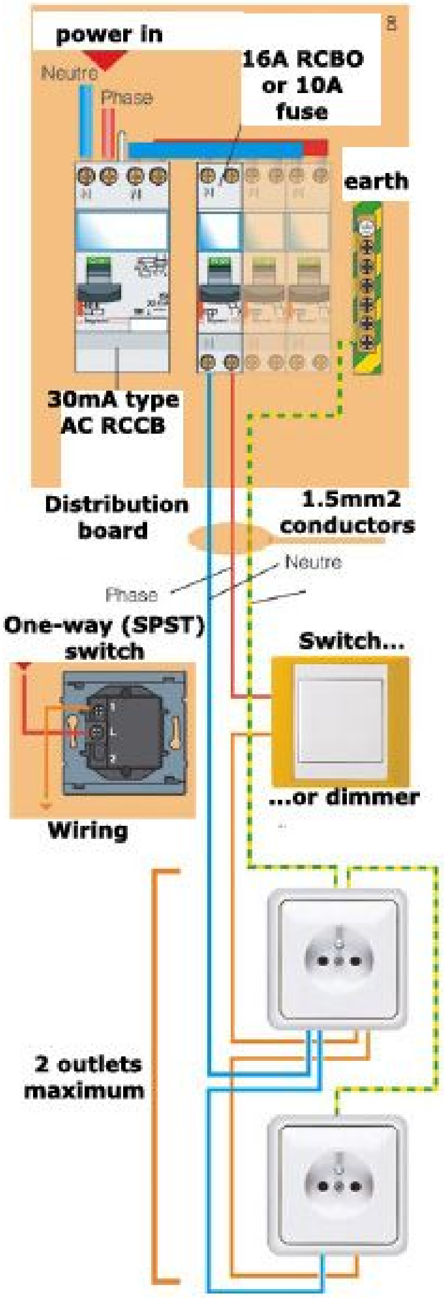


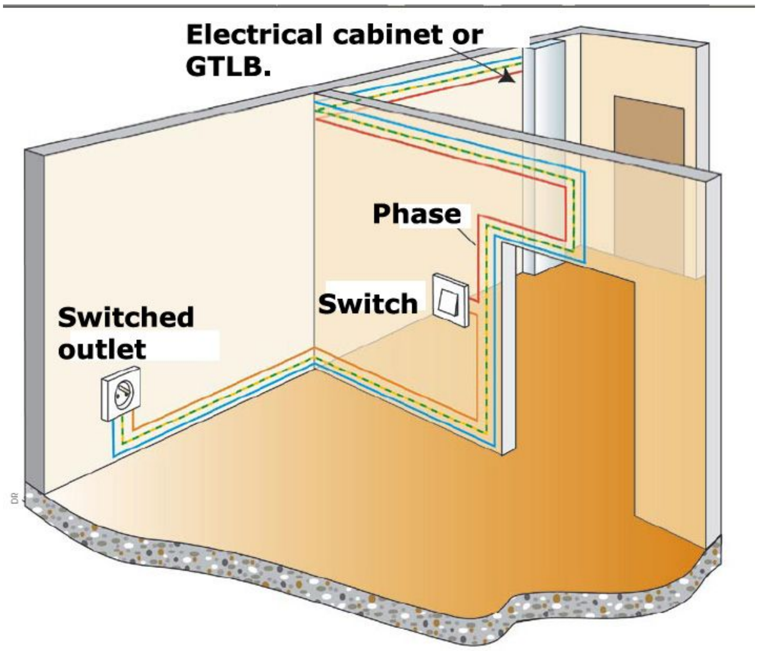
For protection devices, see the "Protection Devices" chapter.
For wiring 32A three-phase outlets, see the "Three-phase Power" chapter.

1.4. SWITCHED OUTLETS

The idea here is to control the phase conductor using a switch, so that the switch can be used to turn the device plugged into the outlet on and off.

This system can only be used with 16A outlets, and is limited to 2 outlets controlled by a switch as shown below:





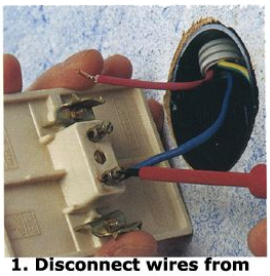
CAUTION: The switch is always on the phase. The neutral does not pass through the switch. The switch has 2 contacts, one for connecting the phase (often labelled with the letter "P"), the other for the line to the outlet.
Since the outlet needs both the phase and the neutral, you can't wire an extra outlet directly to the switch.

1.5. REPLACING AN OUTLET

An outlet that's been pulled out may have exposed live parts, and should be replaced.

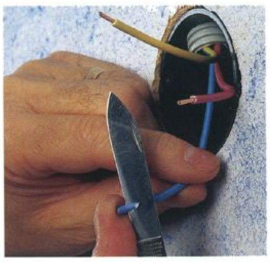
First, the line must be isolated from the power supply. Next, verify the absence of current at the outlet using a voltage detector (see the "Basic Measurements" section).

Then proceed as follows:



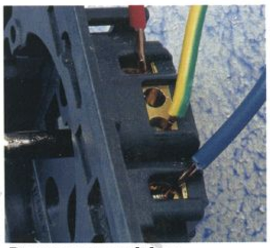
1. Disconnect wires from the old outlet.

2. Cut off the ends of the wire cores.

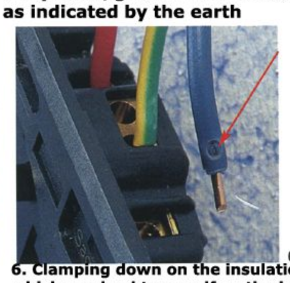


3. Strip about 5mm of the wires (using a knife or wire strippers)

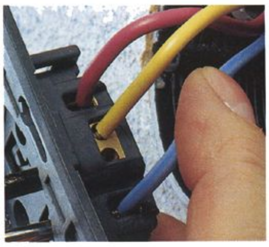
4. Connect the wires, insulation flush with the connector clamps, the yellow/green in the centre as indicated by the earth



5. Dangerous wiring. Insulation has been stripped too far, posing a shock

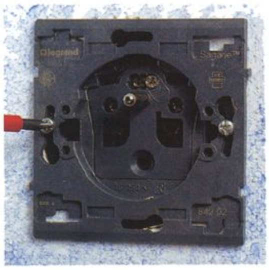


6. Clamping down on the insulation, which can lead to a malfunctioning, or a completely non-functioning, outlet.

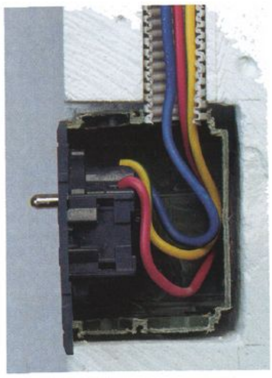


7. Correct wiring (3-wire set-up).

8. Outlet mounting using tee-nuts.



9. Outlet mounting using screws. The mounting screws are located outside the mechanism.

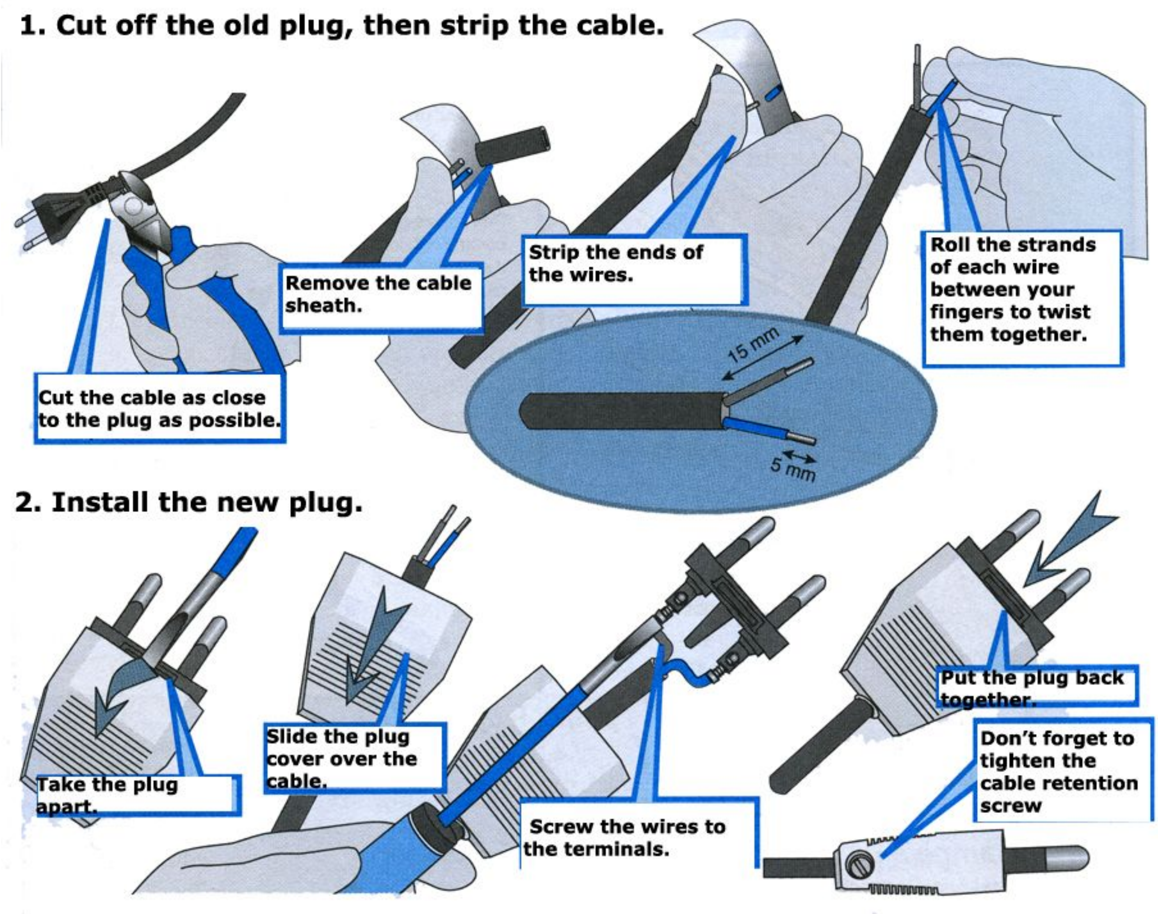


10. Arrange the wires in the box.

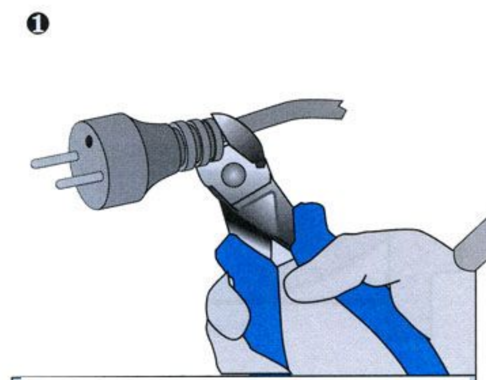
11. Attach the frame with screws.

12. Attach the face-plate.

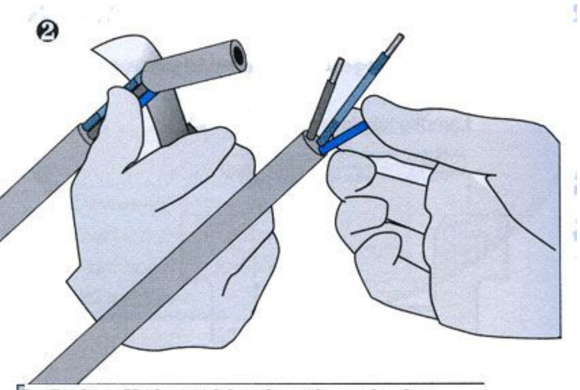
1.6. REPLACING A 6A MALE PLUG



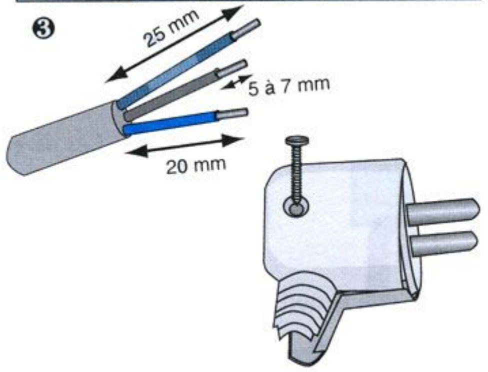
1.7. REPLACING AN EARTHED 10/16A MALE PLUG



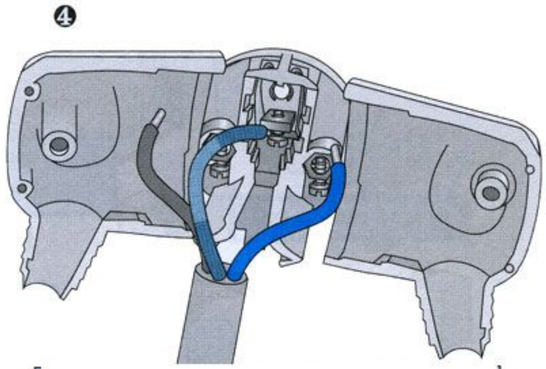
1. Replacing an earthed plug.
If the plug can't be taken apart, cut the cable as close to the plug as possible. Otherwise, take the plug apart.



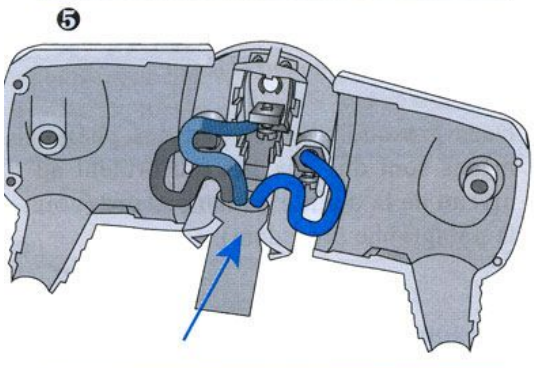
2. Strip off the cable sheath and wire insulation. Roll the strands of each wire between your fingers to twist them together



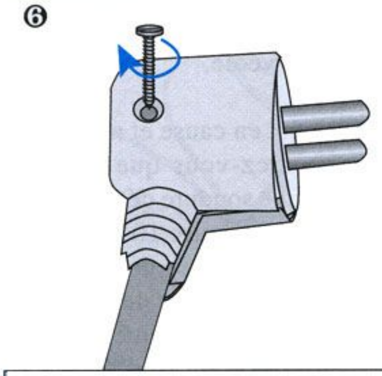
3. Strip the cable according the measurements above. The earth wire (green and yellow) should always be longer. Ready a new plug.



4. Connect the earth wire to the contact corresponding to the earth jack. The phase and neutral are connected separately to the pin contacts.



5. After connecting the wires, slide the cable into the retaining collar. Depending on the model, the retention mechanism might consist of a screw with a clamping plate.



6. Put the new plug back together.

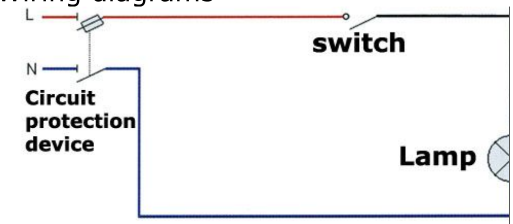
2. LIGHTING CIRCUITS

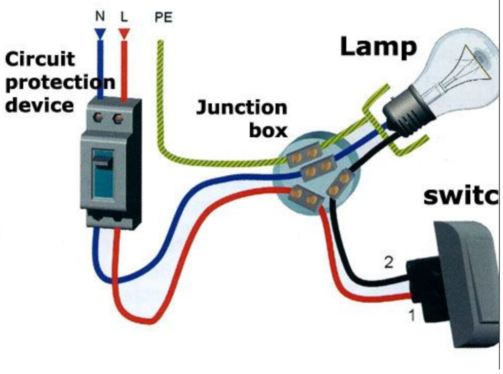
Lighting circuits should be wired with 1.5mm^2 conductors.
No circuit should supply more than 8 light fittings.

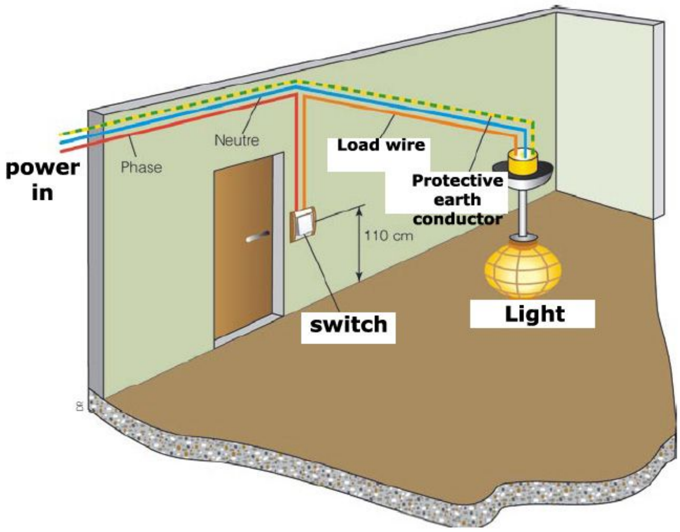
2.1. THE ONE-WAY LIGHTING CIRCUIT

This is the simplest set-up; there is only one control—the switch—which cuts the circuit's phase. The neutral and the earth connect directly to the light fitting.
Make sure that the wire exiting the switch is a different colour than the phase—orange, for example. We call this the "load wire."

Wiring diagrams





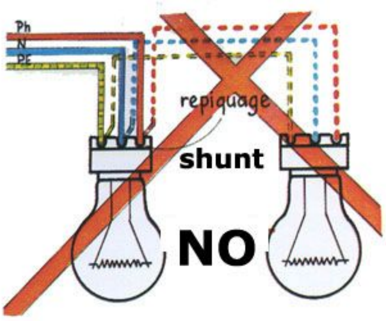


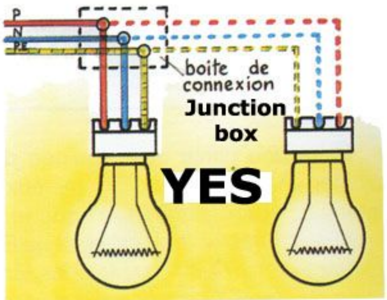
While not all light fixtures need an earth conductor, it is required in all lighting circuits. See the "Earth Electrode" section.

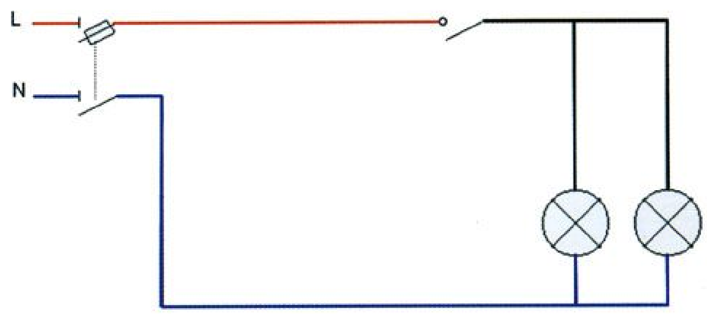
Respect the following standards:

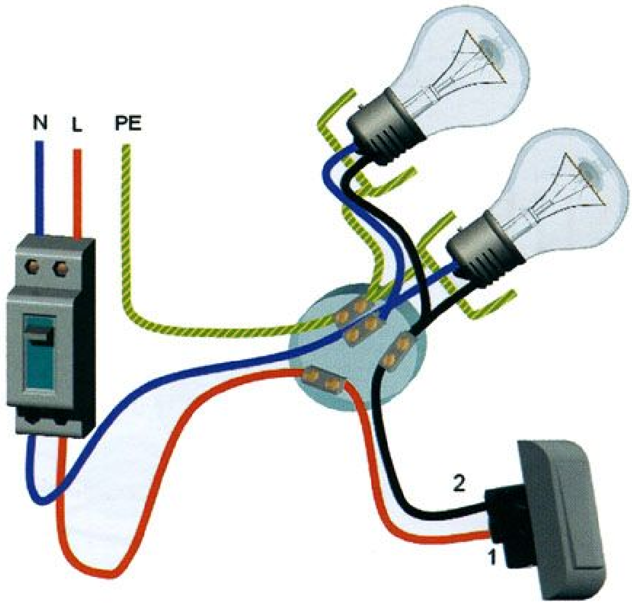
Circuit type	Copper wire cross-section	Rated current of protection device		Installation limits
Lighting circuit	1.5 mm^2	16A circuit breaker	10A fuse	Max. 8 light fittings per circuit

Several light fittings can be controlled by a single switch by connecting them at a junction box, not at the fixtures themselves:



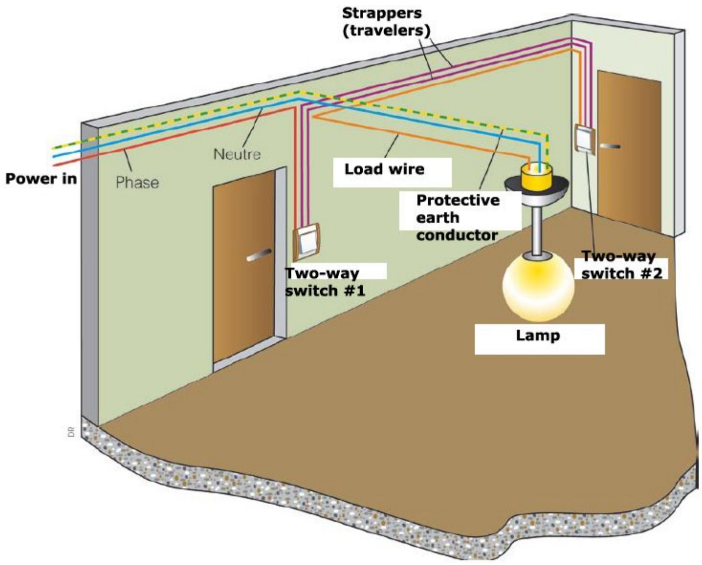



L
N

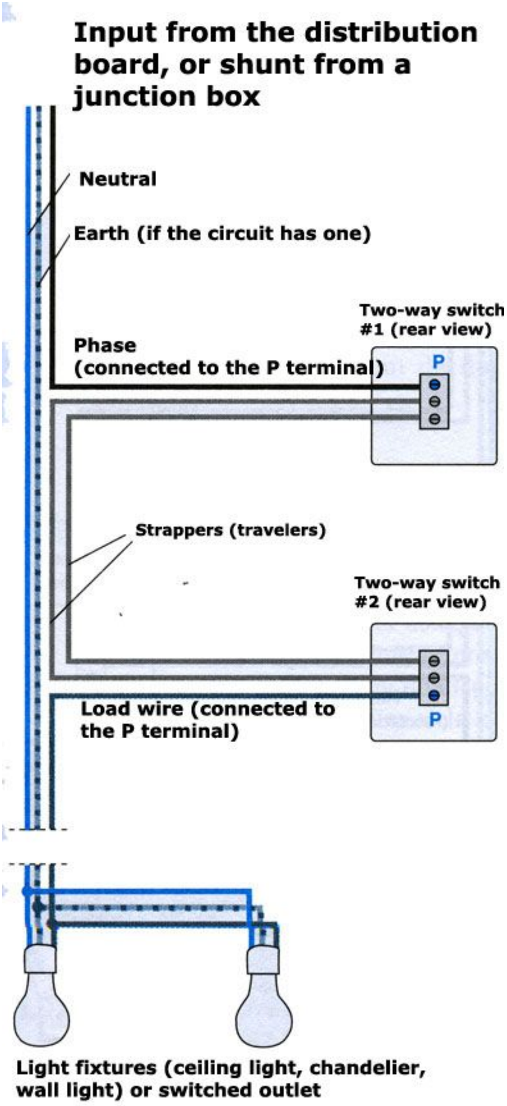

N
L
PE
2
1

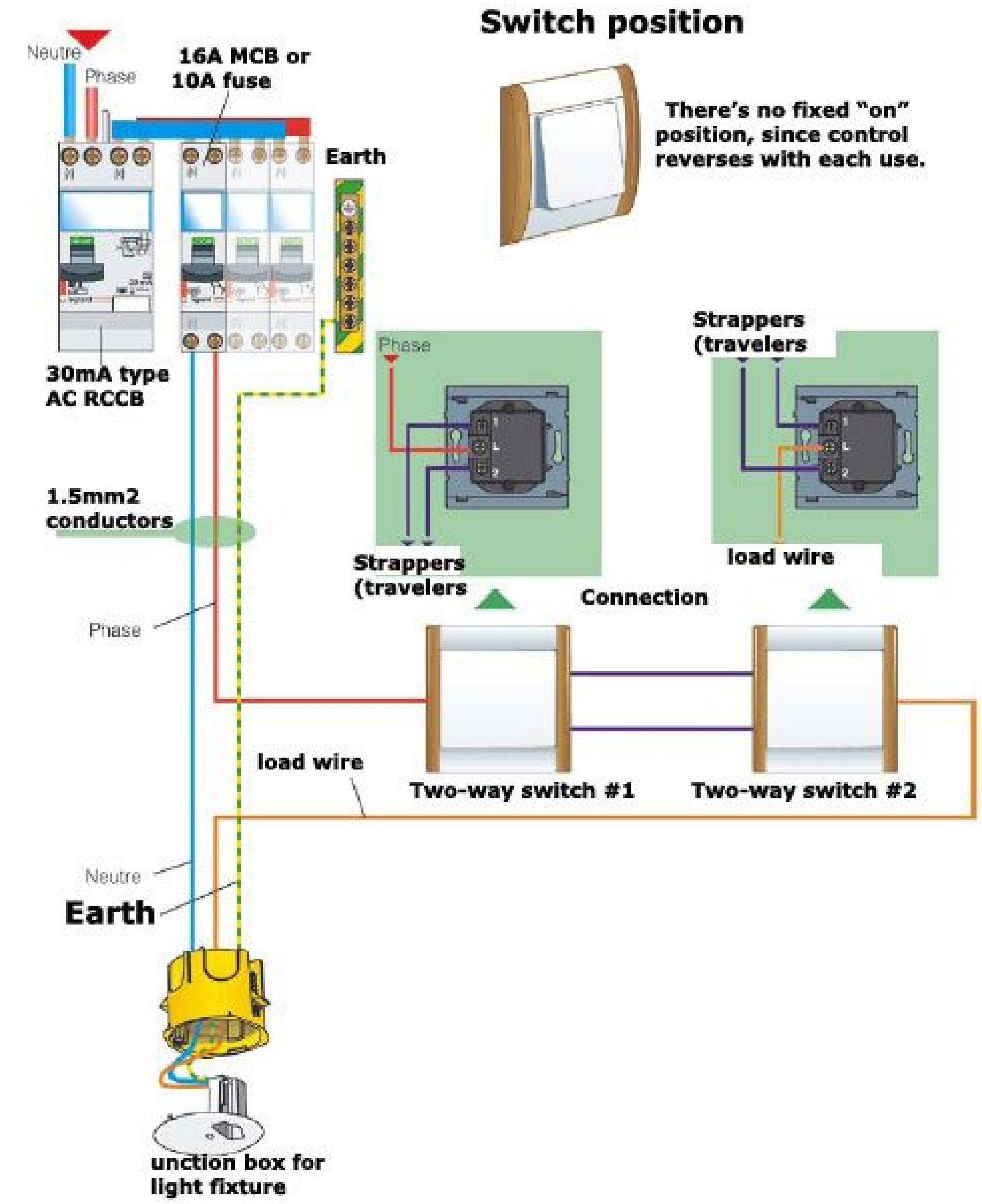
2.2. TWO-WAY LIGHTING

This set-up allows you to control the same circuit from two different locations. It's appropriate for short hallways and rooms with two entrances. A single light fixture is controlled from 2 separate locations using 2 switches. Switches must be of the "two-way" (SPDT) type, with three connection terminals.



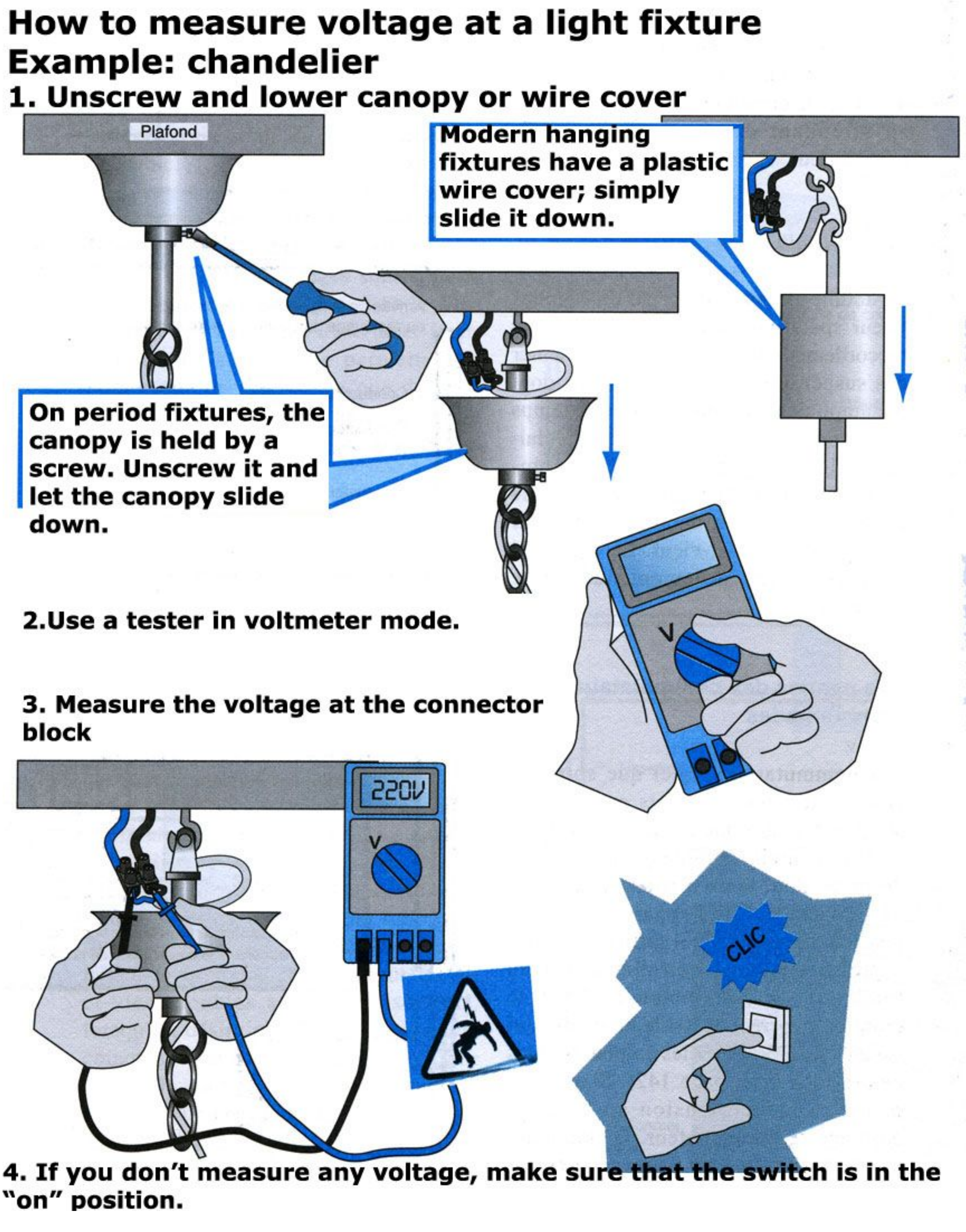
Circuit protection and conductors are the same as in other lighting circuits.




Switch position
Neutre
Phase
16A MCB or
10A fuse
Earth
There's no fixed "on"
position, since control
reverses with each use.
30mA type
AC RCCB
Strappers
(travelers
Phase
1.5mm2
conductors
Strappers
(travelers
load wire
Connection
Phase
load wire
Two-way switch #1
Two-way switch #2
Neutre
Earth
unction box for
light fixture

2.3. HOW DO I TEST A LIGHT FIXTURE?

To test for voltage at the fixture, proceed as follows:



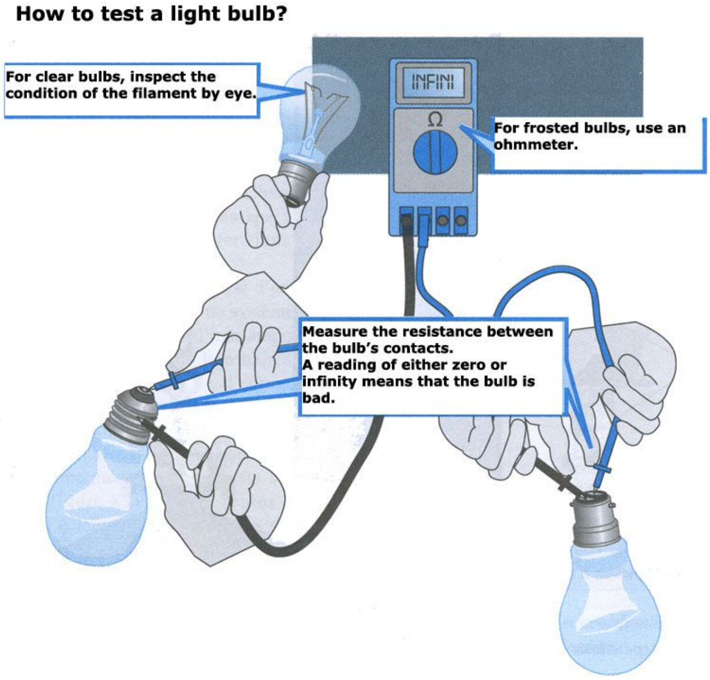
If you find 220V, the circuit is good—it's the light fixture that's the problem. In this case, check the bulbs and connections.

If, after trying the switch in both positions, you still don't measure any voltage, the fixture is not the problem.

2.4. HOW DO I TEST A LIGHT BULB?

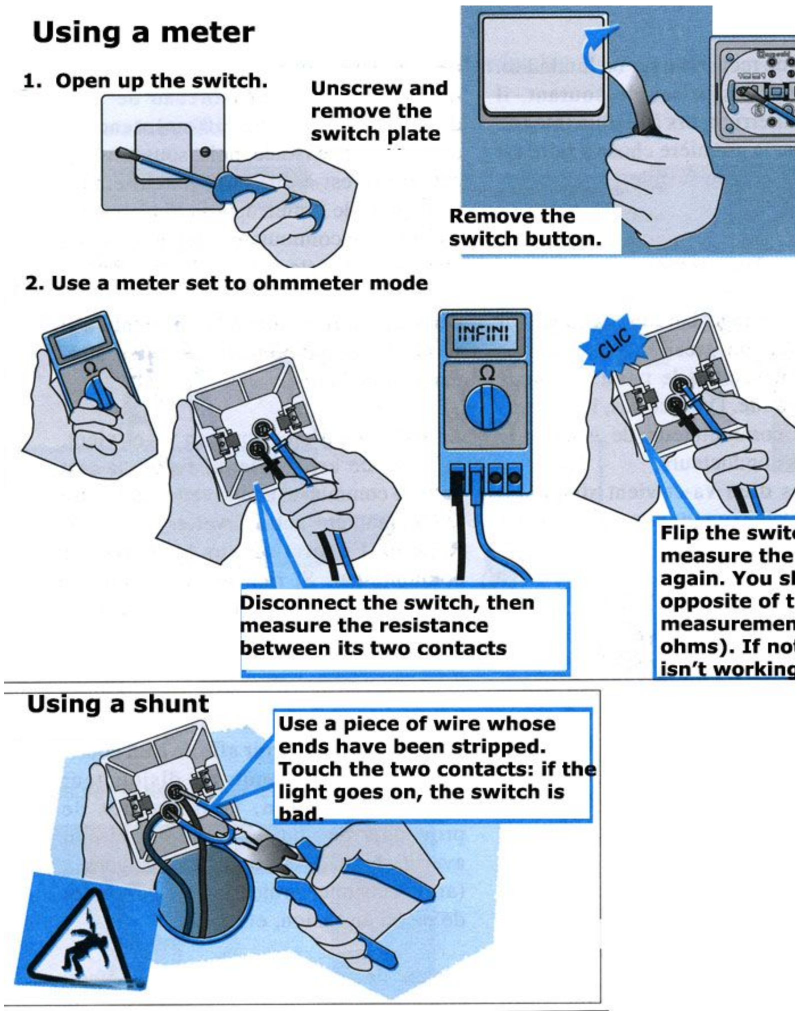
For some opaque bulbs, it's hard to judge the condition of the filament with the naked eye.

In these cases, test the bulb with a multimeter in ohmmeter mode: a zero reading indicates a short-circuit (rare); an infinite reading means that the filament is burnt out.



2.5. HOW DO I TEST A SWITCH?

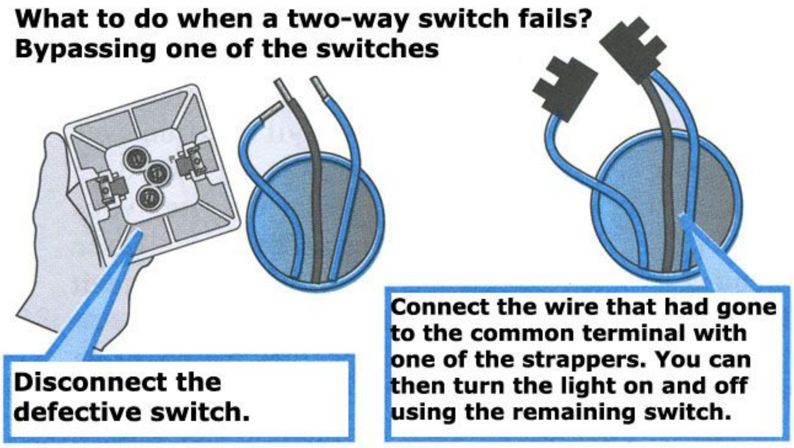
Wear and tear, poor installation, or a short-circuit can destroy a switch. To check the condition of a switch, follow these steps.



The meter should read zero for one switch position, and infinity for the other.

If you don't have a meter, test the switch with a shunt made from about 10cm of insulated wire. If short-circuiting the contacts of a switch under live conditions causes the light to go on, the switch is bad.

Use the same method for a two-way switch. If it's not possible to replace a two-way switch that has failed, do the following:



2.6. LOW POWER CONSUMPTION LAMPS

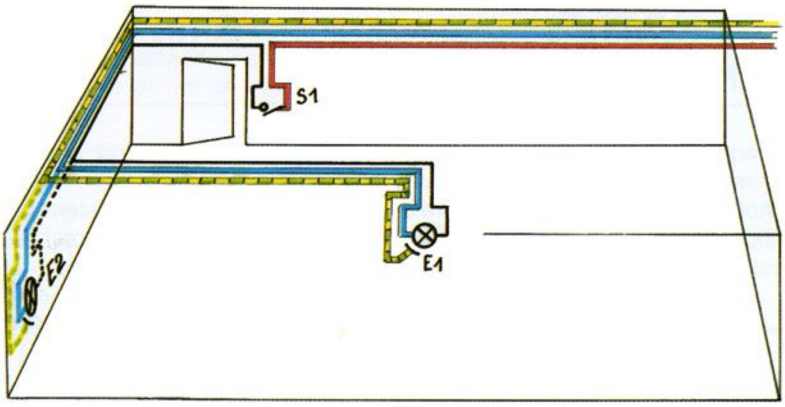
At MSF you can now use the following 2x23W low power consumption lamp
Code: PLIGLAMFC46

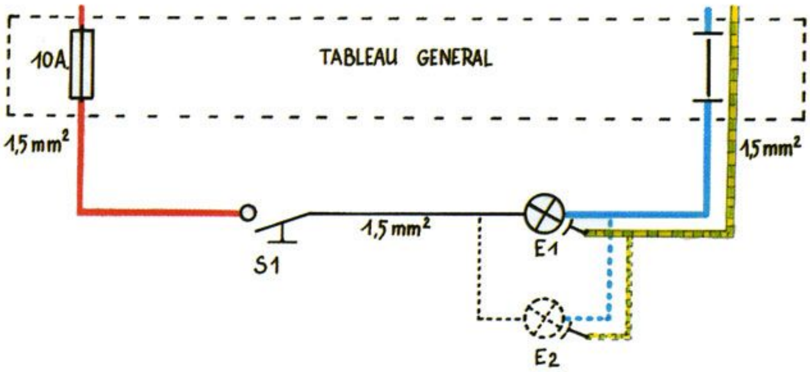
These lights can be controlled with a switch, and also offer three 16A 2-pin outlets. They come with 5m of cable and may be installed outdoors.

The bulbs are available under code PLIGFLUOC23.
These lamps are included in the 6KVA electrical supply kit. See the " Generator Sets at MSF" chapter.

2.7. HOW DO I ADD A LIGHT FIXTURE?

You'd like to add a second light fixture (E2) in a room already equipped with one light fixture (E1). Wire as shown in the following schematic:



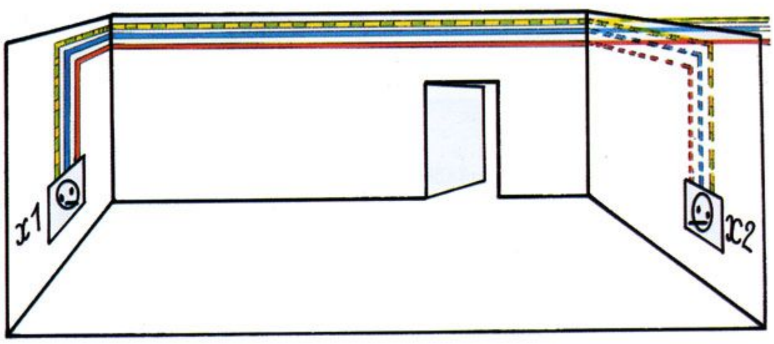


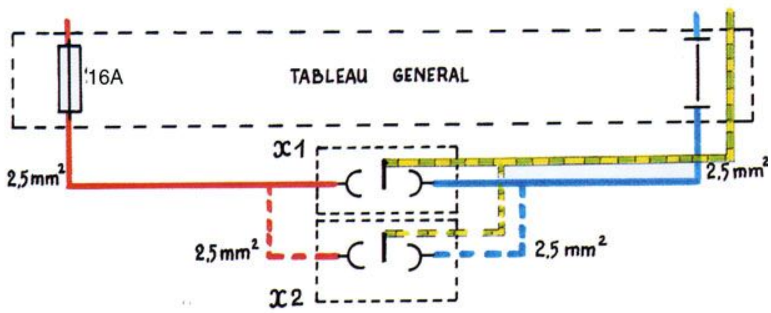
CAUTION: wire connections in a junction box, not at the existing light fixture. See above.

2.8. HOW DO I ADD A 16A CONVENIENCE OUTLET?

In a room already equipped with an electrical outlet, you'd like to add a second outlet in a different location. Connect the two outlets in parallel, wiring them according to the schematic opposite.

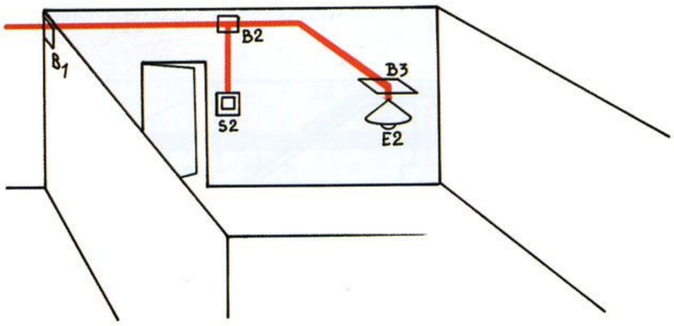
Unlike light fixtures, these connections can be done at the existing outlet.



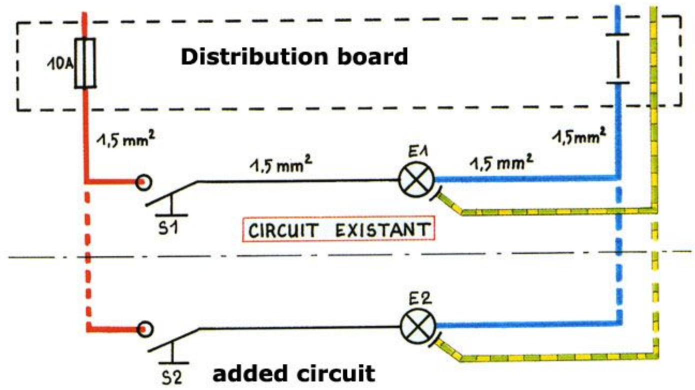


2.9. HOW DO I ADD A ONE-WAY LIGHTING CIRCUIT?

Here you're adding a circuit consisting of a switch and a light fixture in parallel with an existing circuit. From the existing junction box (B1), wire according to the following schematic:



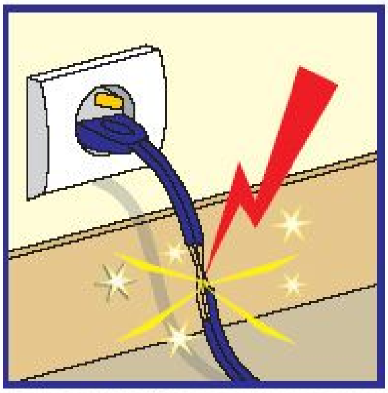
B1: existing junction box
B2: flush-mounted junction box
B3: electrical box for light fixture
S3: one-way light switch
E1: light fixture



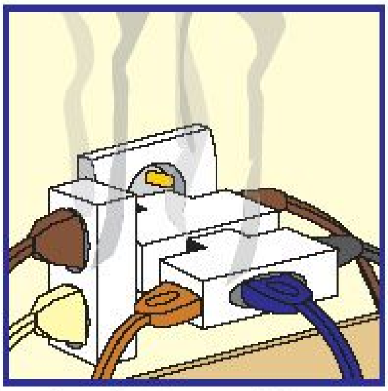
RISKS

1. INTRODUCTION

Odourless, silent and invisible—under certain circumstances, electrical energy can compromise people’s safety or damage equipment. In inexperienced hands, electricity is dangerous. Under certain conditions, it’s the human body that acts as a conductor or a load. For equipment, the dangers are short circuits and overloads. For people, the dangers are insulation faults that lead to direct or indirect contact.



Short circuit: Caused by contact between the phase and neutral, it creates a dramatic rise in current, which leads to a significant increase in the temperature of the conductors, and thus to the risk of fire.



Overload: Caused by a current that’s too high with respect to the diameter of the conductors. Consequences are similar to

Direct contact: Contact between the human body, a live conductor and the earth. Current passes through the body, and can result in electrocution.

Indirect contact: Contact between the human body, the live case of a defective electrical appliance, and the earth. Can cause electrocution.

2. SHORT CIRCUIT

This is a **strong** overcurrent of **short duration.**

In single-phase systems, there's a short circuit whenever the phase and neutral accidentally come into contact; in three-phase, when there is contact between two of the phases. For DC, short circuit occurs when the two polarities come into contact.

This can happen when there's a break in the insulation as a result of a cable being crushed, for example, or when two conductors come in contact via a tool or water on the lines. At these times, the resistance is close to zero and thus the current reaches very high values (U=RxI) very quickly. The sudden temperature increase of the conductors can cause the insulation and copper cores to melt.

3. OVERLOAD

This is a **weak** overcurrent of **long duration**.

It's caused by a current that's too high with respect to the diameter of the conductors.

There are two kinds of overload:

- normal overloads, which occur when a motor starts up, for example. These are short-lived and pose no danger.
- Abnormal overloads occur when too many appliances are connected to the same circuit or the same outlet, or when a connection terminal isn't properly tightened. These problems are found, for example, in old buildings with too few outlets, as the number of electric devices increases—when a multiple outlet receptacle has a hairdryer, an electric heater and an electric kettle all plugged in. The current is lower than that of a short circuit, but the results are identical: overheated wires, damaged insulation, high risk of fire.

4. INSULATION FAULTS

These are caused by damage to the insulation of one or more phase conductors. This problem can lead to current leakage in current-carrying lines, or in household appliances, if the damaged conductor touches the appliance's metal casing.

An insulation fault can also be caused by moisture from water damage or natural humidity in the wall.

These faults can be very dangerous, especially when a person comes into contact with the conductor, a metal casing, or a defective electrical appliance.

Consider two cases:

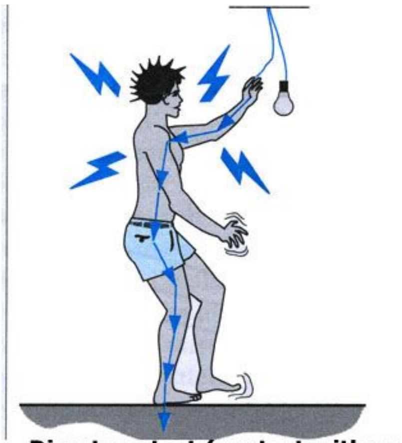
- **direct contact:**

this occurs when a person directly touches a phase conductor whose insulation is lost or damaged.

The electric current passes through the human body on its way back to earth, posing the risk of electrocution.

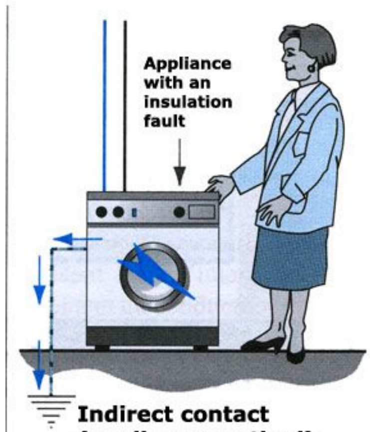
indirect contact:

This occurs when a damaged wire comes into contact with the metal casing of a household appliance. If the appliance—which is insulated from the earth by its glides—isn't earthed, the current will pass through the human body upon contact.



Direct contact (contact with an exposed conductor)

Indirect contact (appliance not earthed)



Indirect contact (appliance earthed)

In both cases, the passage of current through the human body causes an electric shock. The consequences, which range from a simple tingling to death, depend on:

- the voltage to which the person is exposed,
- the current's path through the body (heart, brain, etc.),
- the duration of the current.

Below 50V AC, in dry conditions, there is no risk of death. In a wet environment, like a bathroom, anything over 12V poses a risk.

A man with dry hands, standing on dry ground in a good pair of shoes, has a resistance of 500,000Ω. At 220V, a current of 220/500000= 0.45mA will pass through him.

If the ground is moist and his hands are wet, his resistance can drop to 2000Ω, and the current running through him will increase to 220/2000= 110mA. Enough to kill him instantly.

A few important numbers:

WARNING: direct current is more dangerous than alternating current of the same magnitude. AC causes a "let-go" reflex that almost instantaneous interrupts the contact, while DC causes the opposite, a tetanic spasm that prolongs it.

5. OVERVOLTAGE

Finally, there's the risk related to overvoltages—primarily those caused by lightning. If lightning strikes near a power line, its magnetic effect can create an overvoltage of more than 400,000V, and propagate along the line. While the utility company (EDF in France) installs protection devices, the risk can never be completely eliminated.

You can protect yourself from lightning by using adapters or power strips equipped with devices that protect sensitive equipment, like computers, from lightning.

Radio installations will have surge protection modules.

PROTECTION DEVICES

This refers to all the devices used to prevent or limit the risks discussed in the preceding chapter. Depending on the age of the installation and the country, some of these devices may not be present.

1. THE MAIN CIRCUIT BREAKER OR ISOLATING SWITCH

1.1. ITS FUNCTION

The main circuit breaker is placed at the head of the installation, immediately after the electric meter. By cutting off both the phase and neutral, it shuts off power to the entire circuit. Cut-off may be done manually or triggered automatically by a fault.

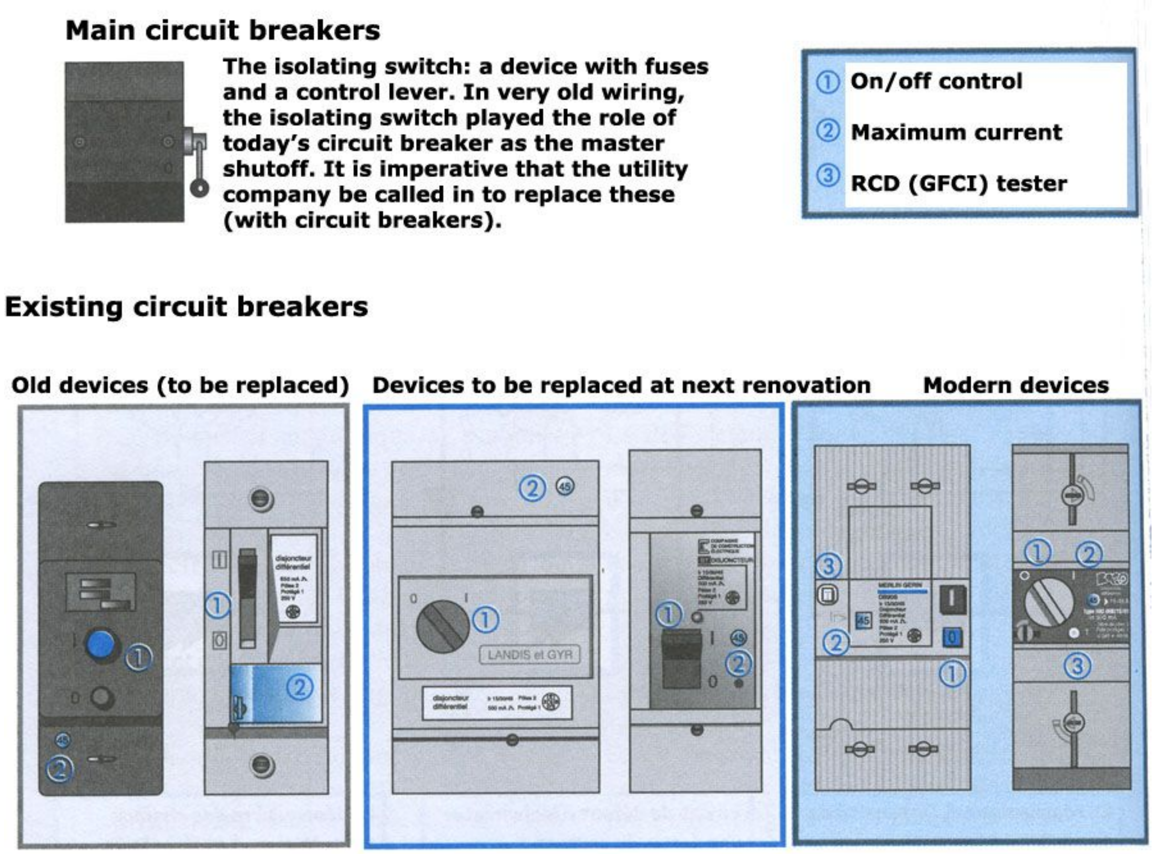
Thus the main breaker's job is to provide:

- a barrier against general **overload** of the installation relative to the subscribed demand,
- thermal magnetic protection against **short circuits**,
- residual current protection against **insulation faults**, to protect humans from current leakages over 500mA. Note that this is far beyond the electrocution threshold of the human body.

The main circuit breaker is normally sealed; opening it for the purposes of exceeding the subscribed demand is prohibited.

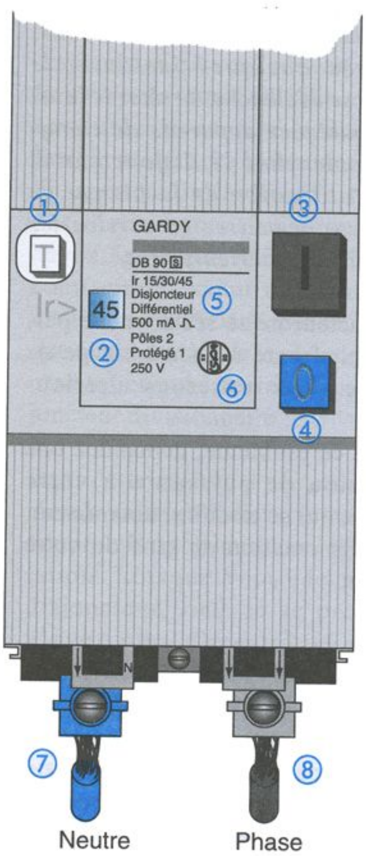
1.2. MODELS

There are various models you might come across, depending on the country and the age of the installation:



Isolating switches were used before the advent of circuit breakers; while their fuses provide protection against overloads and short circuits, they offer no earth fault protection. Some circuit breakers only provide 650mA residual current protection, rather than the recommended 500mA. Newer models allow testing of residual current protection.

Single phase circuit breaker:



1 **RCD test button**

2 **Current for which circuit breaker is set (possible settings are indicated by Ir)**

3 **"On" button**

4 **"Off" button**

6 **Conforms to French standards.**

7 **Neutral terminal**

8 **Phase terminal**

5 **Device characteristics:**
DB90 is the model numbers indicates that this is a selective device (designed to operate with high sensitivity 30mA RCDs). If this symbol is absent, the device is instantaneous.
Ir 15A/30A indicates the possible settings for maximum current.
Disjoncteur différentiel 500mA indicates that this is an RCBO with 500mA sensitivity.
Pôles 2 protégé 1 indicates a single-phase device (2 poles, for the phase and the neutral).
Pôles 4 protégés 3 indicates a 3-phase device (4 poles, for the three phases and the neutral).
250V indicates the single-phase operating voltage, 440V the 3-phase operating voltage.

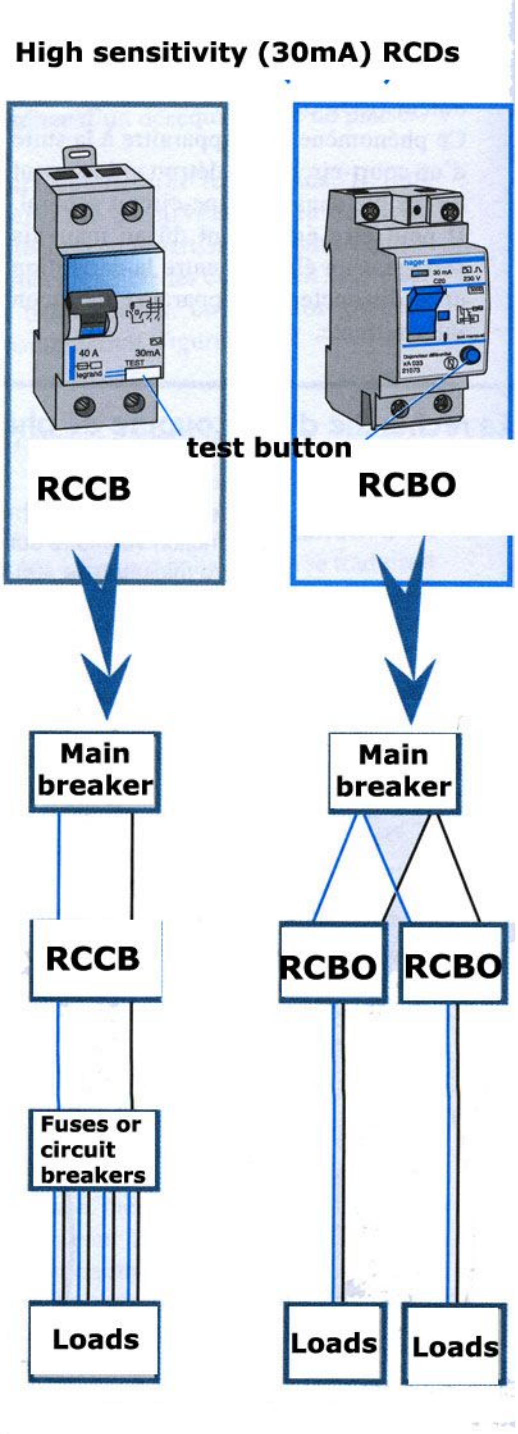
Three-phase circuit breaker: see the "Three-phase Power" chapter.

2. HIGH SENSITIVITY 30MA RESIDUAL CURRENT DEVICES (RCDS)

2.1. FUNCTION

High sensitivity (30mA) RCDs are required protection for all power outlet circuits, bathroom wiring and lighting circuits.

They are installed between the main circuit breaker and the individual circuit protection devices:



They're designed to detect current leaks of 30mA, unlike the main circuit breaker's 500mA. They cut the circuit as soon as they detect leakage current over 30mA, below the lethal threshold for humans (see the "Risks" chapter for some important numbers). They are, therefore, more effective at protecting people against **indirect contact** than are main circuit breakers.

CAUTION: These are only effective when used in conjunction with an effective earthing system for metal objects. See the "Earthing" chapter.
An unearthed RCD will not protect people.

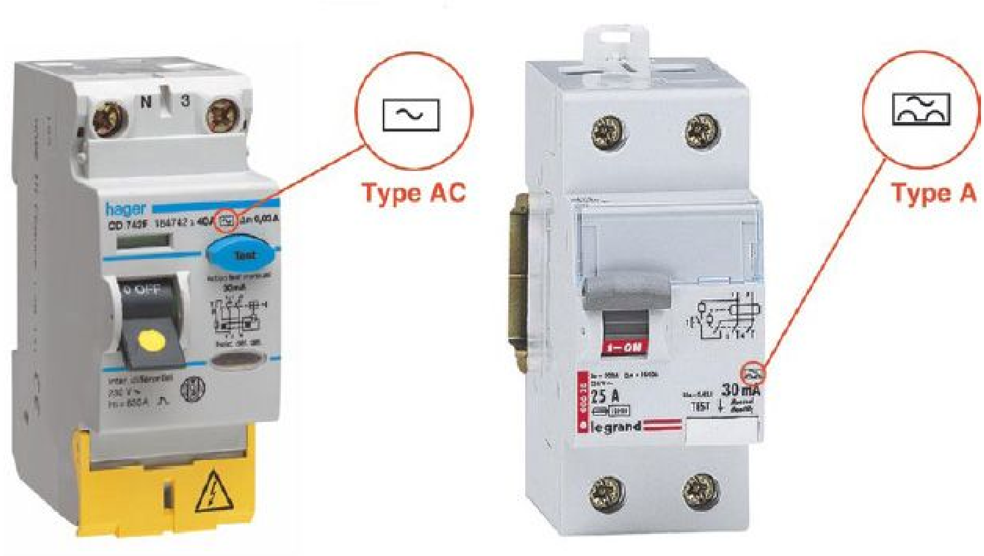
RCDs ensure simultaneous cut-off of phase and neutral; the neutral must be on the terminal marked "N."

2.2. MODELS

There are two types of high sensitivity residual current devices: residual current circuit breakers (RCCB) and residual current circuit breakers with overload protection (RCBO). Both devices have a reset/on-off lever and a test button.
In addition to their sensitivity (30mA), they are characterized by the rated current they can handle (25, 40 or 63A), and must be set according to the circuits they protect.

2.2.1. RCCBs (residual current circuit breakers):

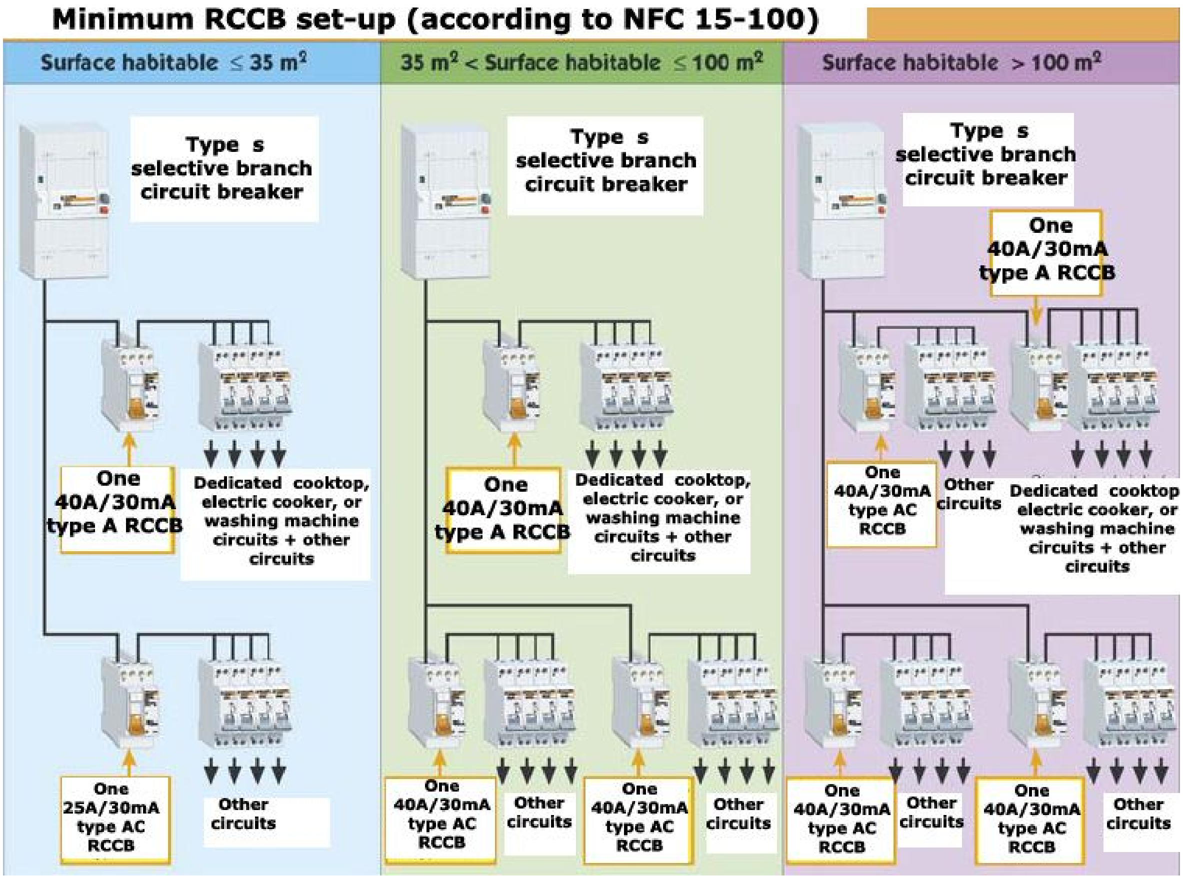
These are the most common; they're equipped with only a residual current detection device. They protect against **insulation faults**, but do not detect short circuits or overloads. Several circuits can be grouped under the same RCCB. They are either type AC or type A (for cookers, cooktops, and washing machines).



Living area	Minimum number of RCCBs Type AC		Type A
≤ 35 m²	1 x 25 A	+	1 x 40 A
Entre 35 et 100 m²	2 x 40 A	+	1 x 40 A
> 100 m²	3 x 40 A(1)	+	1 x 40 A

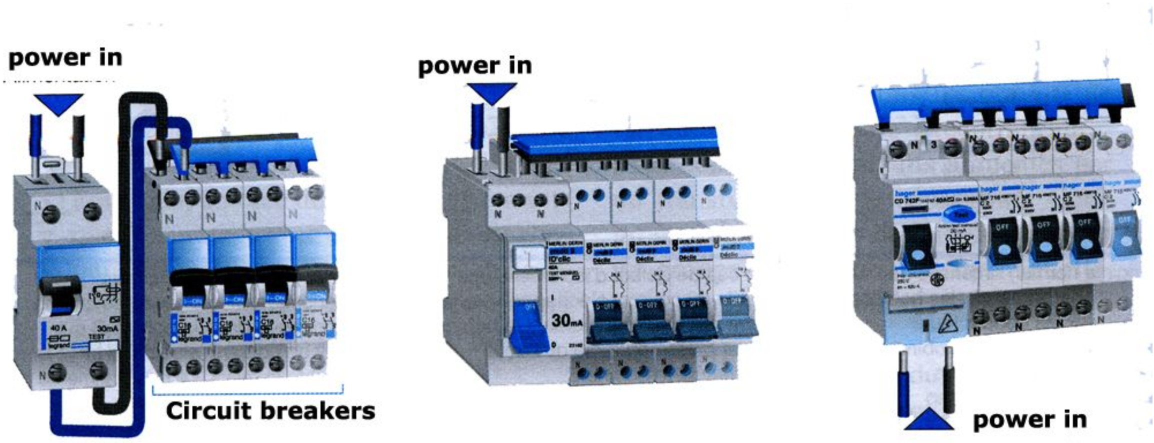
(1)With electric heaters over 8kVA, replace one 40A type AC RCCB with a 63A type AC RCCB.

In France, standards for a minimum set-up, as a function of area, are shown below:



RCCBs must be tested at least once a month by pressing the test button. Doing so creates a leakage path, and the breaker should trip.

They can be connected in various ways:




RCCB with input and output from the top


Power in
RCCB (standard connection)
To circuit protection devices

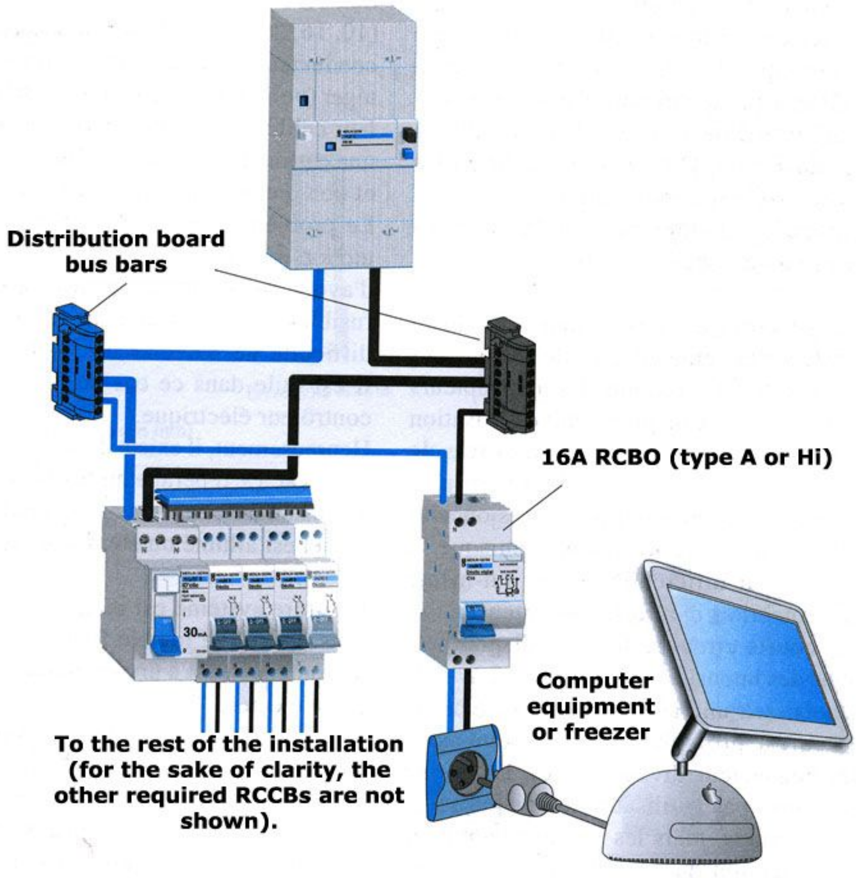

RCCB with power coming in from the bottom (indicated by a protective shield).

2.2.2. RCBOs (residual current circuit breakers with overload protection):

Unlike RCCBs, which protect only against **insulation faults**, RCBOs also protect against **short circuits and overloads.**

Like RCCBs, these also need to be tested monthly: press the test button—the breaker should trip.

More expensive, these are used only to protect certain sensitive circuits like computers and freezers. Use of RCBOs is limited to protecting sensitive lines that must not be cut as a result of a fault on another circuit. Do not group several circuits on an RCBO.



3. FUSED CIRCUIT BREAKERS

3.1. FUNCTION

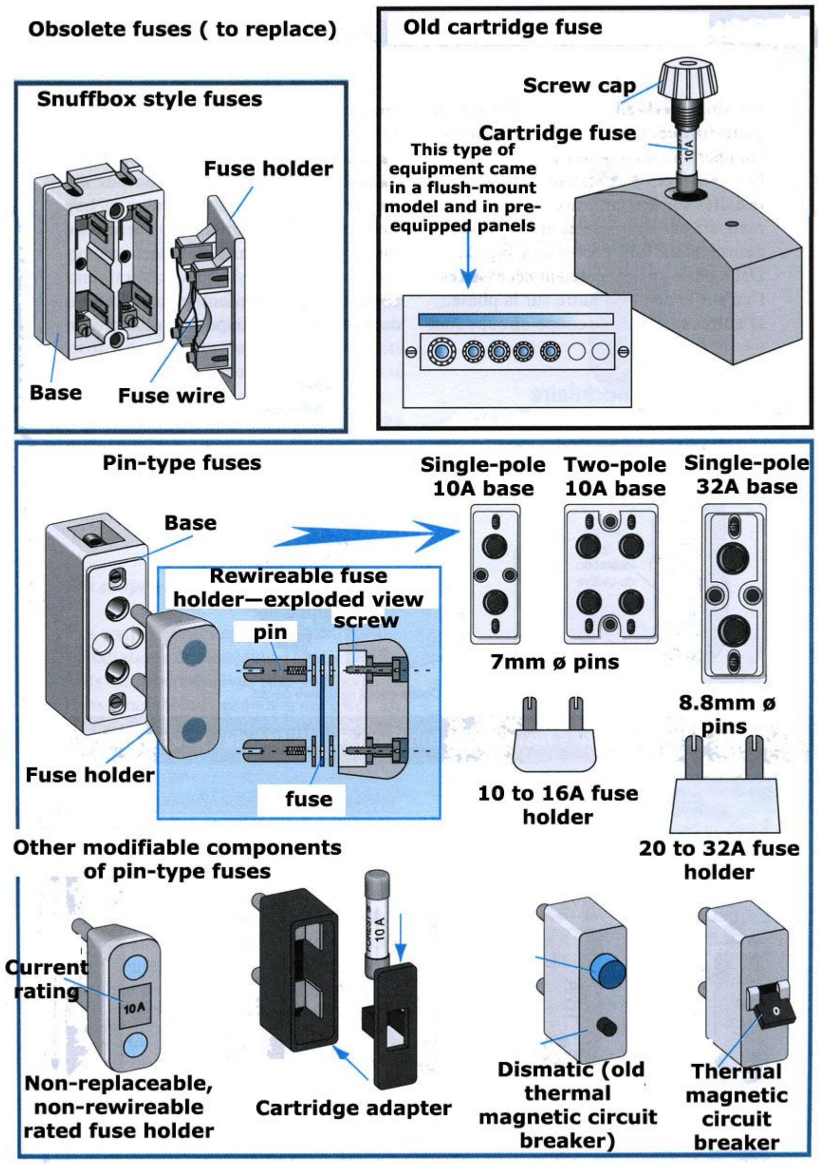
These protect against **overloads** and **short circuits**. They are used upstream in the circuit, after the RCCB. They contain a fuse. The fuse itself is a conducting wire, through which the current in the protected lines passes. An abnormal rise in current overheats the wire, which ultimately melts, causing a break in the circuit. See the "Fused circuit breakers" section.

Within the unit, the fuse itself is placed on the phase conductor: the phase is protected, and the neutral is cut mechanically when the unit trips. When the circuit breaker is open, both phase and neutral are cut. At this point there is no voltage in the circuit. This is called **single-pole with neutral** protection.

They're not very expensive, but when a fuse goes it must be found and replaced.
The fuses, and thus the circuit breakers, are rated in amperes, corresponding to the circuits they'll be protecting.

3.2. MODELS

- older models: These may still be found in old installations, or in the field.



Pin-type fuse holders

Cartridge fuse holder

Base

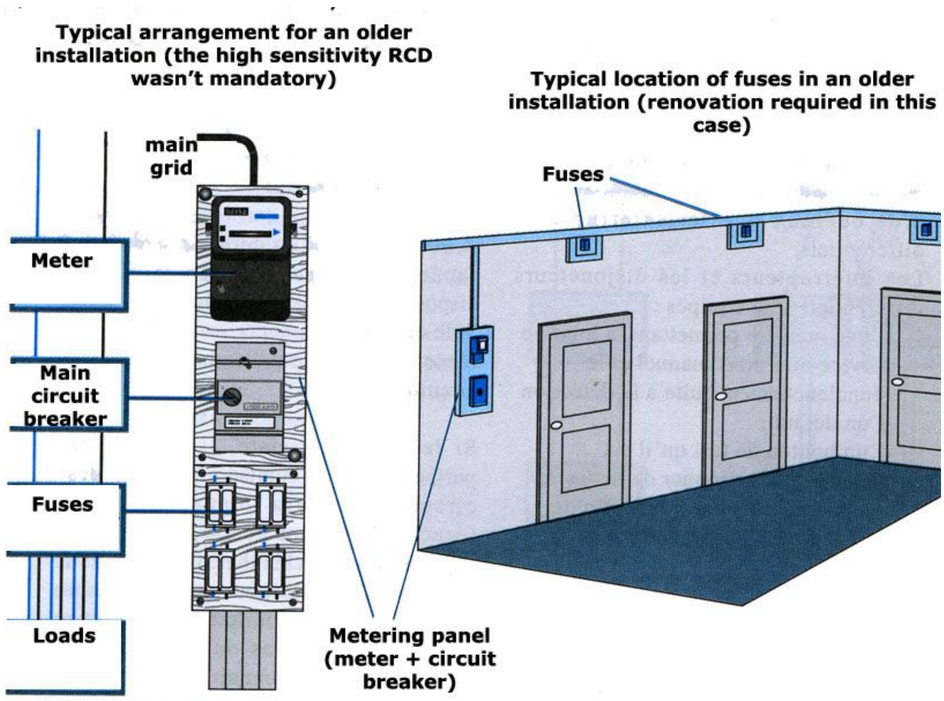
Old fuse pane

To remove the cartridge, push the support via the hole

These should be replaced as soon as possible. See below.

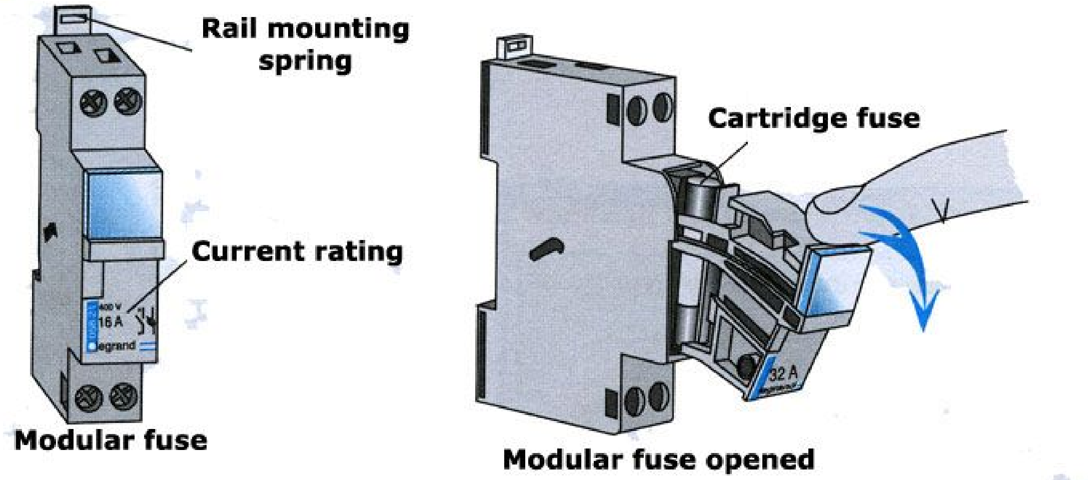
On wooden panels, fuses provided **two-pole protection**, and so two fuse holders are needed: one on the neutral, the other on the phase. To be sure, turn on the lights in a room, then pull out a fuse for that room: the lights will go out. Replace the fuse, then pull out the circuit's other fuse. If the lights go out again, you know you have two-pole protection. Otherwise, if only one fuse breaks the circuit, it's **single-pole** device: only the phase is protected, and broken.

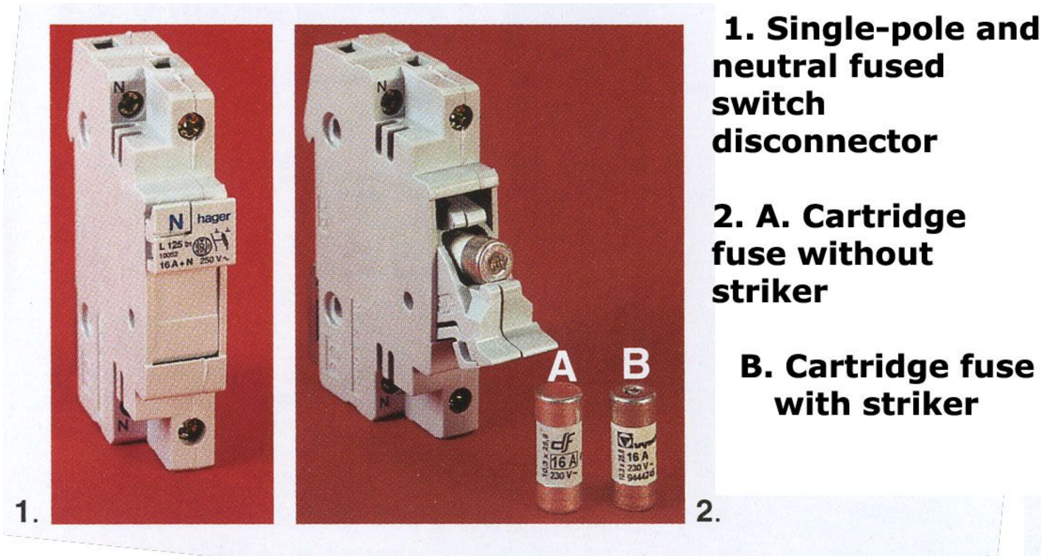
In older installations, fuses are placed between the main circuit breaker and the outgoing lines in the following locations, on a wooden panel or scattered throughout the house:



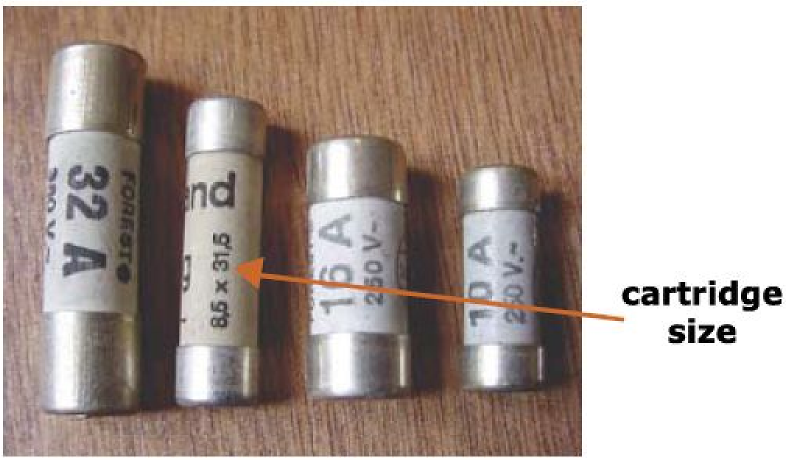
newer models:

These are made to be mounted on panels specifically designed for the purpose. While all cut both phase and neutral when the fuse blows, the fuse itself protects only the phase conductor. The neutral is interrupted mechanically when the fuse blows.



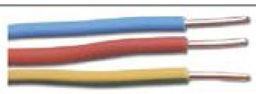
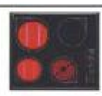


While their external dimensions are the same no matter what their rating, the holders only accept fuses sized for this rating. This prevents errors such as placing a 10A fuse in a 32A fuse holder.



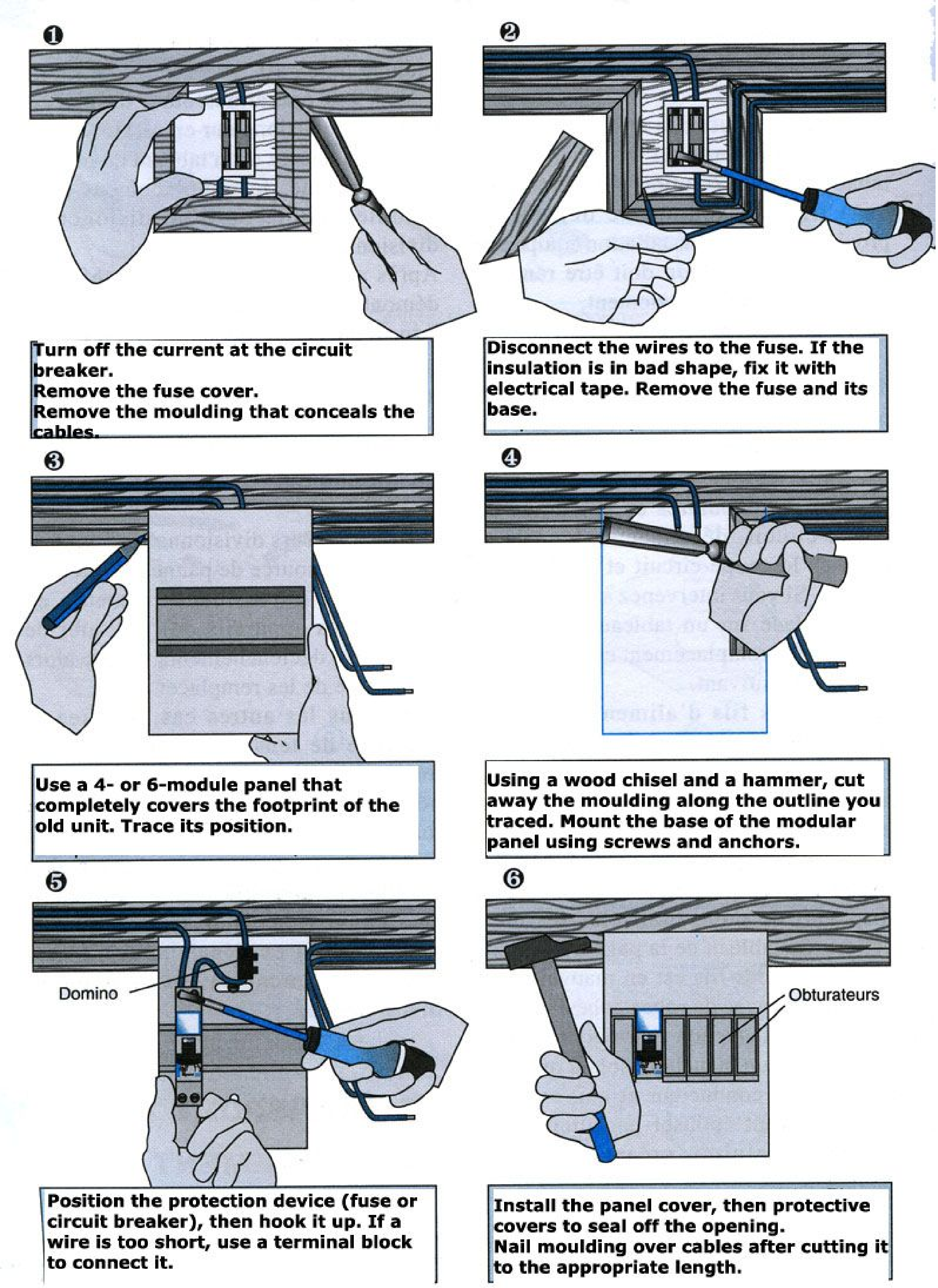
Fuses should be sized according to the following table:

Sizing fuses				
Circuit type	Maximum number of loads		Conductor cross-section (mm^2)	Rating in amps (A)
	Promotelec	Standards		
Lighting	5	8	1.5	10
Power outlets	5	8	2.5	20
Clothes washer	1	1	2.5	20
Dishwasher	1	1	2.5	20
Clothes dryer	1	1	2.5	20
Freezer	1	1	2.5	20
Cooker or cooktop	1	1	6	32
Standalone oven	1	1	2.5	20
Convection heater ≤ 2.2kW	—	—	1.5	10
Water heater	1	1	2.5	20
Whole-house fan	1	1	1.5	10

Fuse selection						
Maximum rated current	10A	10A	16A	16A	16A	32A
	1,5 mm^2	1,5 mm^2	2,5 mm^2	2,5 mm^2	2,5 mm^2	6 mm^2
	8,5 x 23	8,5 x 23	10,3 x 25,8	8,5 x 31,5	8,5 x 31,5	10,3 x 38
typical use		 (1)				

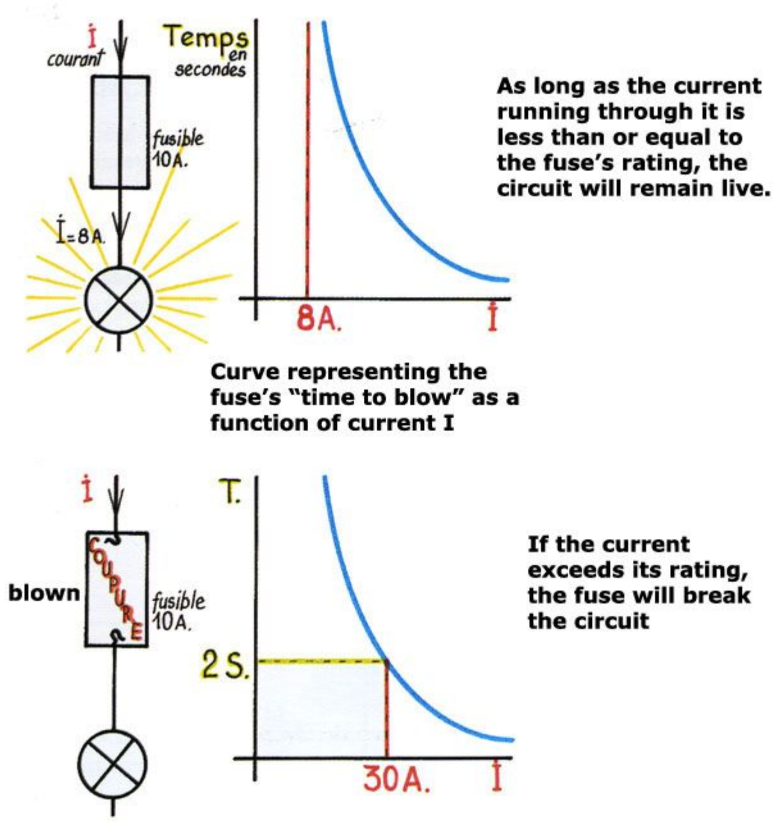
(1) **At least 10A, for a maximum 2300W load**

Replacing an old fuse with a modern one:
This can be done as illustrated below:



3.3. FUSES

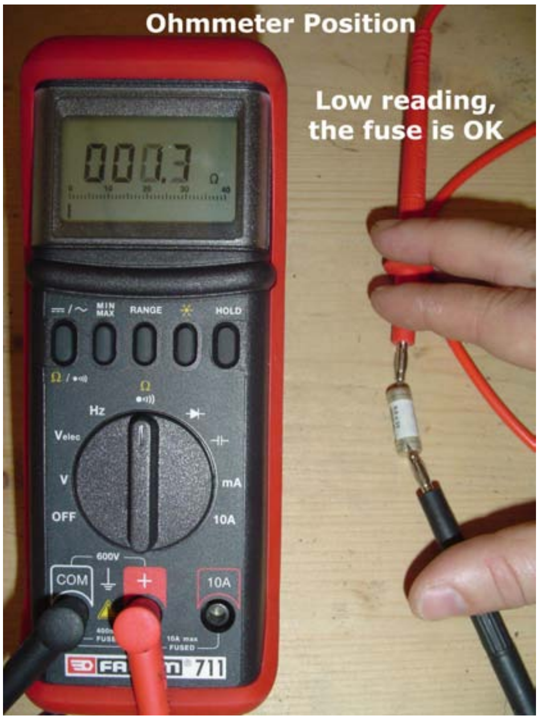
➡ How do they work?

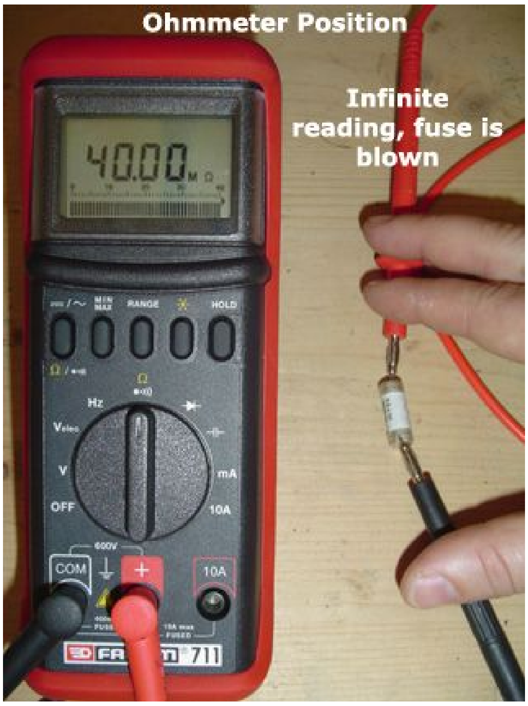


We see that the greater the overcurrent, the faster the fuse blows. In practice, if a fuse blows instantaneously this means there's a short circuit (large overcurrent, short duration); on the other hand, if a fuse takes several seconds to blow, then there's an overload (weak overcurrent, long duration). See the "Troubleshooting" chapter.

➡ How do you test them?

Use a multimeter set to ohmmeter mode, or to continuity testing in the buzzer position. If the multimeter reads 0Ω or a very low value, there's no resistance and the fuse is good. If the multimeter shows an infinite or very high (in MΩ) reading, the fuse is blown.

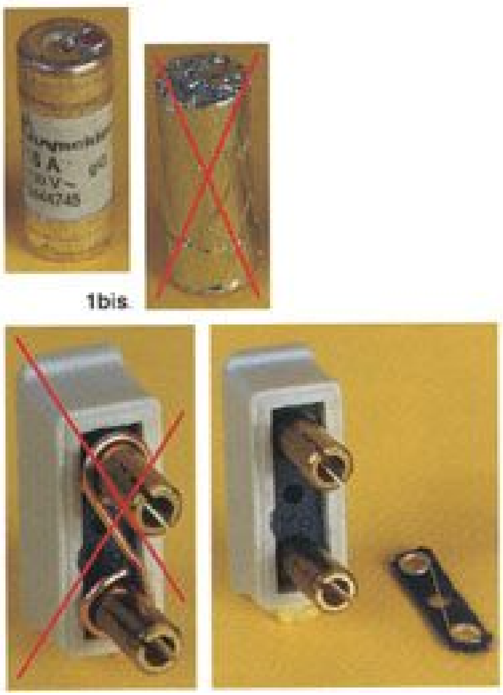




How do you replace them?

Once a fuse blows, it must be replaced with one that's identical: same type and same rating as the original.

You should NEVER perform the following makeshift repairs:



WARNING: These makeshift repairs are PROHIBITED. Circuits are no longer protected, and there's a greater risk of fire. Use only wires rated for the circuit, or appropriate fuse strips.

4. MINIATURE CIRCUIT BREAKERS (MCB)

4.1. FUNCTION

Like fuses, they protect against **overloads** and **short circuits**. They, too, are used upstream in the circuit, after the RCCB.

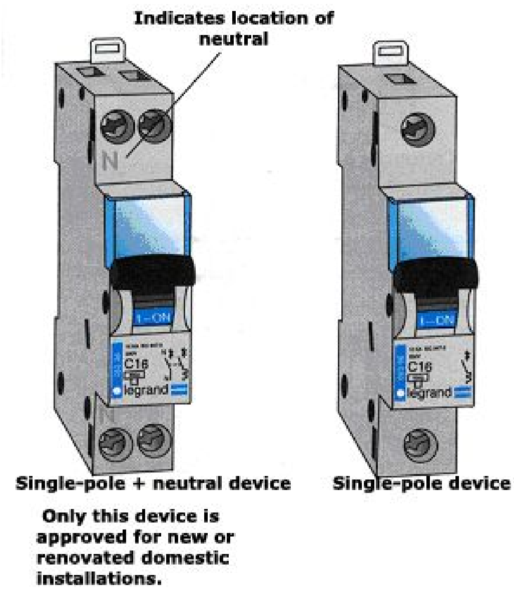
A thermal magnetic device protects the faulty circuit by opening it instantaneously (phase + neutral). While they're more expensive than fuses, they're faster, more reliable, safer, and don't need to be replaced when they trip. When something goes wrong on the line, the MCB trips and the lever flips down, allowing immediate visual identification of the faulty circuit. After correcting the problem, simply push the lever back up to reclose the circuit.

4.2. MODELS

You usually find single-pole and neutral MCBs; the neutral conductor is indicated by the letter "N." These cut both the phase and neutral when they trip.

There are, however, some single pole models that interrupt only the phase.

To recognize these, check the number of wires going through the breaker: if only one wire goes through (in at the top, out at the bottom), it's a single-pole.



4.3. SIZES

All MCBs have the same external dimensions, and are rated according to the circuits they need to protect:

Sizing MCBs				
Circuit type	Maximum number of loads		Conductor cross-section (mm^2)	Rating in amps (A)
	Promotelec	Standards		
Lighting	5	8	1.5	16
Power outlets	5	8	2.5	25
Clothes washer	1	1	2.5	25
Dishwasher	1	1	2.5	25
Clothes dryer	1	1	2.5	25
Freezer	1	1	2.5	25
Cooker or cooktop	1	1	6	38/40
Standalone oven	1	1	2.5	25
Convection heater ≤ 2200W	—	—	1.5	16
Water heater	1	1	2.5	25
Whole-house fan	1	1	1.5	16

MCB selection

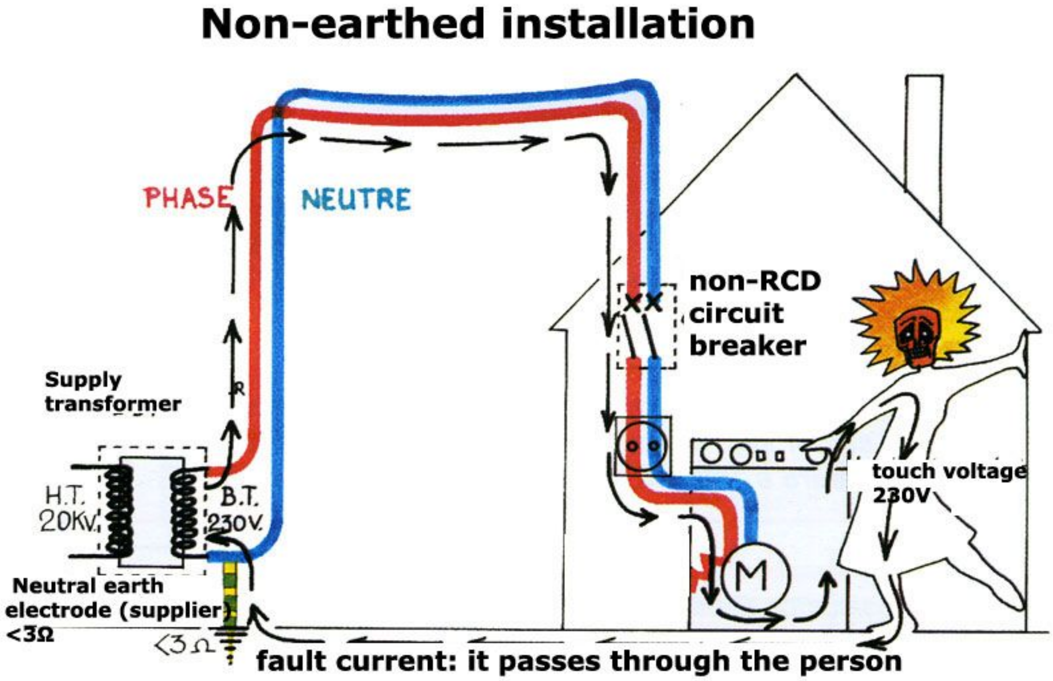
Rated current	16A	16A	20A	10A	20A	20A	32A
	1,5 mm^2	1,5 mm^2 (1)	2,5 mm^2 (2)	1,5 mm^2	2,5 mm^2	2,5 mm^2	6 mm^2
Typical uses				(3)			

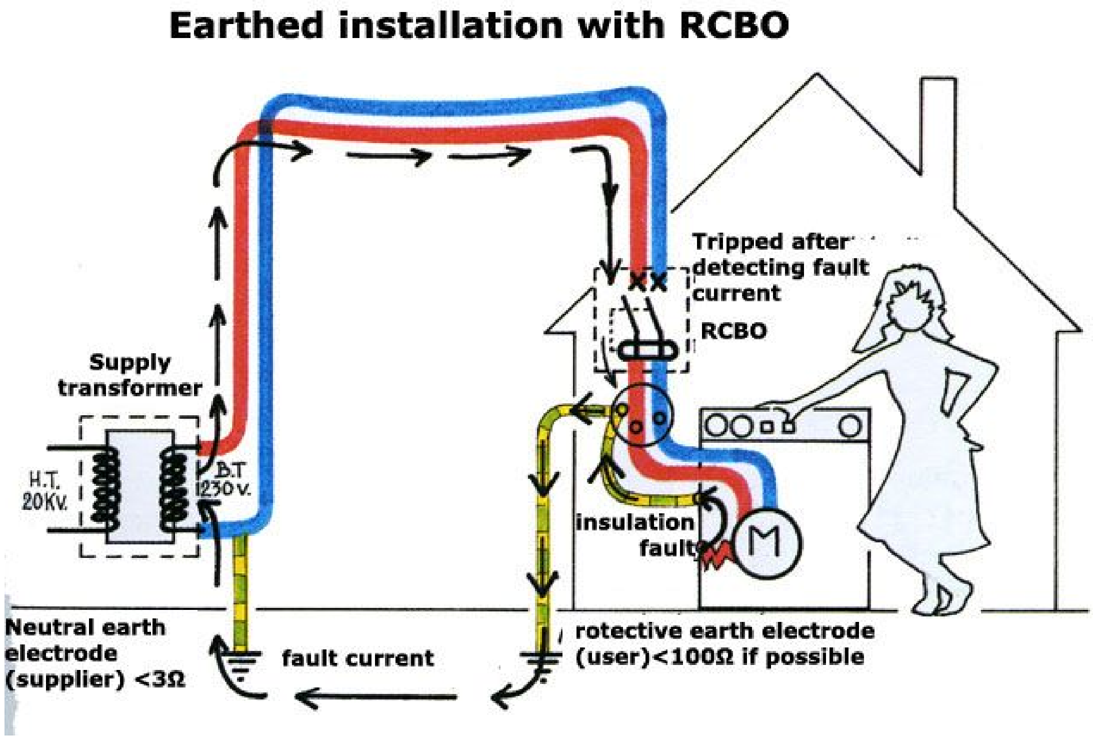
(1) 5 outlets, maximum (2) 8 outlets, maximum (3) At least 10A, for a maximum 2250W load

5. EARTHING

5.1. PRINCIPLE

In tandem with a residual current device (RCD), earthing is **ESSENTIAL** to interrupting the power supply when there's an **insulation fault**—for example, when a live wire comes loose and touches the washing machine's chassis. It channels the fault current into the earth, preventing injury to people. The earth connection picks up fault currents, allowing RCDs to measure them and trip. Earthing thus consists of linking the installation's various circuit components and appliances to the earth electrode.





5.2. WHAT SHOULD BE EARTHED?

Any metal part of any component that can be touched, which is normally insulated but might come in contact with the current: refrigerators, motors, lamps, fluorescent lights, outlets, radios.

5.3. WHAT MAKES A GOOD EARTH ELECTRODE?

A good earth electrode should have an electrical resistance below some maximum threshold determined by the main service breaker's protection:

100Ω for a 500mA RCD,
167Ω for a 300mA RCD,
500Ω for a 100mA RCD.

The lower the resistance, the better it will work.

This resistance varies, however, with the dimensions of the earth electrode and the soil type.

Typical values for earth electrodes (in ohms)			
Earth electrode configuration (8 x 7m single-family house)	Soil type		
	Moist backfill fat arable	Coarse backfill lean arable	Dry rocky dry sand
Foundation ring	3 - 10	30 - 60	100 – 200
2m vertical stake	2 - 75	220 - 300	750 – 1500
4 vertical stakes (one at each corner, interconnected)	6 – 18	60 - 120	220 – 450
10m trench	8 - 30	90 - 120	300 - 600

Example: An 2m long earth stake will be suitable in moist backfill for a 500mA RCD.

NOTE: The earth resistance cannot be measured using a conventional multimeter; you need an earth resistance tester.

5.4. THE EARTH ELECTRODE

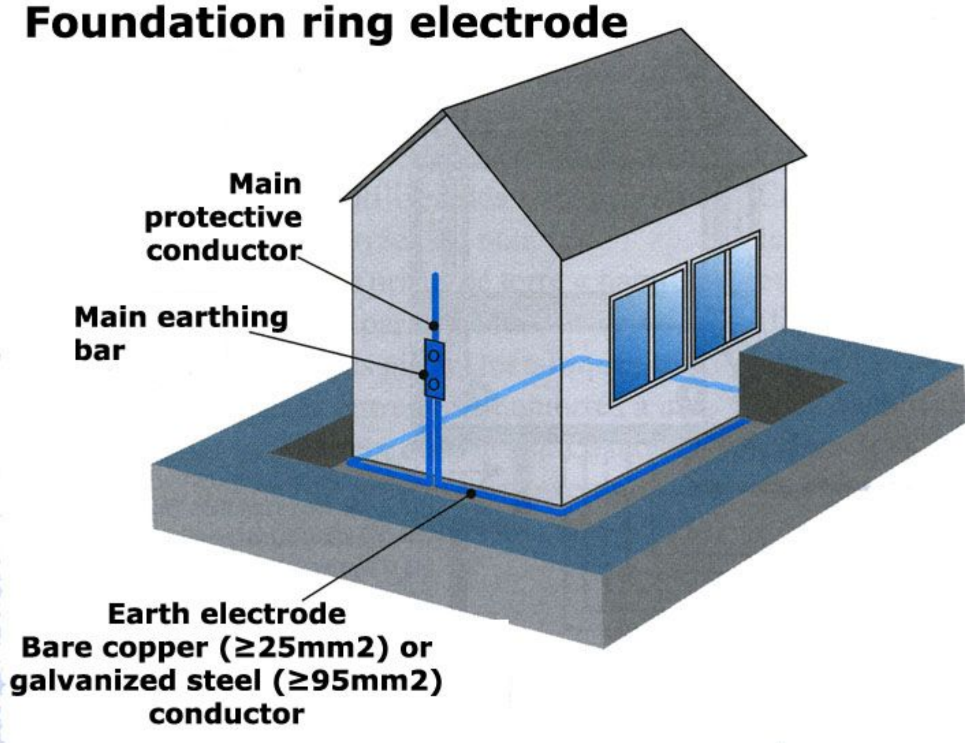
The earth electrode can be defined as all the buried and interconnected conductors that provide an electrical connection to the earth.

There are three possible methods:

- **a ring at the base of the foundation:**

While this is the most effective solution, it can't be added to an existing structure. The electrode encircles the building within the foundation's blinding concrete.

Foundation ring electrode

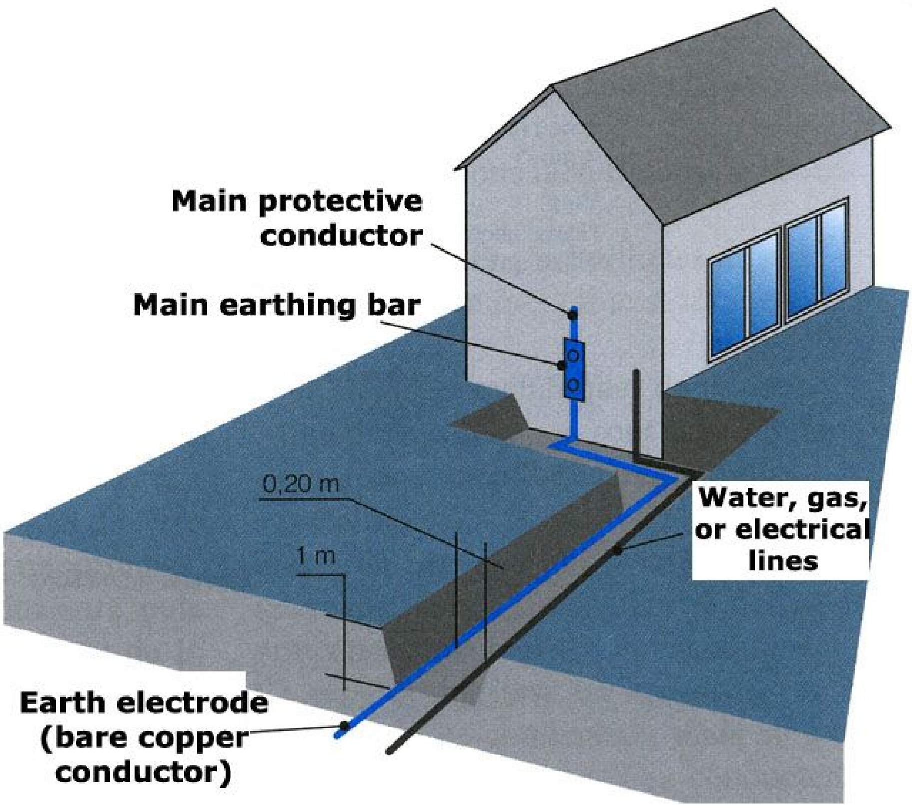


Use either 25mm^2 (or greater) bare copper, or 95mm^2 galvanized steel.

➔**the horizontal trench:**

Here the conductor is buried at a depth of between 1 and 1.6m. The trench is then filled with stone-free soil.

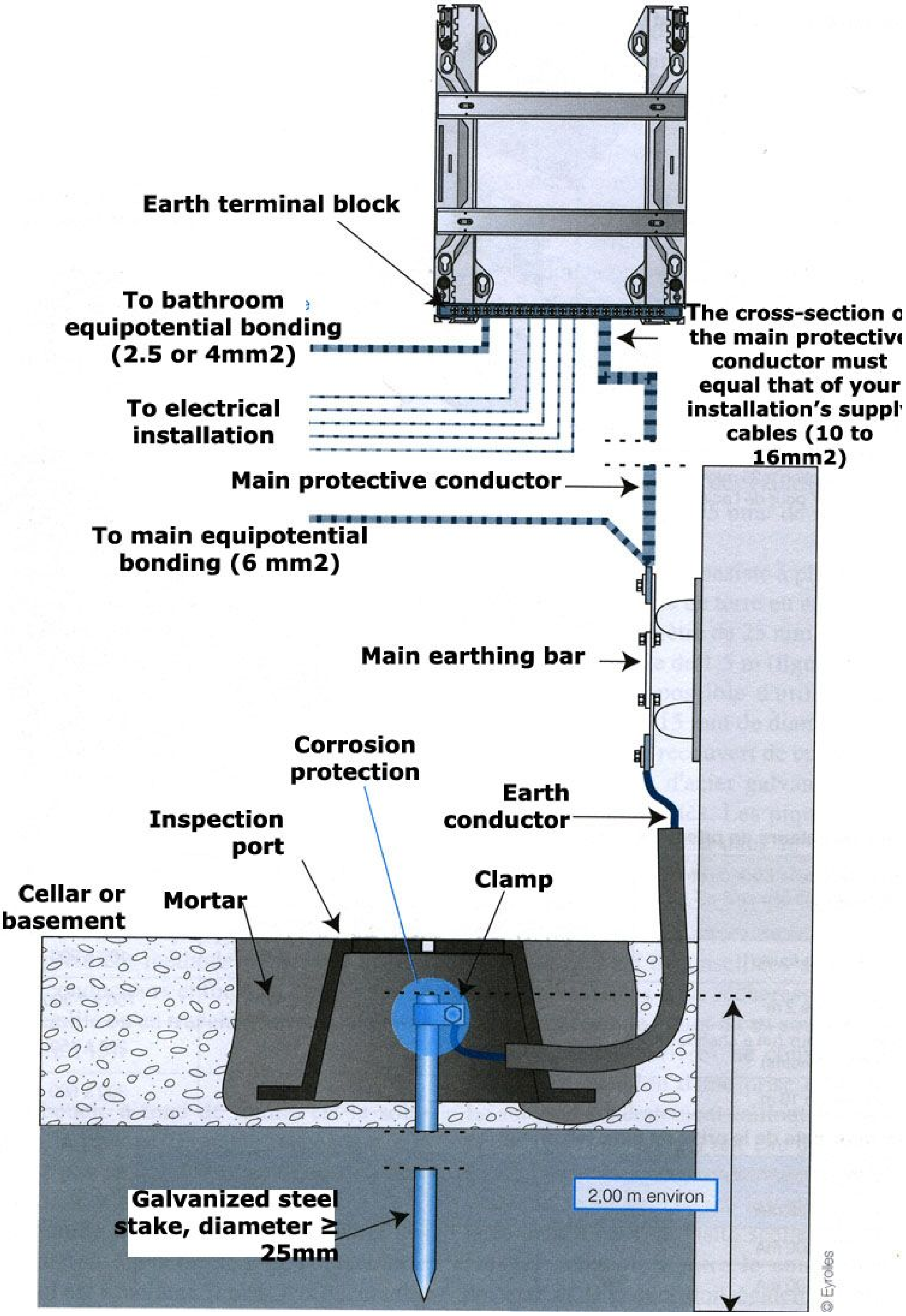
Horizontal trench earth electrode



Use either 25mm^2 (or greater) bare copper, or 95mm^2 galvanized steel.

the stake:

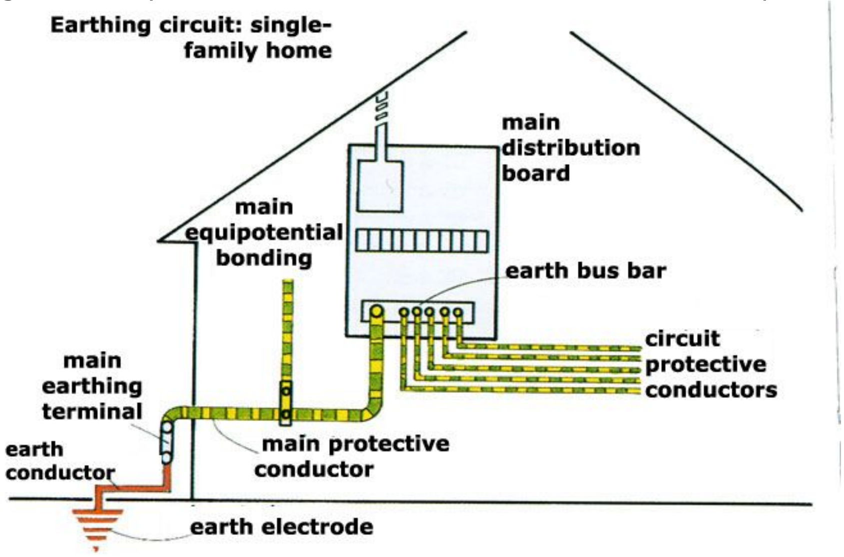
Here, one or several galvanized steel stakes, at least 25mm in diameter and 1.5m in length, are driven into the ground.



The stake should be driven into ground that is sheltered from drying and frost. Sinking the earth electrode into a pond or running water is prohibited.

5.5. PROTECTIVE CONDUCTORS

Identified by their green and yellow colour, these interconnect the metallic parts of loads.

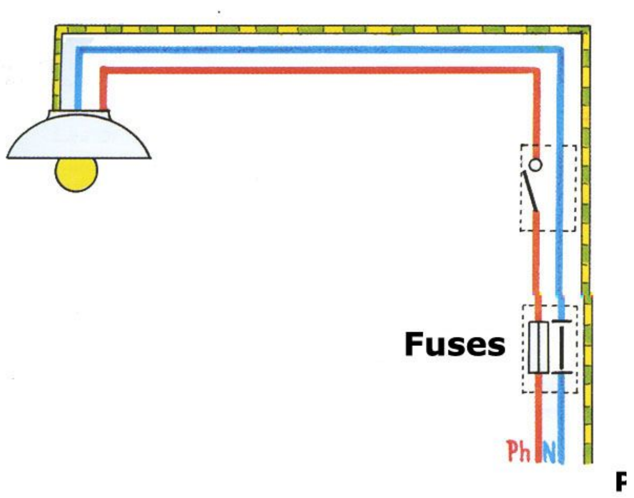


- **The earth conductor** links the earth electrode to the main earthing terminal or bar. It must have a cross-section of at least:
  - 16mm² for insulated copper
  - 25mm² for bare copper
  - 50mm² for steel.

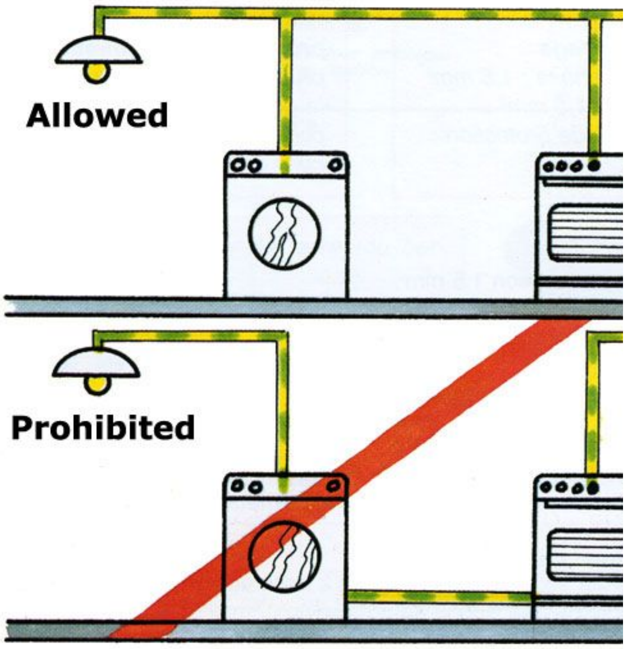
- **The main protective conductor** connects the distribution board to the earthing terminal/bar. Its cross-section will depend on the cross-section of the installation's supply cables (see section on "Wiring protection devices"):
  - $10mm^2$ for $10mm^2$ supply lines
  - $16mm^2$ for 16, 25 or $35mm^2$ supply lines

- **The circuit protective conductors** go from the distribution panel to the electrical appliances. Their cross-section must equal that of the live conductors (phase, neutral). Example: A lighting circuit with a $1.5mm^2$ phase conductor should have a $1.5mm^2$ earth conductor. When an earth conductor is shared by several circuits, its cross-section must equal that of the largest phase conductor.

They should be installed without any breakers.



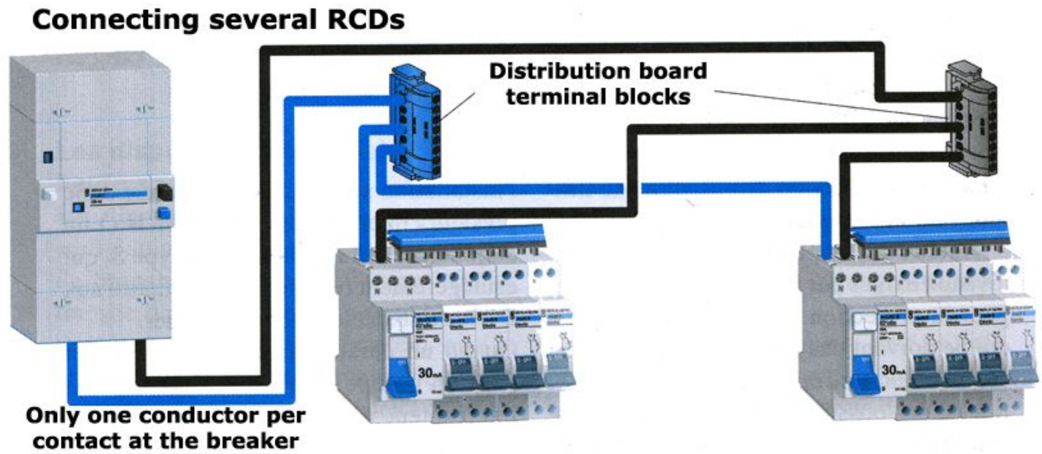
Metal appliances should be earthed in parallel, not in series.

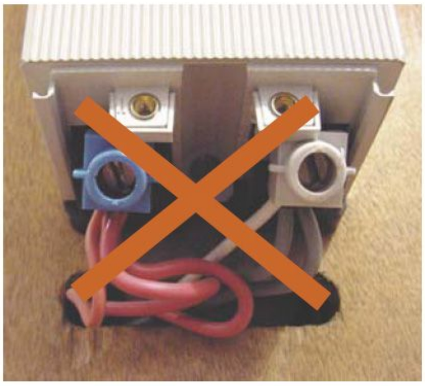


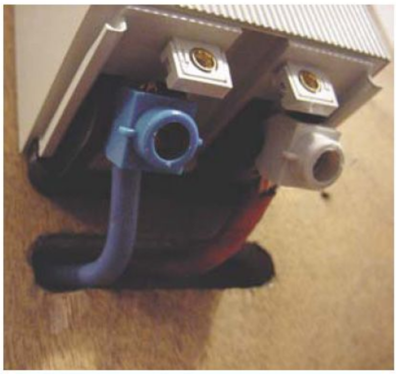
6. WIRING PROTECTION DEVICES

6.1. CONNECTIONS BETWEEN THE MAIN CIRCUIT BREAKER AND RCDS

Use terminal blocks to hook up several RCDs under the main circuit breaker, since there should never be more than one conductor per connector at the main breaker.



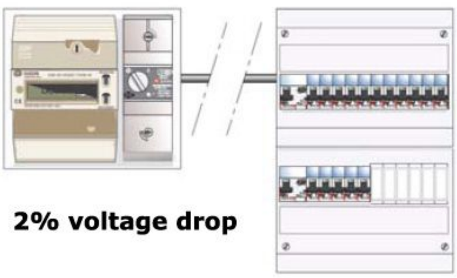




NOTE: the diameter of the supply cables will depend on the breaker's current setting:

Minimum cross-section of supply cables to board			
Circuit breaker setting (A)	45	60	90
Conductor cross-section (mm^2)	10	16	25

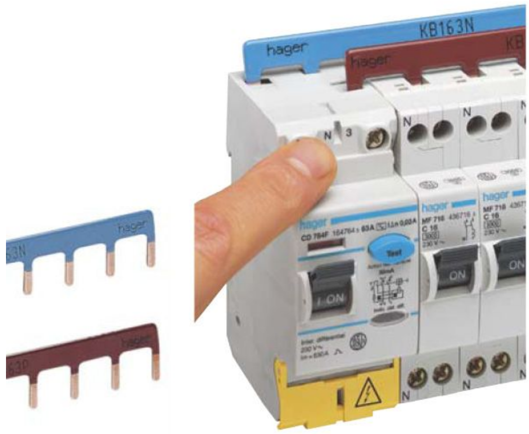
When the main circuit breaker is far from the distribution panel, conductor cross-section should be chosen to limit the length-dependent voltage drop between them according to the following table:



Maximum conductor length and cross-section					
Section en mm^2	Main circuit breaker rating				
	15	30	45	60	90
10	68 m	34 m	23 m	_	_
16	109 m	55 m	36 m	27 m	_
25	170 m	85 m	57 m	43 m	28 m
35	239 m	119 m	80 m	60 m	40 m

6.2. CONNECTIONS ON THE DISTRIBUTION BOARD

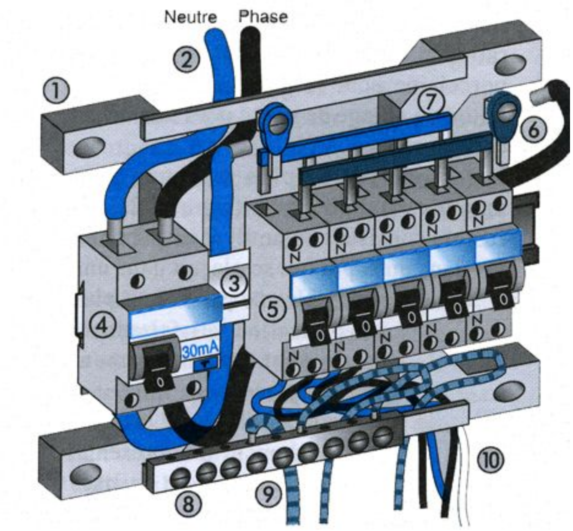
Power from the RCCB is distributed to the circuit protection devices (fuses or MCBs) using comb bus bars.



The basic layout on the distribution board is thus:

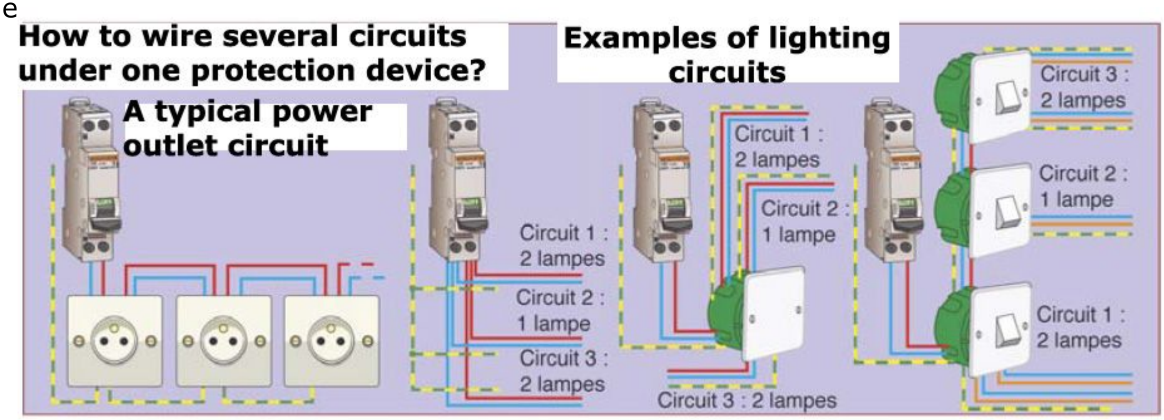
Typical wiring

1. Chassis
2. Circuit breaker incoming lines
3. Rail. 30mA RCCB
5. MCBs
6. Connector
7. Comb bulbar
8. Earth bulbar
9. Incoming line from earth electrode
10. Outgoing lines



6.3. HOW DO YOU WIRE SEVERAL CIRCUITS UNDER ONE PROTECTION DEVICE?

By using the diagrams:



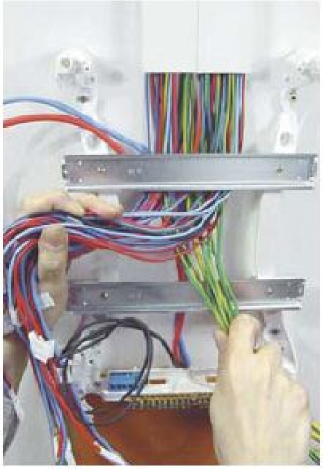
7. CURRENT RATINGS OF PROTECTION DEVICES FOR VARIOUS CIRCUIT TYPES

7.1.1. Number of utilization points by circuit type				
7.1.1.1. CIRCUIT TYPE	Number of utilization points (NFC 15-100)	Copper conductor cross-section (in mm^{2})	Current rating of protection device (in Amperes)	
			Fuse	Circuit breaker
Lighting circuits	8	1.5	10	16
Switched power outlets	8	1.5	10	16
16A power outlets	5 8	1.5 2.5	Not allowed 16	16 20
Dedicated power outlet circuits (washing machine, dishwasher, clothes dryer, oven, freezer, etc.)	1	2.5	16	20
Single-phase cooker or cooktop	1	6	32	32
Three-phase cooker or cooktop	1	2.5	16	20
Roller shutters	Depends on protection device	1.5	10	16
Mechanical ventilation systems	1	1.5	Not allowed	2 (1)
Non-instantaneous electric water heaters	1	2.5	16	20
Tariff switching, pilot wire, and energy management circuits	1 circuit per function	1.5	Not allowed	2
Other circuits, including a branch distribution board	- - - -	1.5 2.5 4 6	16 16 20 32	10 20 25 32
Single-phase convection or radiant heaters	2250W 4500W 5750W 7250W	1.5 2.5 4 6	10 16 (3500W) 20 25	10 20 25 32
(1) Except in special cases, where the value can be increased up to 16A				

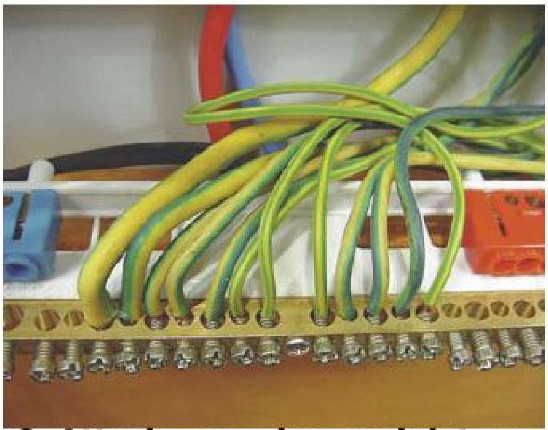
8. THE DISTRIBUTION BOARD

8.1. INSTALLATION AND CONNECTIONS

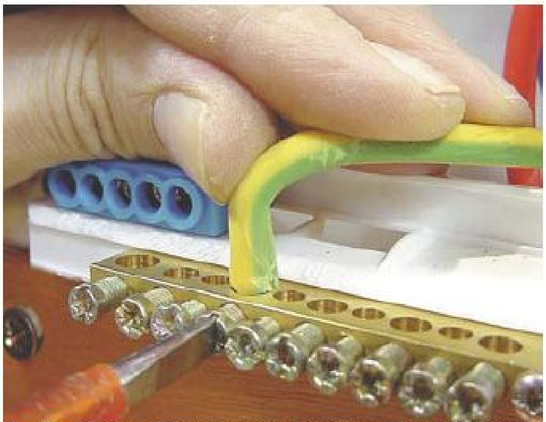
To install a new distribution board, first check that all incoming lines are identified and follow these steps, making sure that the main circuit breaker is in the open (off) position:



5. Separate the earth conductors from their lines, then gather them toward the bottom of the board.

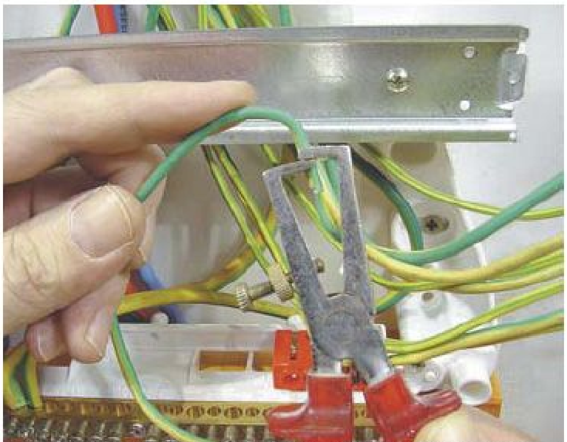


8. Attach one wire per inlet on the bus.



6. Connect the incoming earth electrode wire.

9. Mount the protection devices on the rail.

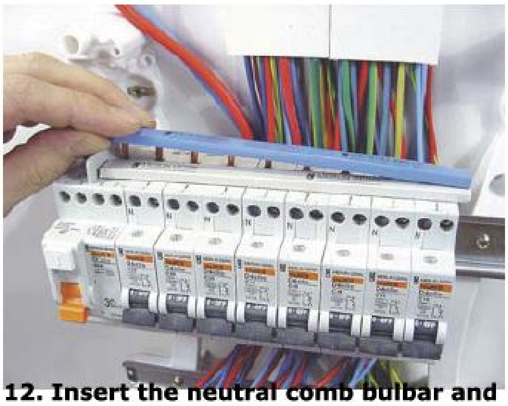


7. Strip, then connect, the other earth wires.

10. Insert the phase comb bulbar.

11.Firmly tighten the phase screws.

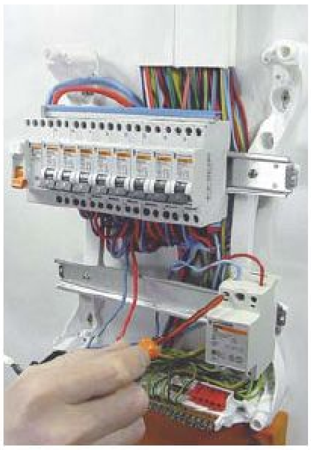
14. All the feeds are connected.1



12. Insert the neutral comb bulbar and tighten screws.

15.Connect outgoing lines to protection devices.

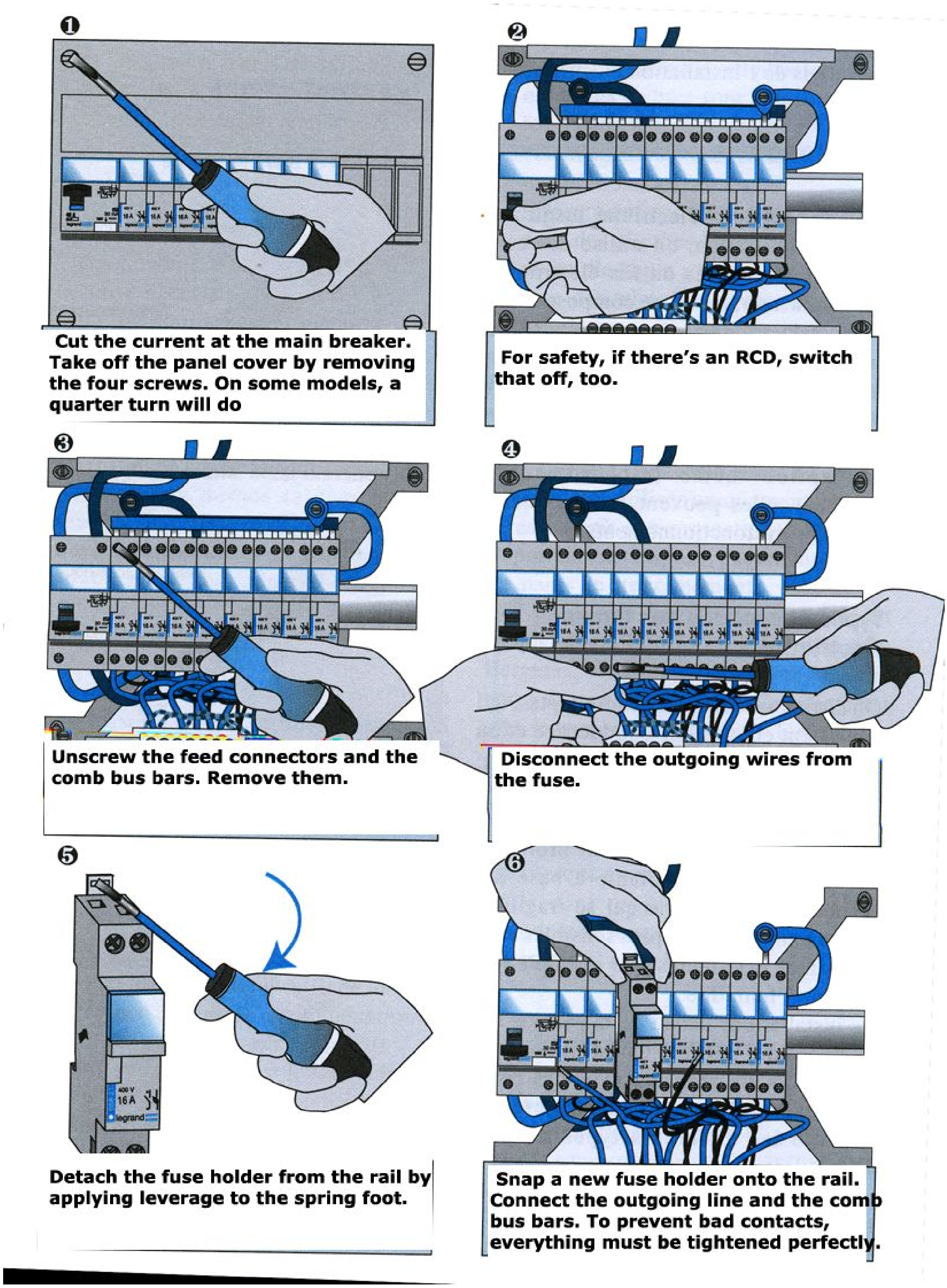
13. Connect the wires from the circuit breaker.



16. Connect the devices serving the board itself (transformer, day/night contactor, etc.).

8.2. REPLACING AN OLD FUSE OR BRANCH CIRCUIT BREAKER

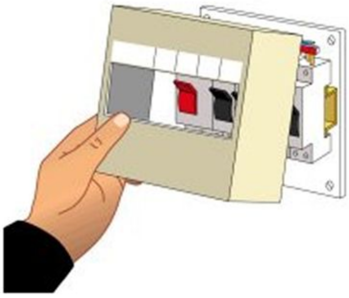
This can be done as illustrated below, once the power is off:



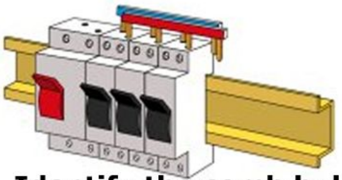
8.3. ADDING A MODULE TO A BOARD

This can be done as illustrated below, once the power is off:

Case 1: The board has an empty position; this is the ideal situation for adding a fuse or circuit breaker.

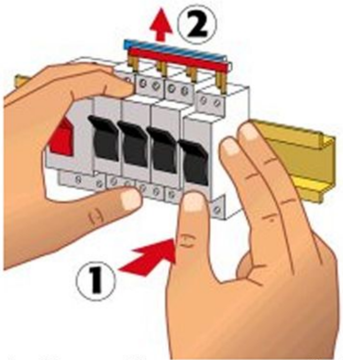


1. Remove the protective cover

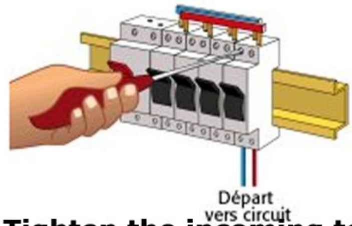


2. Identify the comb bulbar with unoccupied teeth.

3. Remove its protective sleeve, if it has one.



4. Snap the new module into place.

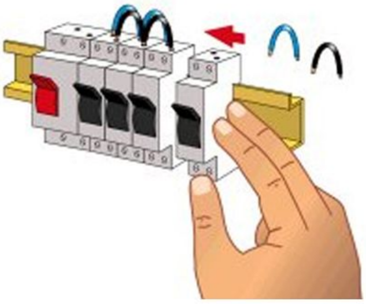


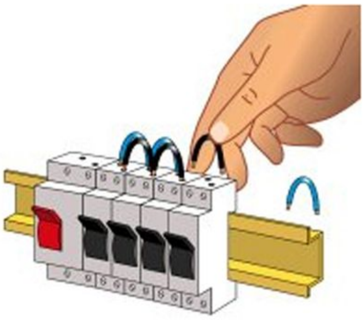
5. Tighten the incoming terminal screws.
6. Connect the outgoing terminals to the circuit you want to protect.
7. Replace the protective cover.

Case 2: A position must to be added to the board

1. Remove the protective cover

2. Snap the new module into the empty position





3. Create a bridge between an existing module and the new one: connect phase to phase and neutral to neutral using wire with the same cross-section as the power feed.

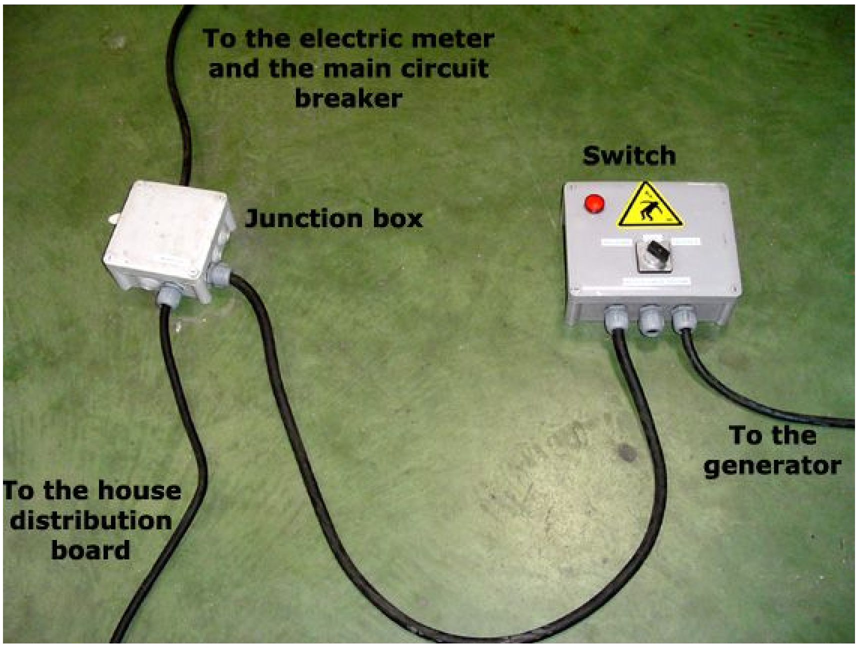
4. Connect the outgoing terminals to the circuit you want to protect.

9. THE TRANSFER SWITCH

9.1. PURPOSE

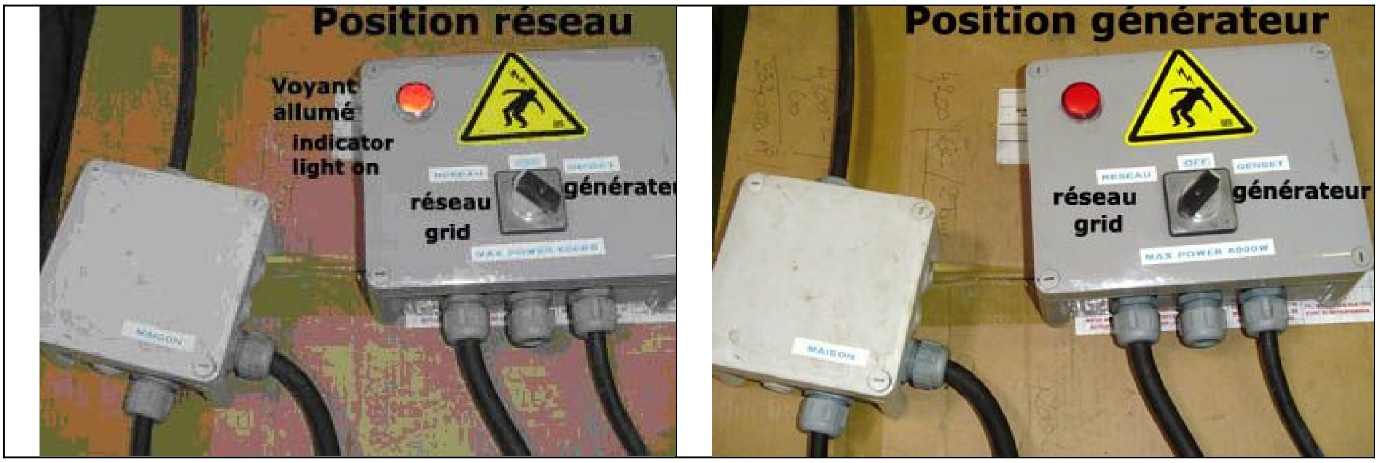
When an emergency generator is used during grid power outages, you must ensure there's no direct connection between the generator and the grid. This is done with a power transfer switch, which toggles between the grid and the generator through a neutral position.

9.2. CONNECTIONS



9.3. HOW IT WORKS

When the grid is supplying power, the indicator light is on and the switch is in the grid position. When there's a grid outage, the indicator light goes off, signalling that the generator must be started. Unplug large loads, start the generator, flip the switch to the generator position, and restart the large loads one at a time.

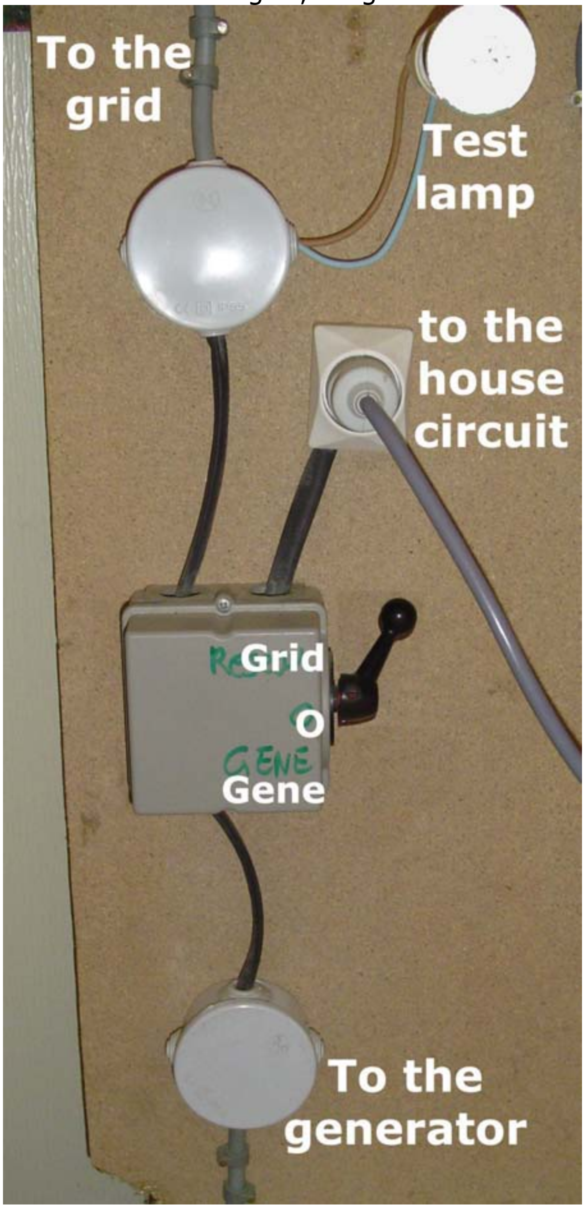


When grid power returns, the indicator light comes back on. Flip the switch to the grid position, and only then turn off the generator.

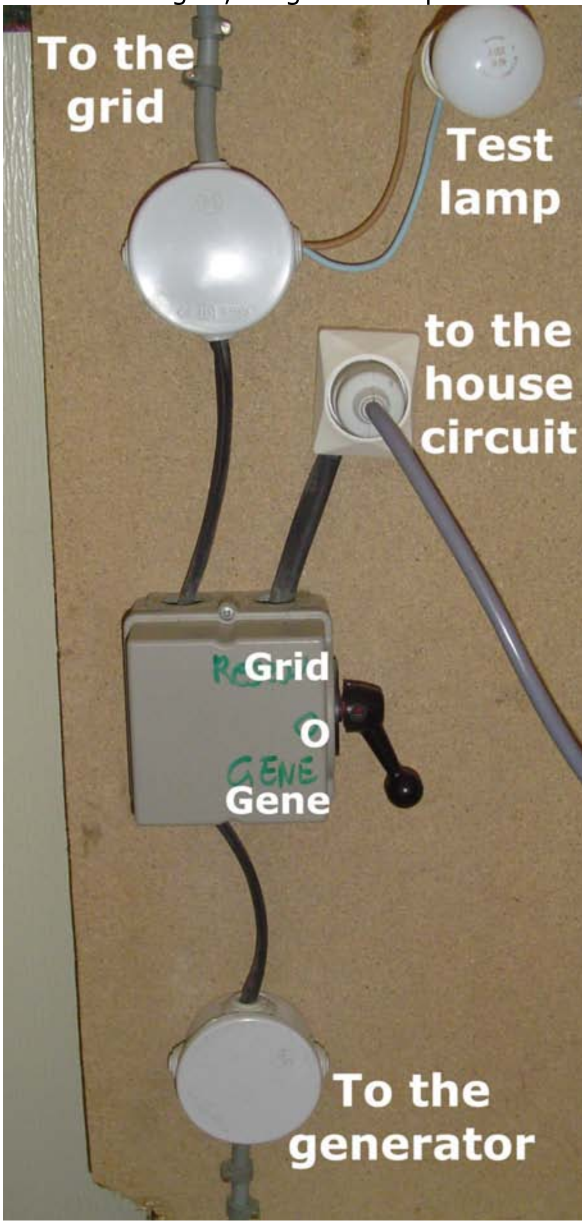
WARNING: Never turn off a generator with the load connected.

For small installations, you can use the set-up below, which works on the same principle:

Power from grid, no generator



Off the grid, on generator power

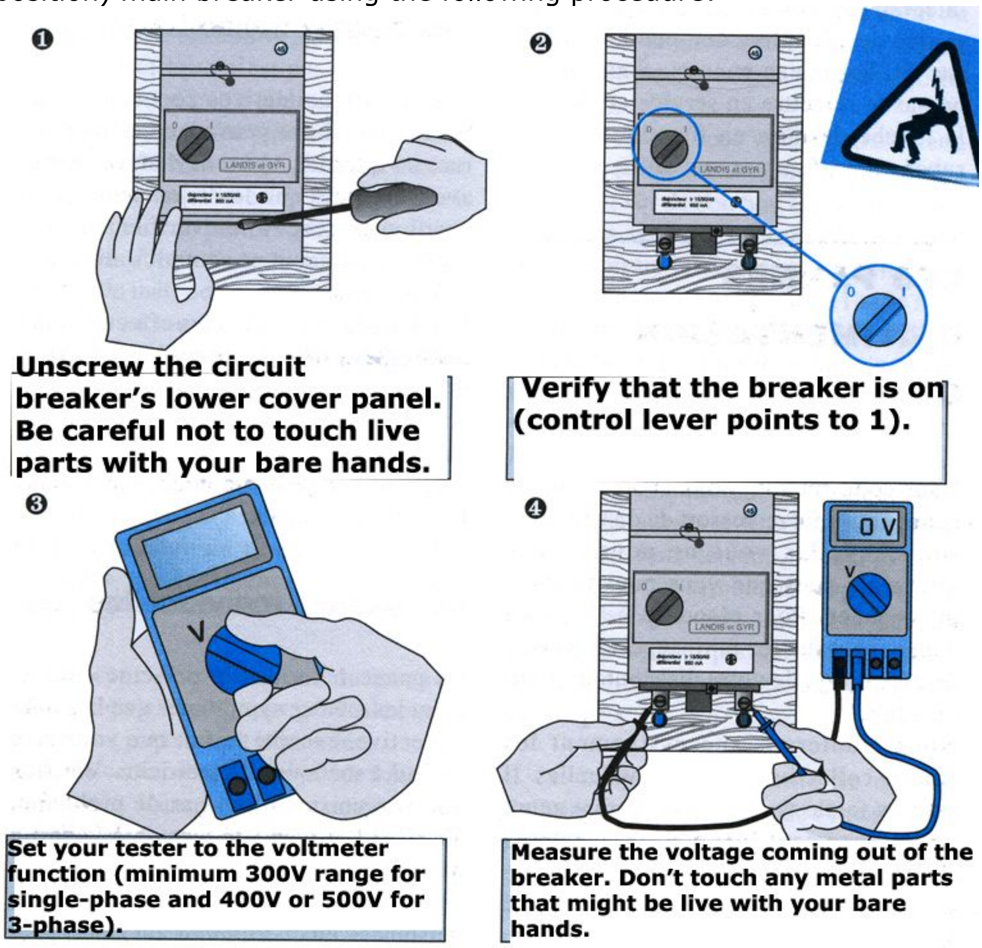


TROUBLESHOOTING

1. TRIPPED MAIN CIRCUIT BREAKER

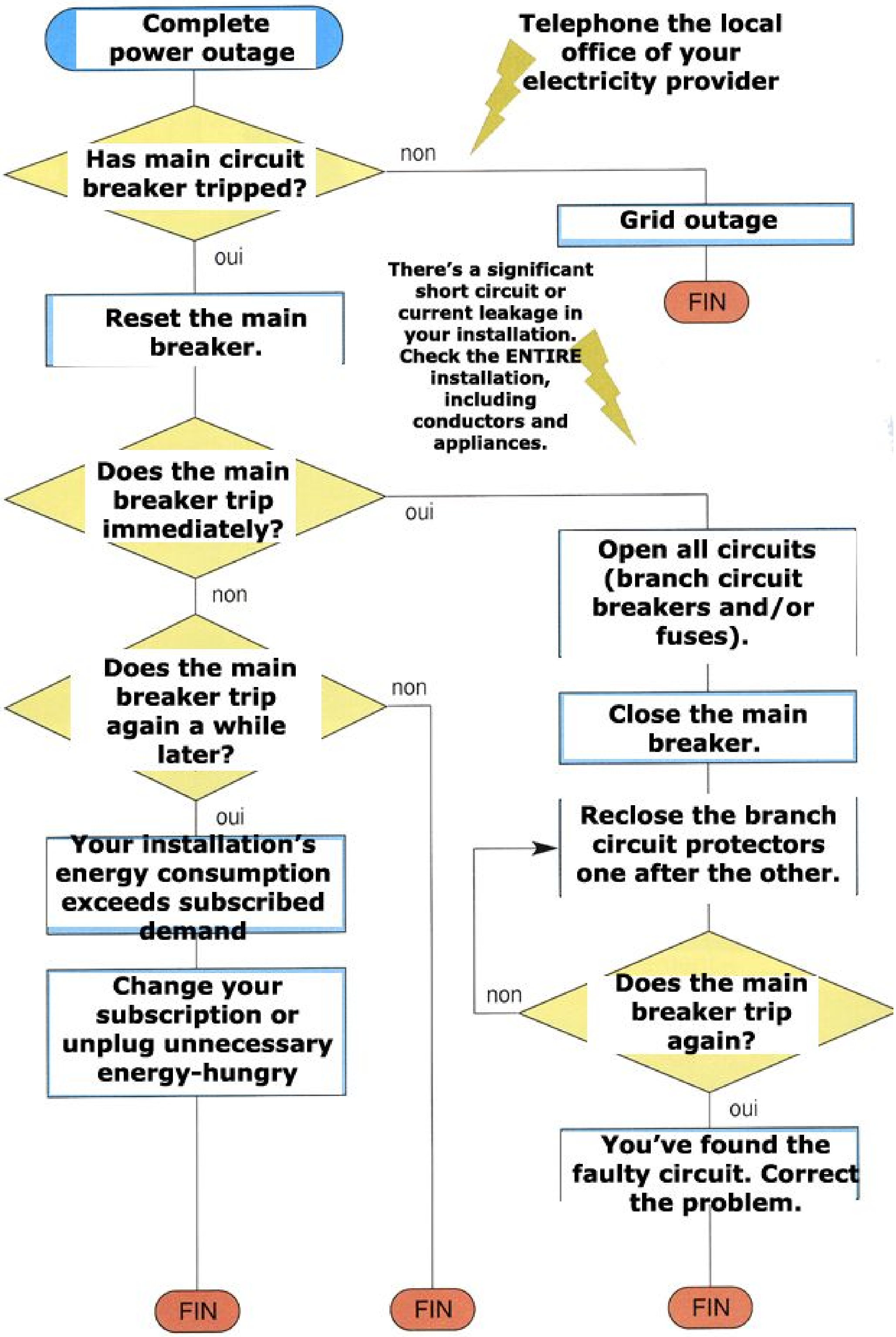
Suddenly, the electricity goes completely off: lights are out throughout house, not a single electrical appliance works. The search for the problem must start near the distribution board and main circuit breaker.

To be sure there's a general outage due to the supplier (for example, EDF in France), test your untripped (in the "1" position) main breaker using the following procedure:

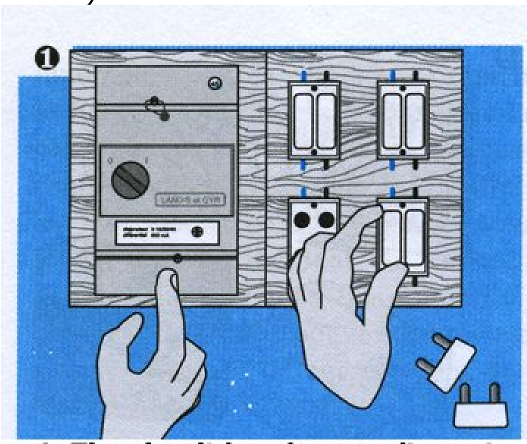


If the voltage reads zero, the power failure is in the grid. If it reads 220V for single-phase, the problem is somewhere in your installation.

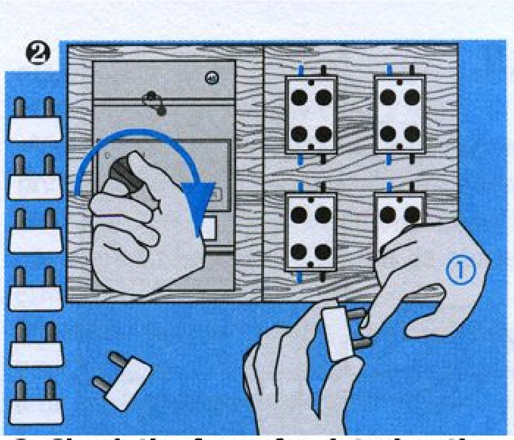
Use the following flowchart:



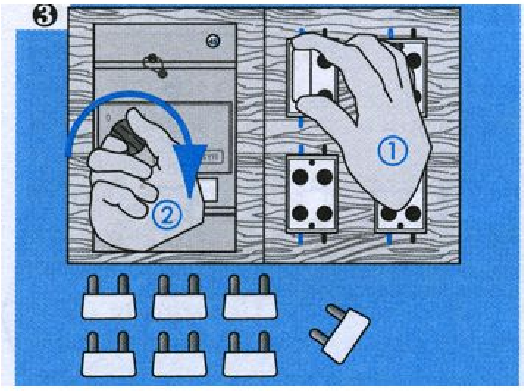
To find the faulty circuit, follow one of the following procedures, depending on whether you have fuses (P+N or 2P)...



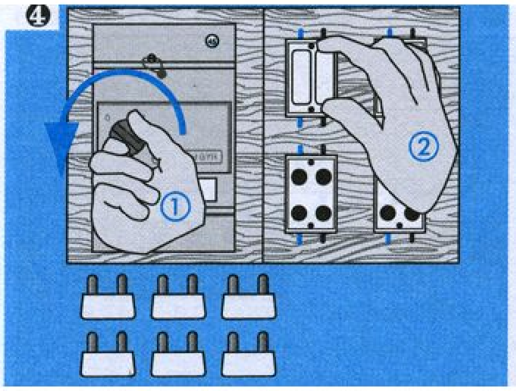
1. The circuit breaker won't reset. Remove all the fuses and check that there's no circuit directly under the



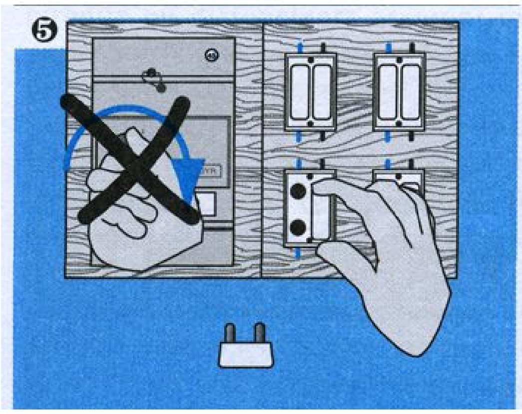
2. Check the fuses for deterioration, and repair any that need it (1). Make sure the circuit breaker resets, then re-open it



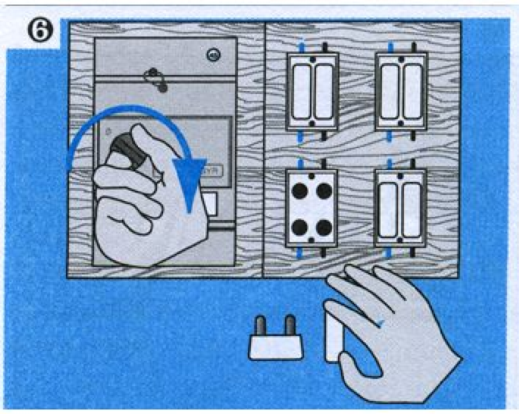
3. Reinsert one fuse (1), and check to see if the breaker will reset (2).



4. Re-open the breaker (1), then put in a second fuse (2). Repeat steps 3 and 4 with all the fuses.



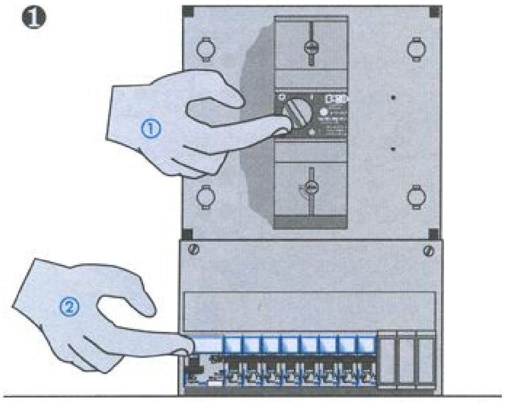
5. When you get to the faulty circuit, you won't be able to reset the breaker.



6. Do not reinsert this circuit's fuses. Reset the breaker in order to use the rest of the installation.

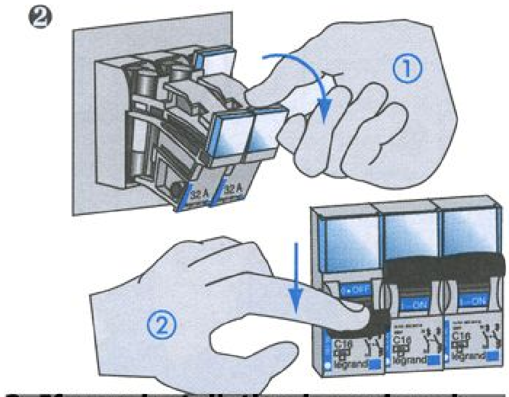
or branch circuit breakers:

❶



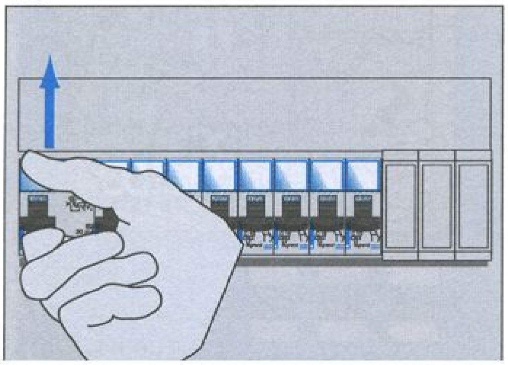
1. The main circuit breaker (1) or the RCD (2, if you have one) refuses to reset.

❷



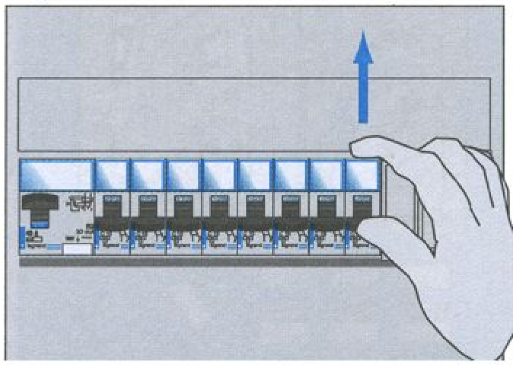
2. If your installation is equipped with modular fuse holders, open the carriers (1). If you have MCBs, push all their levers down to the OFF

❸



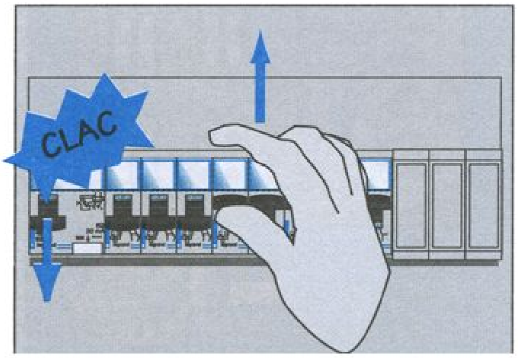
3. Reset the RCD or the main service breaker.

❹



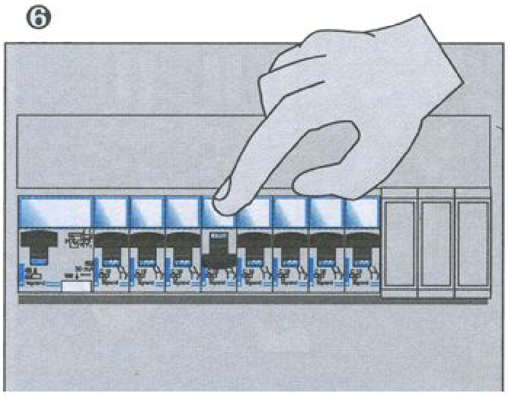
4. Reset each MCB or fuse holder.

❺



5. When you come to the faulty circuit, resetting the branch circuit breaker will trip the RCD or the main breaker.

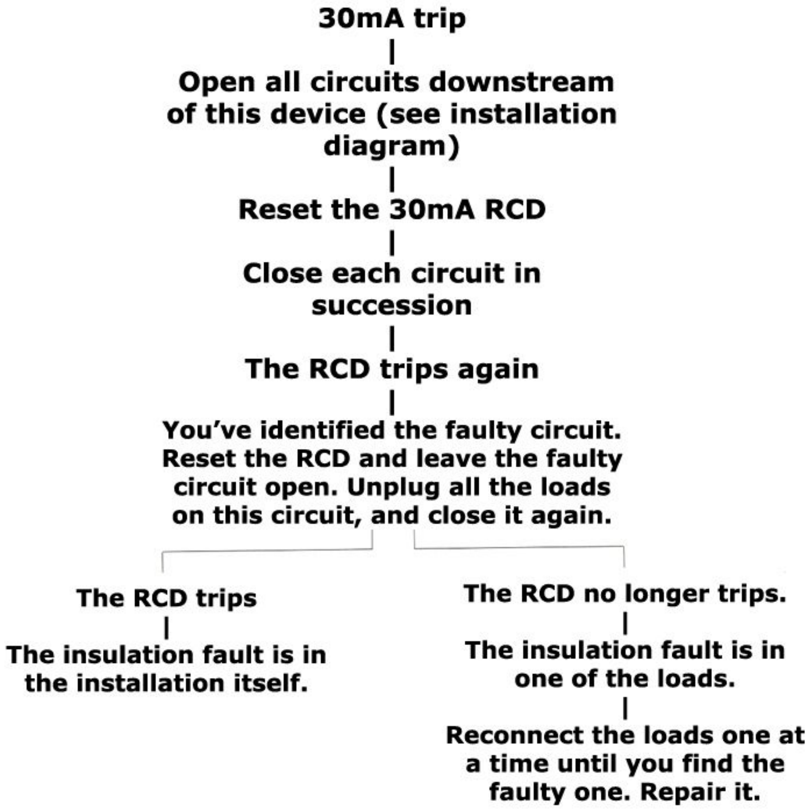
❻



6. Reset all the other branch circuit breakers to use the rest of the installation. Look for the problem in the faulty circuit.

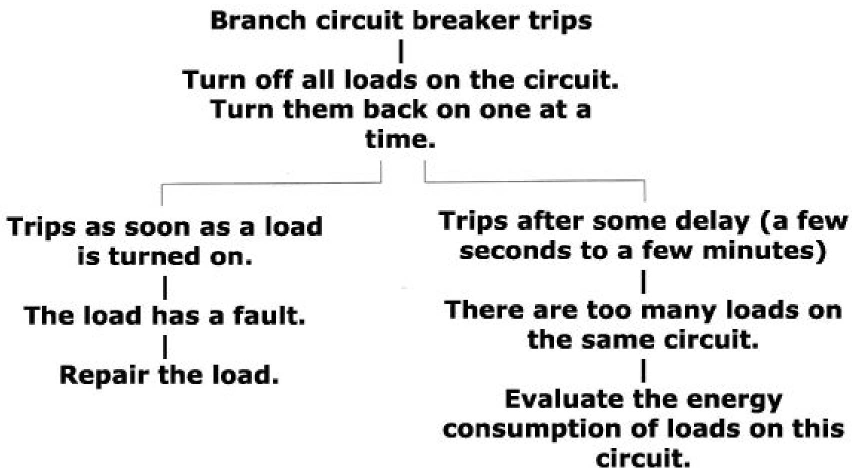
2. TRIPPED 30MA RCD

This means that there's an insulation fault somewhere on the line.
Follow the flowchart:



3. BLOWN FUSE OR TRIPPED MCB

Strictly speaking, a blown fuse or tripped MCB isn't itself a failure, but rather the consequence of one. They occur in response to an overload or short circuit.

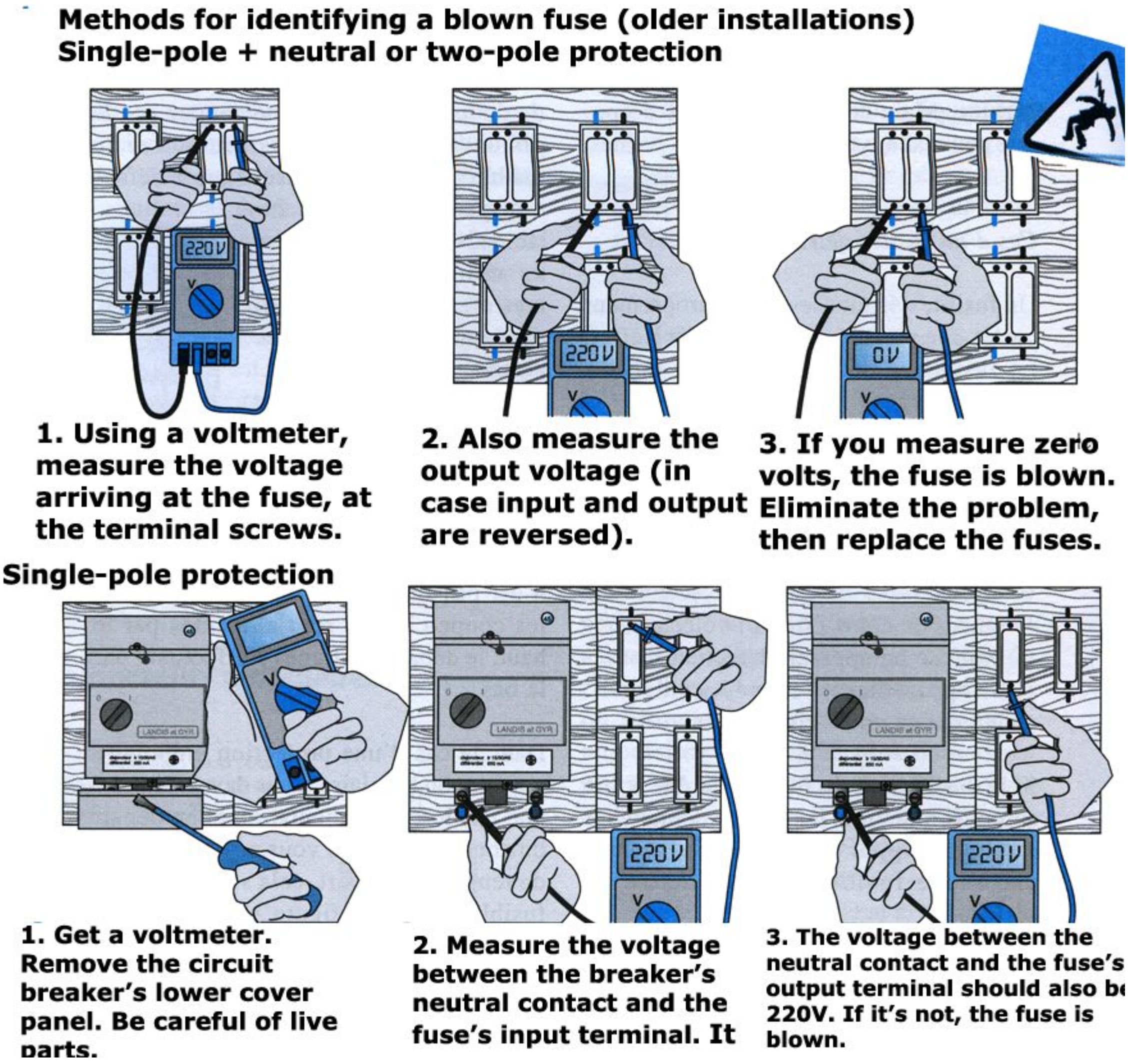


In the former case, a delay in tripping indicates overload or overconsumption. You've got to unplug a few appliances and replace the blown fuse cartridge.

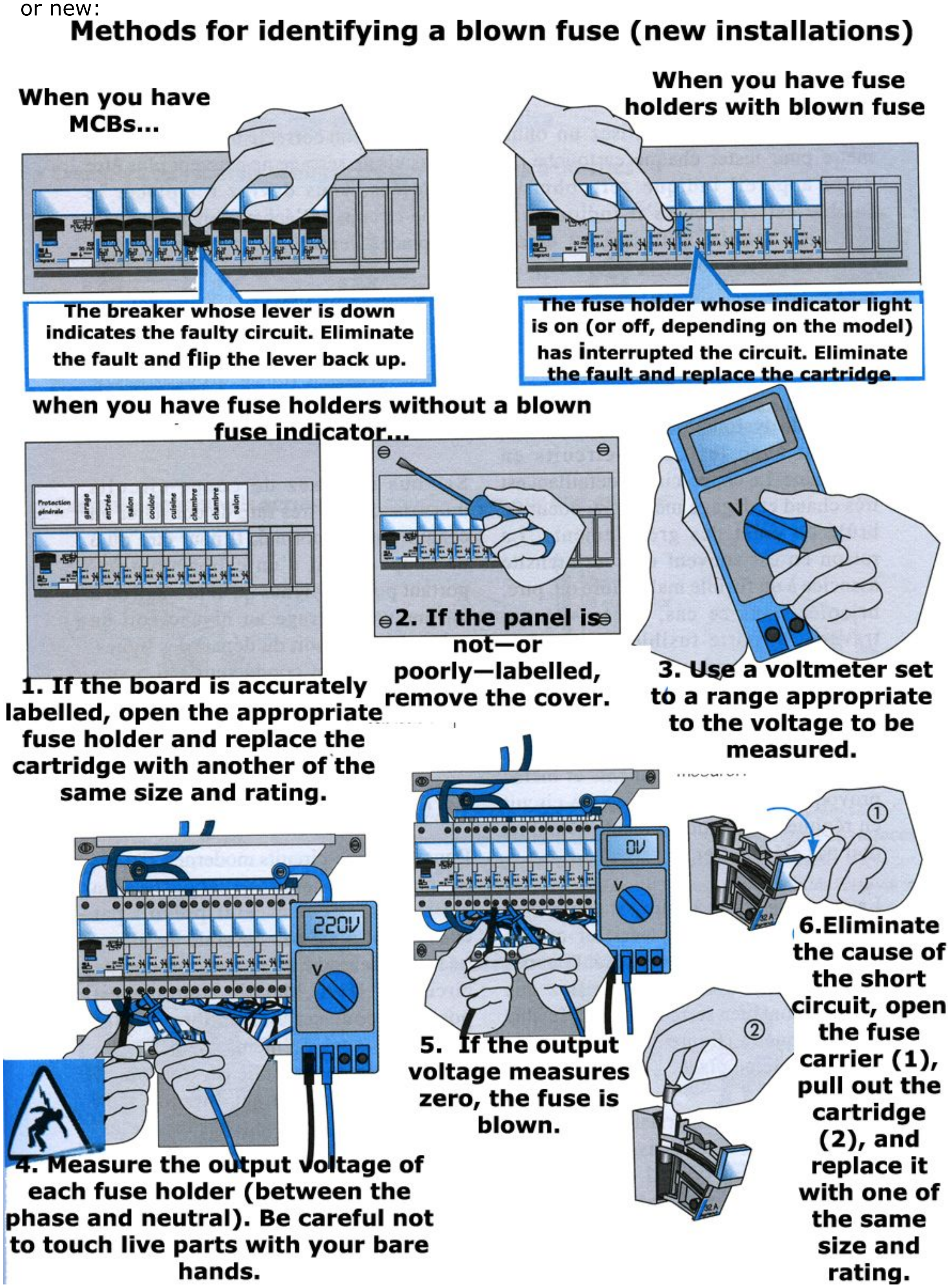
In the latter case, an immediate trip upon turning on an appliance indicates a short circuit. Once you've identified the appliance with the short circuit, check its plug and power cord. Then repair the appliance. If you don't, you'll continue to have the problem.

3.1. HOW DO YOU FIND A BLOWN FUSE?

Follow one of these two procedures, depending on whether your installation is old...



or new:

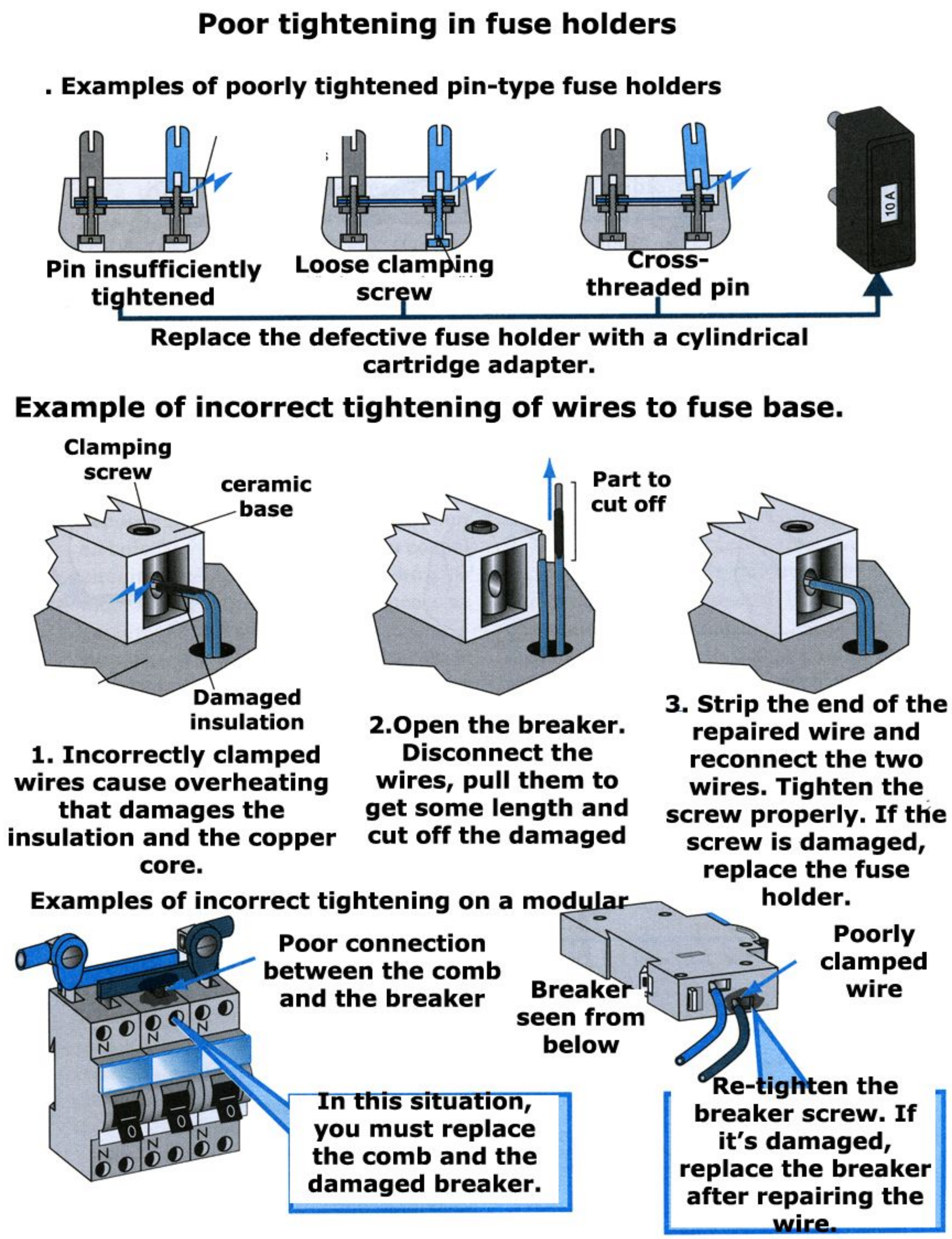


3.2. OVERHEATED FUSE

A normally-functioning fuse shouldn’t get hot.

Nevertheless—and particularly with older ceramic fuse holders—a fuse may heat up, even giving off a burning odour or making sizzling sounds. Often, the problem is an overcurrent due to an incorrect fuse rating or a makeshift repair.

Check the fuse's rating and the tightness of its screws:



4. TOUCH VOLTAGE WITHOUT TRIPPING

This causes a tingling each time you touch an appliance. Here, the installation has two problems going on at once:

- the appliance's metal parts aren't earthed

AND

- there's an insulation fault in a live conductor.

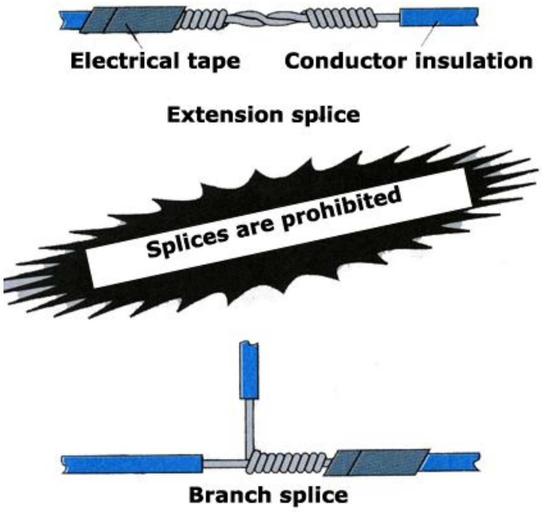
5. CONDUCTOR PROBLEMS

5.1. OVERHEATING

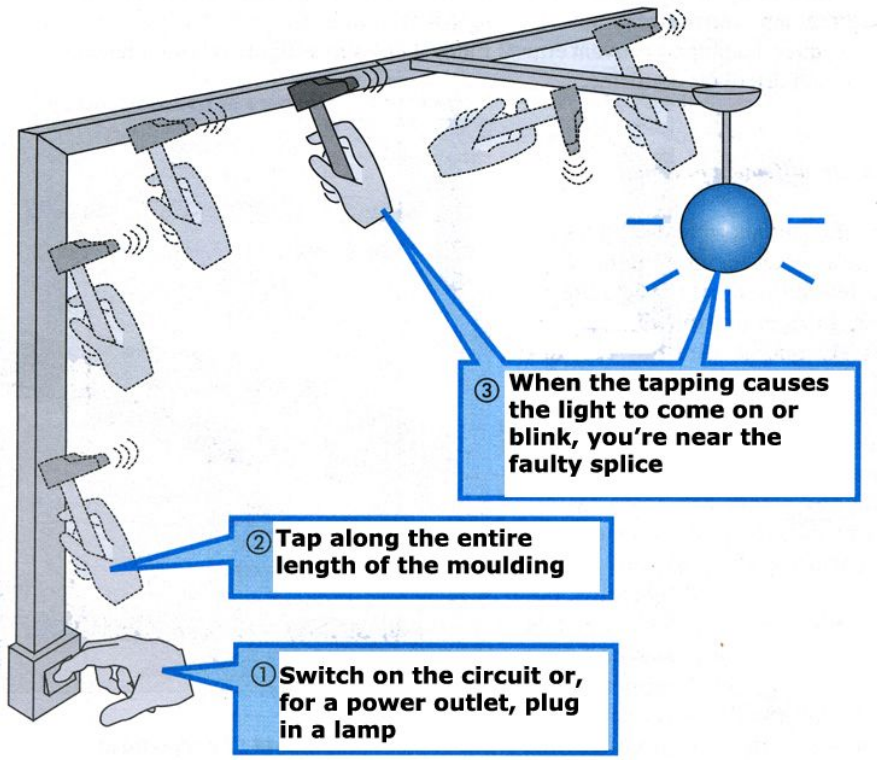
Overheating is extremely bad for conductors, causing premature aging of the insulation, deterioration of connections and, in the worst case, the possibility of fire. It occurs in older installations where conductor cross-section is inadequate for the appliances in use. If protection devices are properly sized, overheating shouldn’t occur. You should check the circuit protection, size it correctly, and avoid connecting large loads on this line. If you need a lot of power, install a new circuit.

5.2. SPLICES

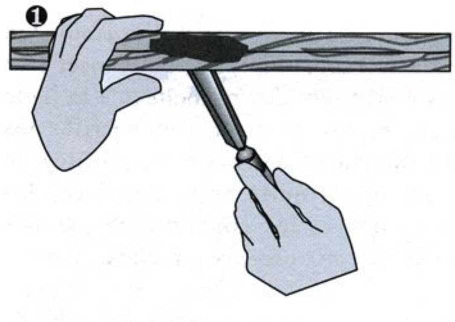
While these are now prohibited, they were formerly used for joins and tie-ins. When consumption gets too high, splices deteriorate until they cause an open circuit, intermittent operation or flickering lights.



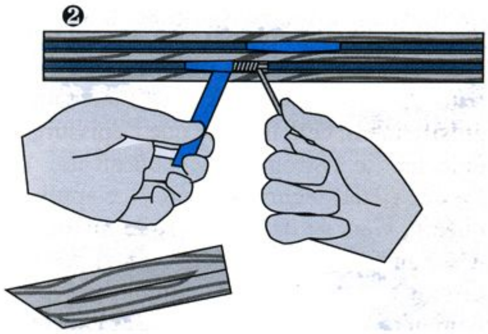
First you have to locate the splice, which is often under wooden moulding:



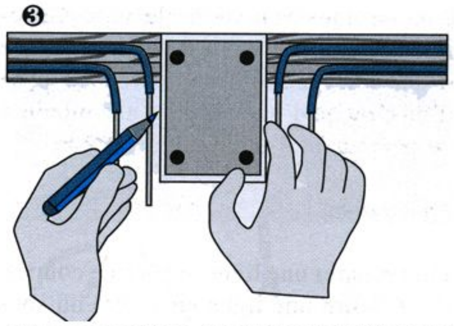
To replace an old splice with a junction box, do the following:



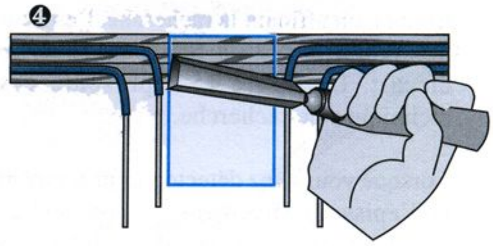
1Once you've located the splice, cut the current at the circuit breaker. Carefully remove the cover moulding



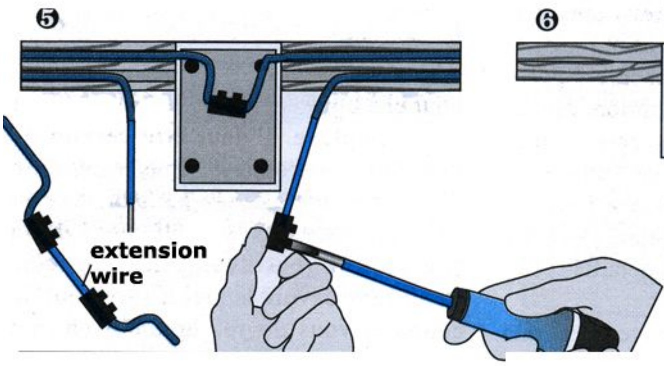
Remove the insulation around the splice, then unwind the conductors to gain some length. If there are two splices and you have any doubts,



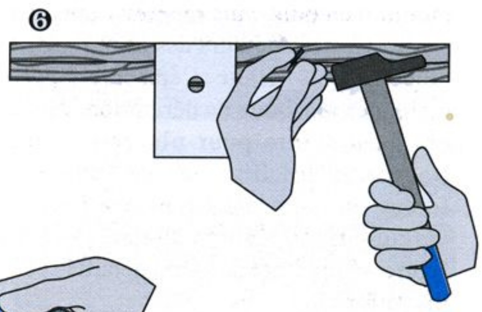
Place a surface-mounted junction box at the splice location and trace around it.



Using a wood chisel and a hammer, carve away the base of the moulding to fit the tracing. Mount the box using screws and anchors.



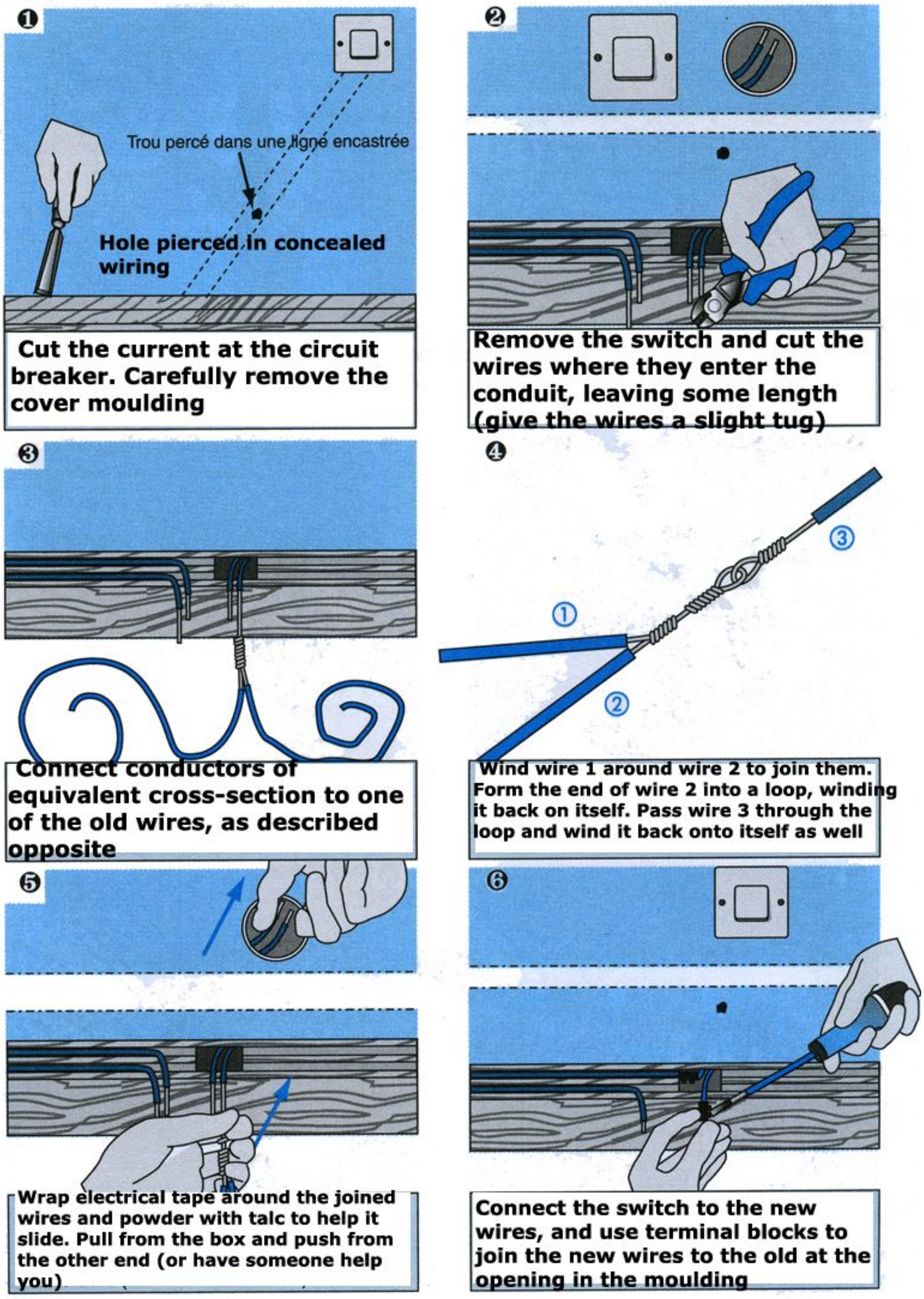
Insulate the exposed conductors, then make the connections. If the wires are too short (broken wire), use two terminal blocks as shown above.



Close the junction box. Nail the cover moulding back on after cutting it to the correct length

5.3. SEVERED LINES

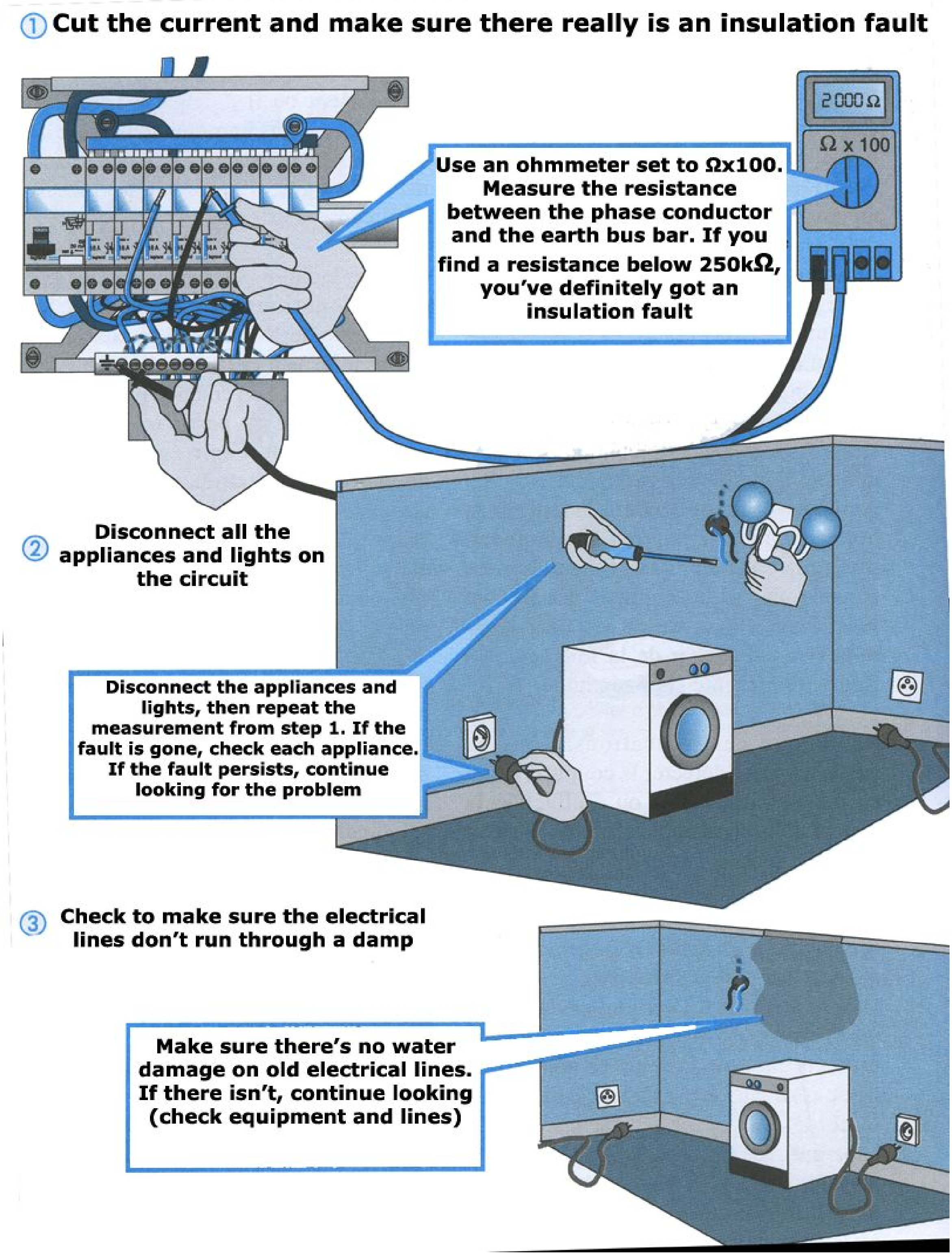
Lines rarely break on their own; it's generally the result of some unfortunate intervention, such as hammering a nail or drilling a hole. For surface wiring, rig up a junction box as shown in the preceding paragraph. For concealed wiring, follow the steps below:



5.4. LINE WITH AN INSULATION FAULT

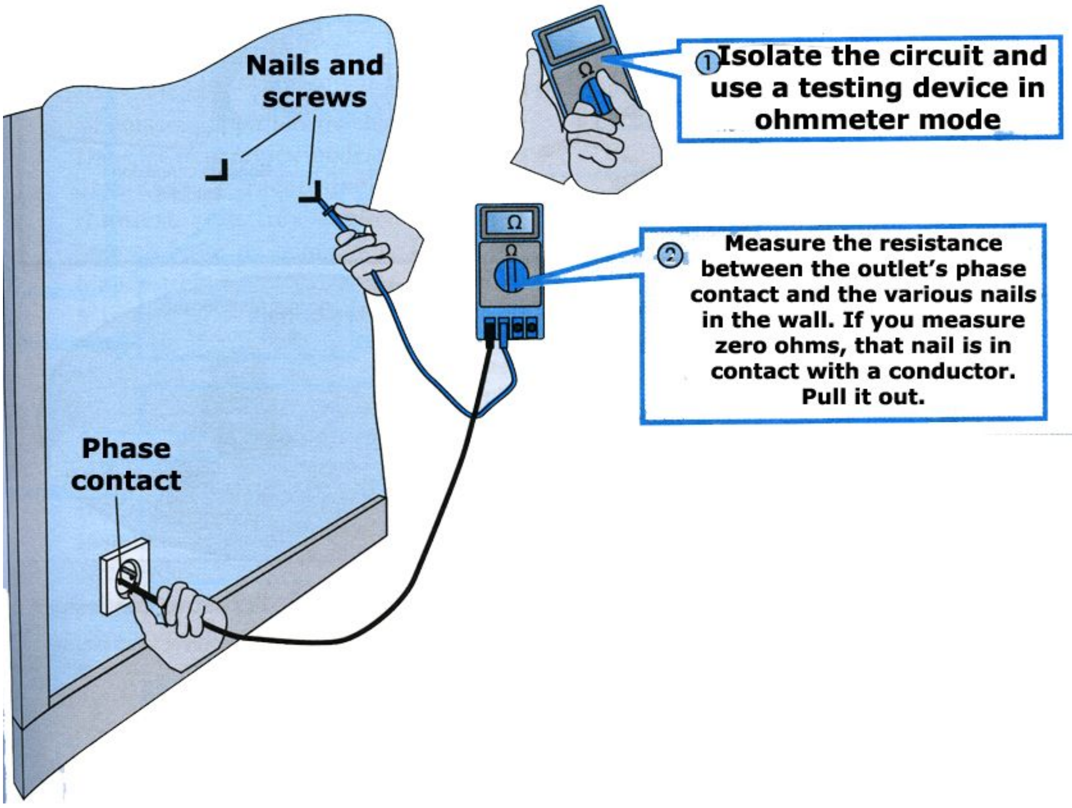
First make sure that the insulation fault is in the line, and not in an appliance or light fitting.

Disconnect all appliances on the line, including the lights, and check to make sure there's still an insulation fault by measuring the resistance between the faulty circuit's phase conductor and the installation's earth. If you measure infinite resistance, there's no insulation fault. On the other hand, a finite resistance—even a very large one—indicates contact between the phase and earth.



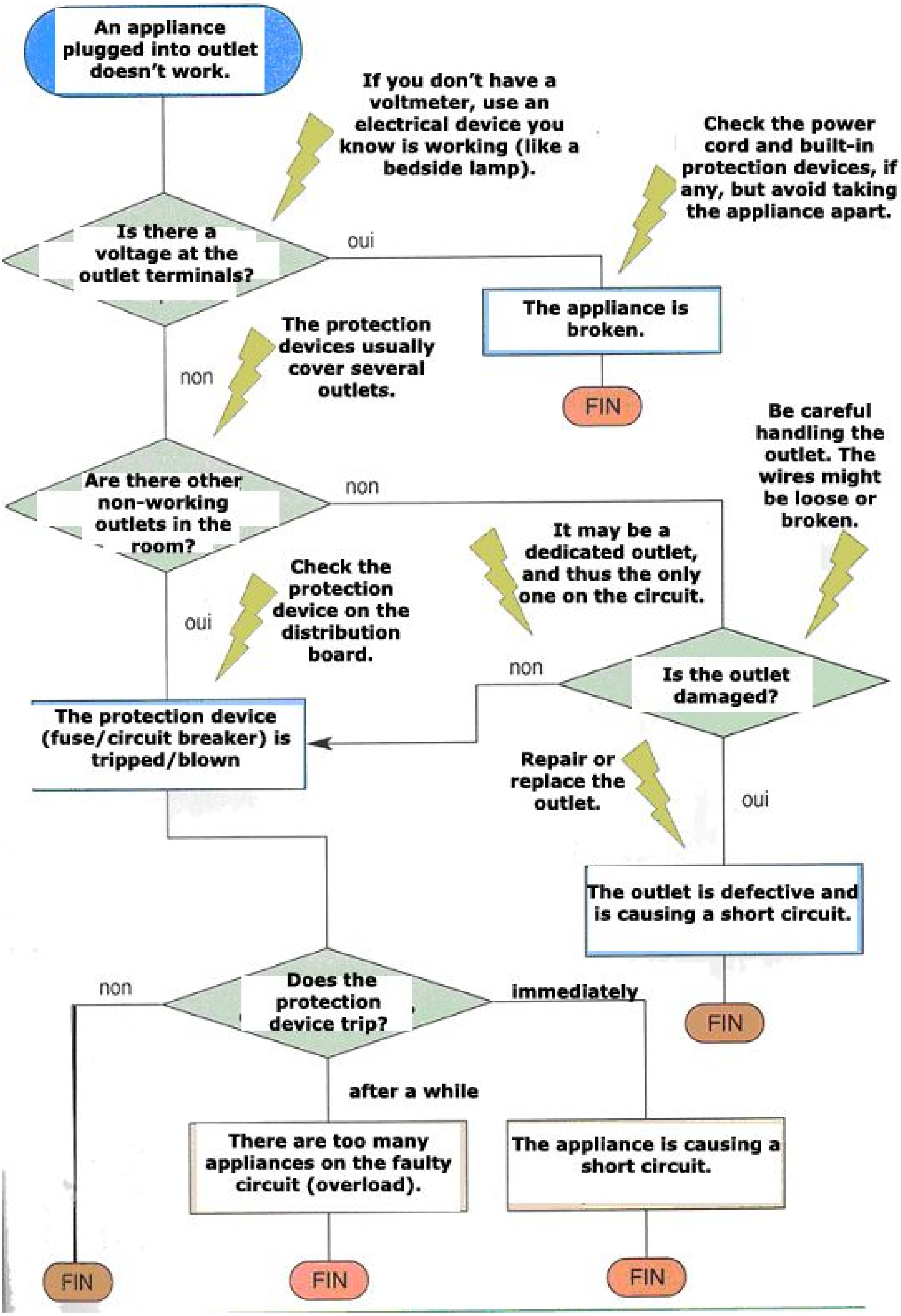
There's either a break in the insulation or a metal object (like a nail or screw) touching the conductor core, especially if there's moisture in the wall.

In the latter case, find the offending nail as follows:



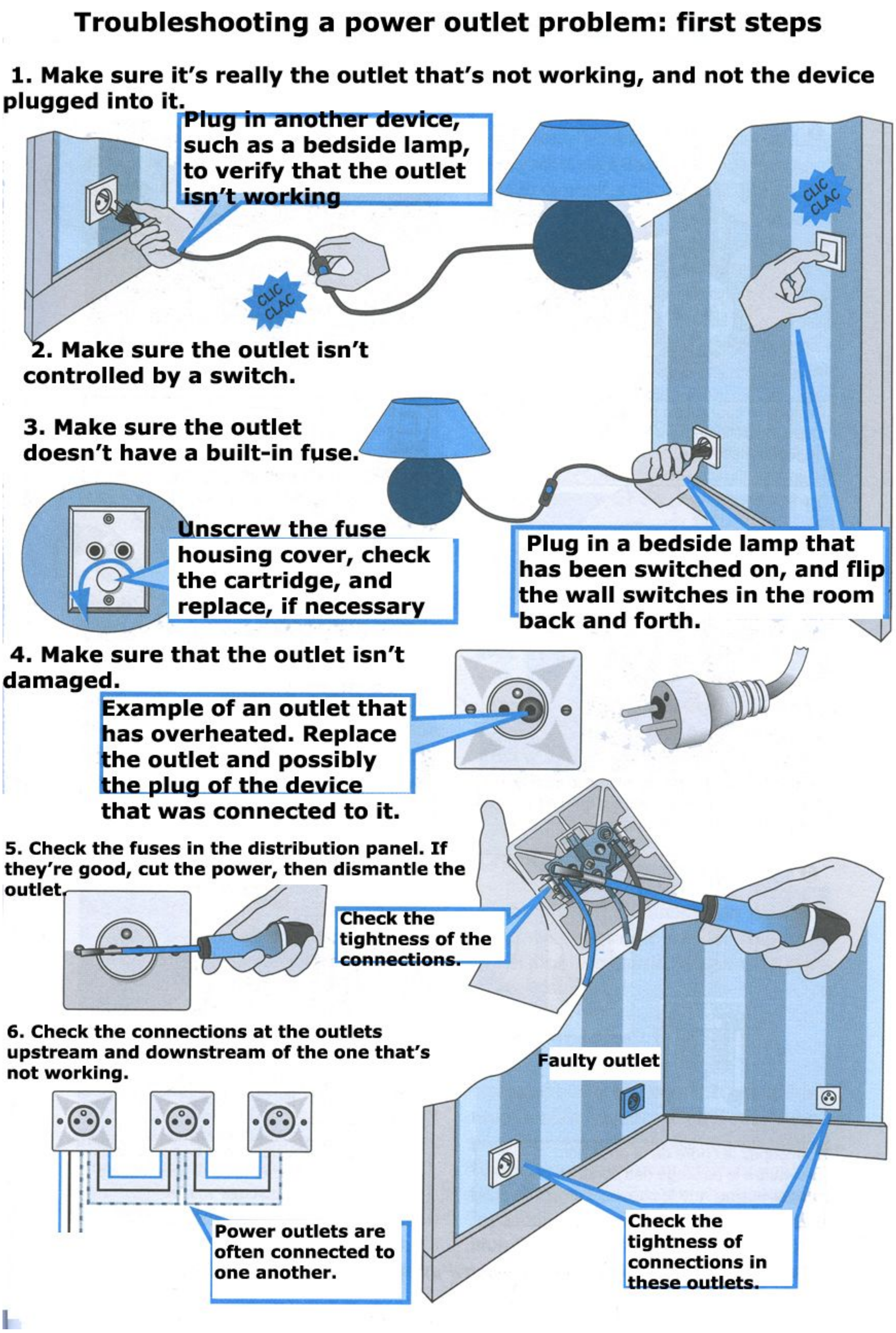
6. PROBLEMS ON A POWER OUTLET CIRCUIT

Work your way through the following flowchart:



6.1. ONLY ONE NON-FUNCTIONING OUTLET

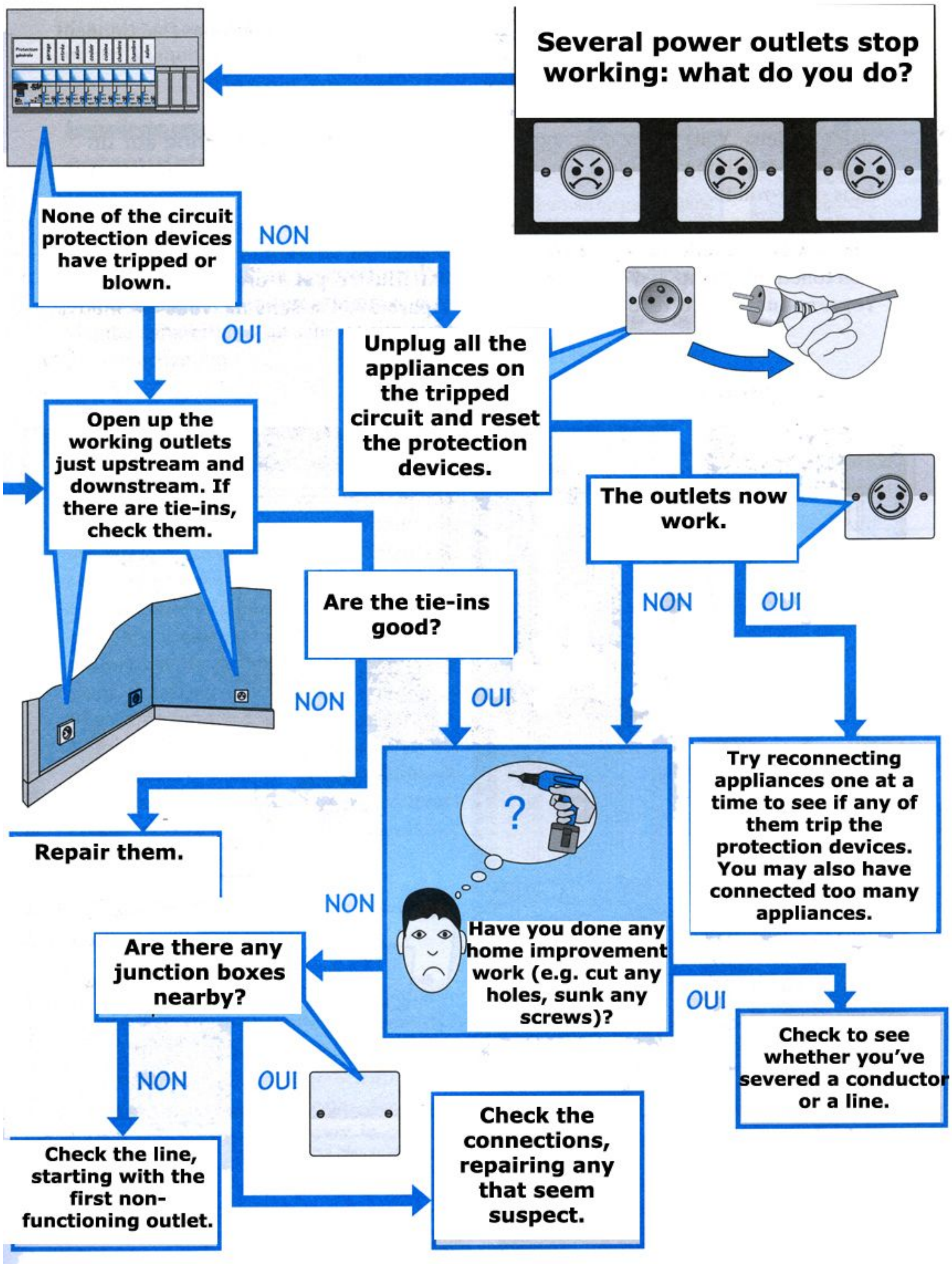
First make sure that it's not the device that's plugged into the outlet that's broken. Test the voltage at the outlet terminals, or plug the device into another outlet that is working.



Now check to see if the outlet has overheated. If this is the case, replace it. See the section "Replacing an outlet". If not, check the tightness of the outlet connections, especially if there's a tie-in to another outlet. Finally, if the outlet isn't the problem, check the incoming line. See the "Conductor problems" section.

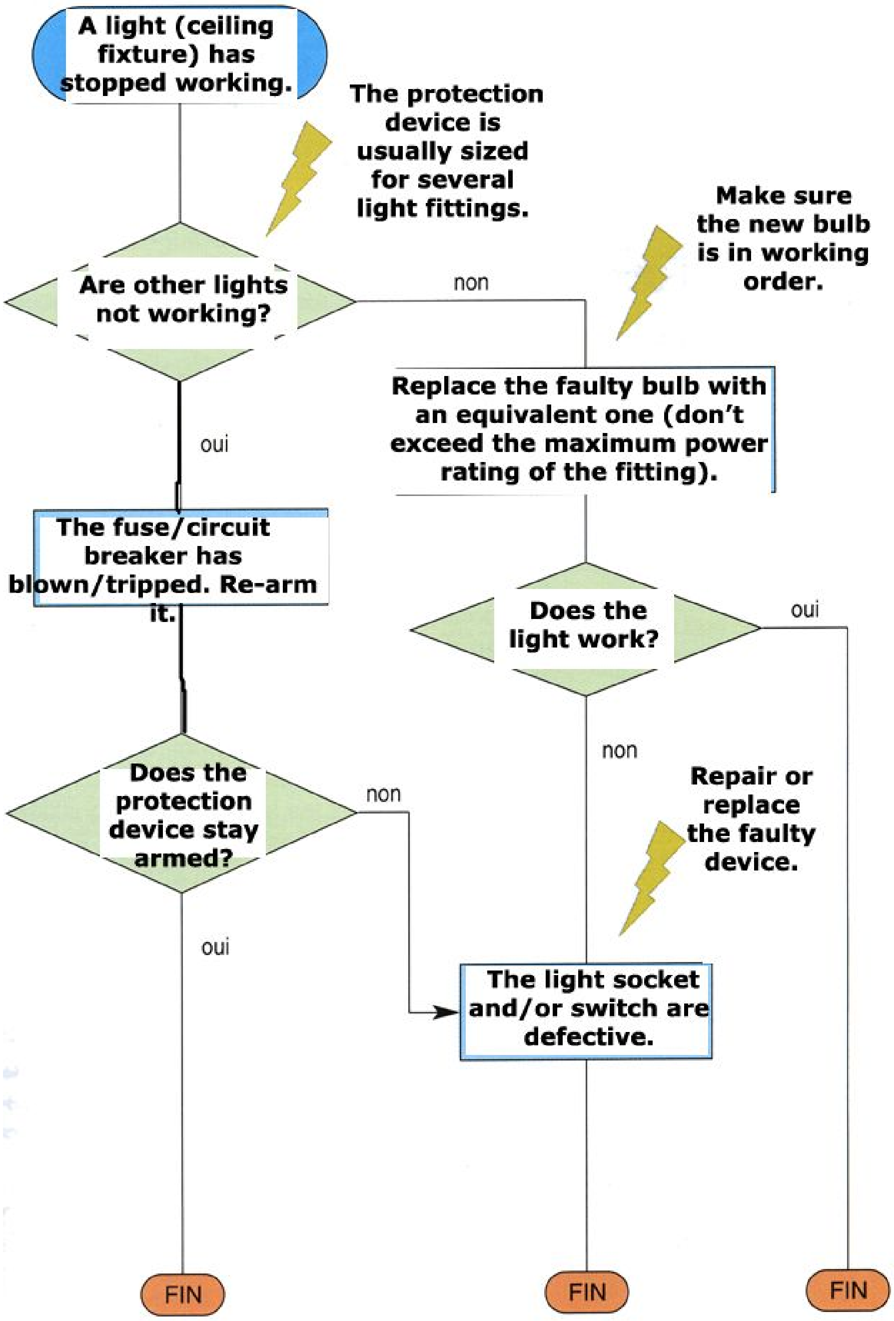
6.2. SEVERAL NON-FUNCTIONING OUTLETS

First check the circuit protection system. If it's alright, the source of the problem may be a tie-in from another outlet.



7. PROBLEMS ON A LIGHTING CIRCUIT

Work your way through the following flowchart:



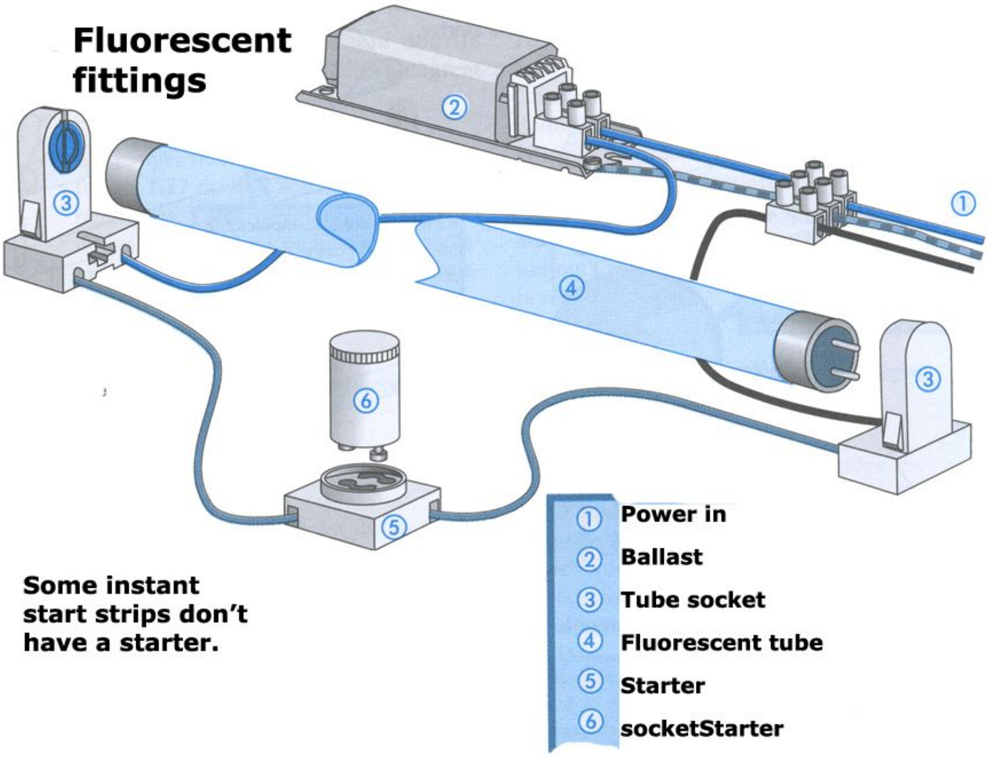
When a bulb used in a light fixture gives off too much heat, a short circuit can occur. The socket and conductors age quickly, and then even minor handling can lead to short circuit.

An overload can occur after modification of the installation: a new light fixture, an add-on... You notice it when the MCB or fuse trips some time later. Use fewer or lower wattage bulbs, or try a different technology (compact fluorescent bulbs, for example).

If your lighting circuit is protected by a 10A fuse, replace it with a 16A MCB.

7.1. FLUORESCENT LIGHTING

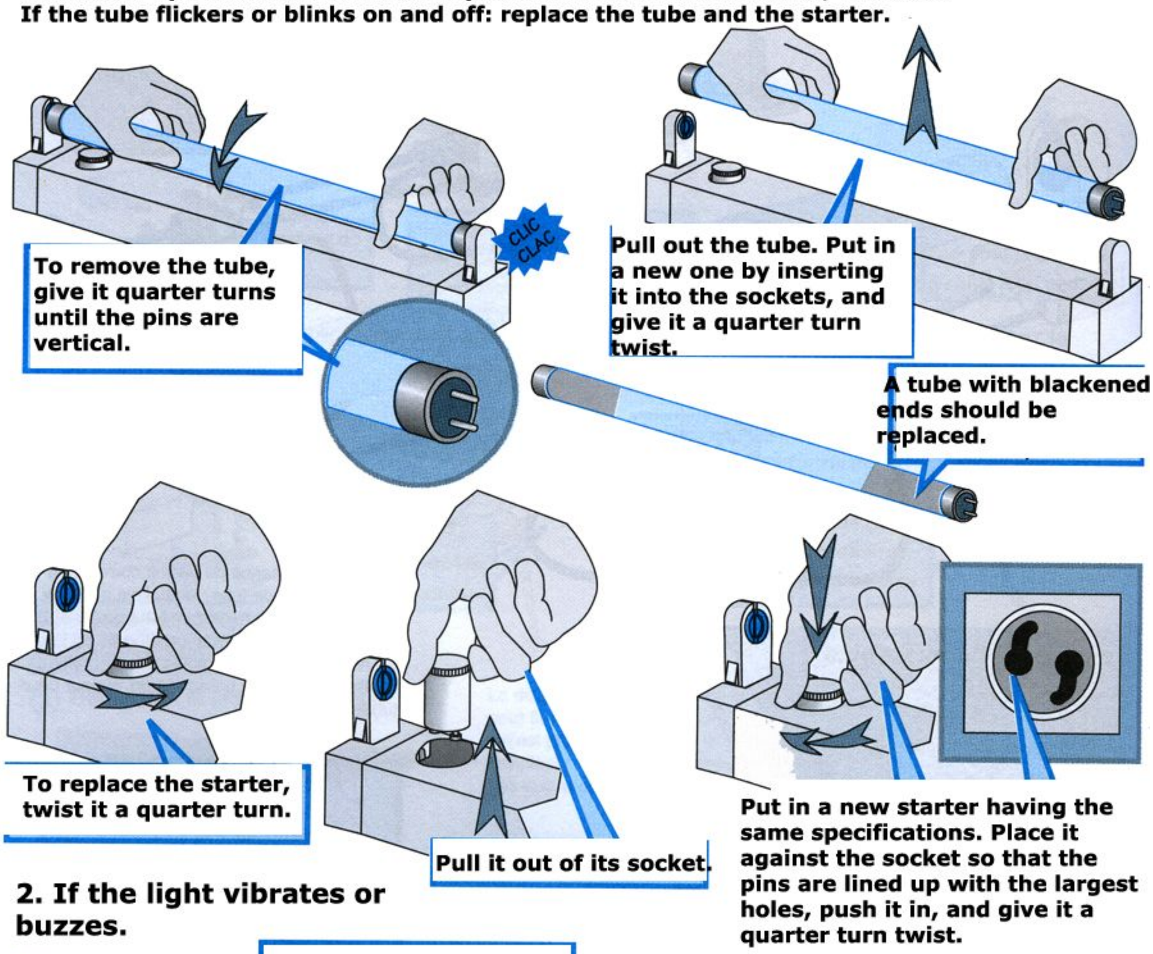
A fluorescent light circuit consists of a terminal block for the feed wires, a ballast, sockets for the fluorescent tube and a starter with its socket/holder.



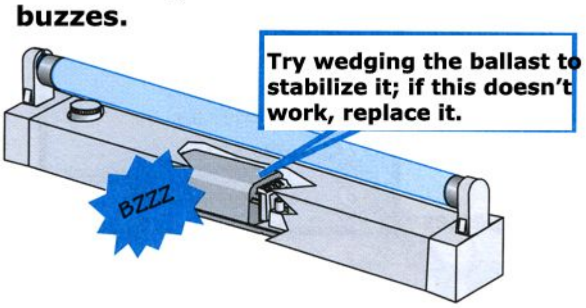
Follow the appropriate procedure for slow start-up, flickering or blinking, buzzing or failure to come on:

Troubleshooting fluorescent strip lights

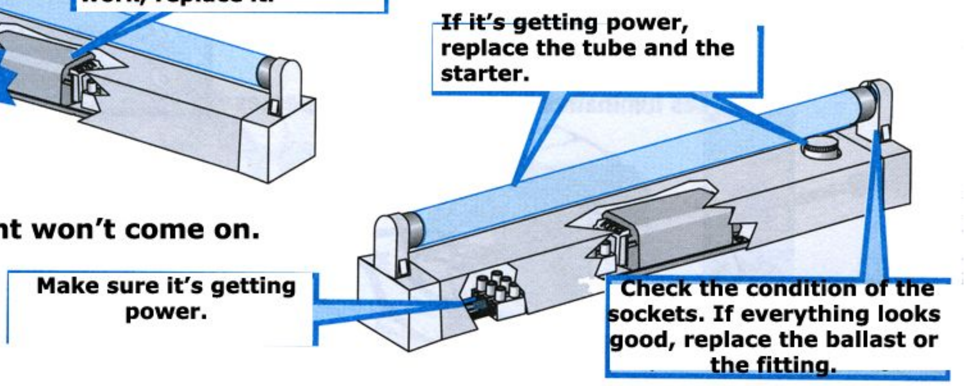
1. If start-up is slow and difficult: replace the starter and the tube, if it's old. If the tube flickers or blinks on and off: replace the tube and the starter.



2. If the light vibrates or buzzes.



3. If the light won't come on.



THREE-PHASE POWER

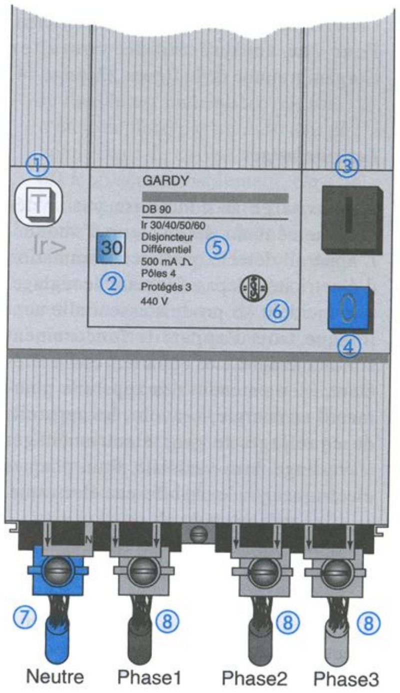
1. BASIC CONCEPTS

Three-phase power uses four conductors—three phases,a neutral and the earth cable.
The voltage between the neutral and each of the phases is 220V.
The voltage between any two phases is 380V.
See the "Types of current" section.

2. THE MAIN CIRCUIT BREAKER IN THREE-PHASE INSTALLATIONS

It is the equipment where to connect the main network or the generator.
It has the same function as the main breaker in single-phase installations, which is to provide:

- a barrier against general **overload** of the installation relative to the source (generator or subscribed demand),
- thermal magnetic protection against **short circuits**,
- residual current protection against insulation faults, protecting humans from current leakages over 500mA. Note that this far surpasses the electrocution threshold of the human body.



1. RCD test button
2. Trip current for which circuit breaker is set (possible settings are indicated by Ir)
3. "On" button
4. "Off" button
6. Conforms to French standards.
7. Neutral terminal
8. Phase terminal

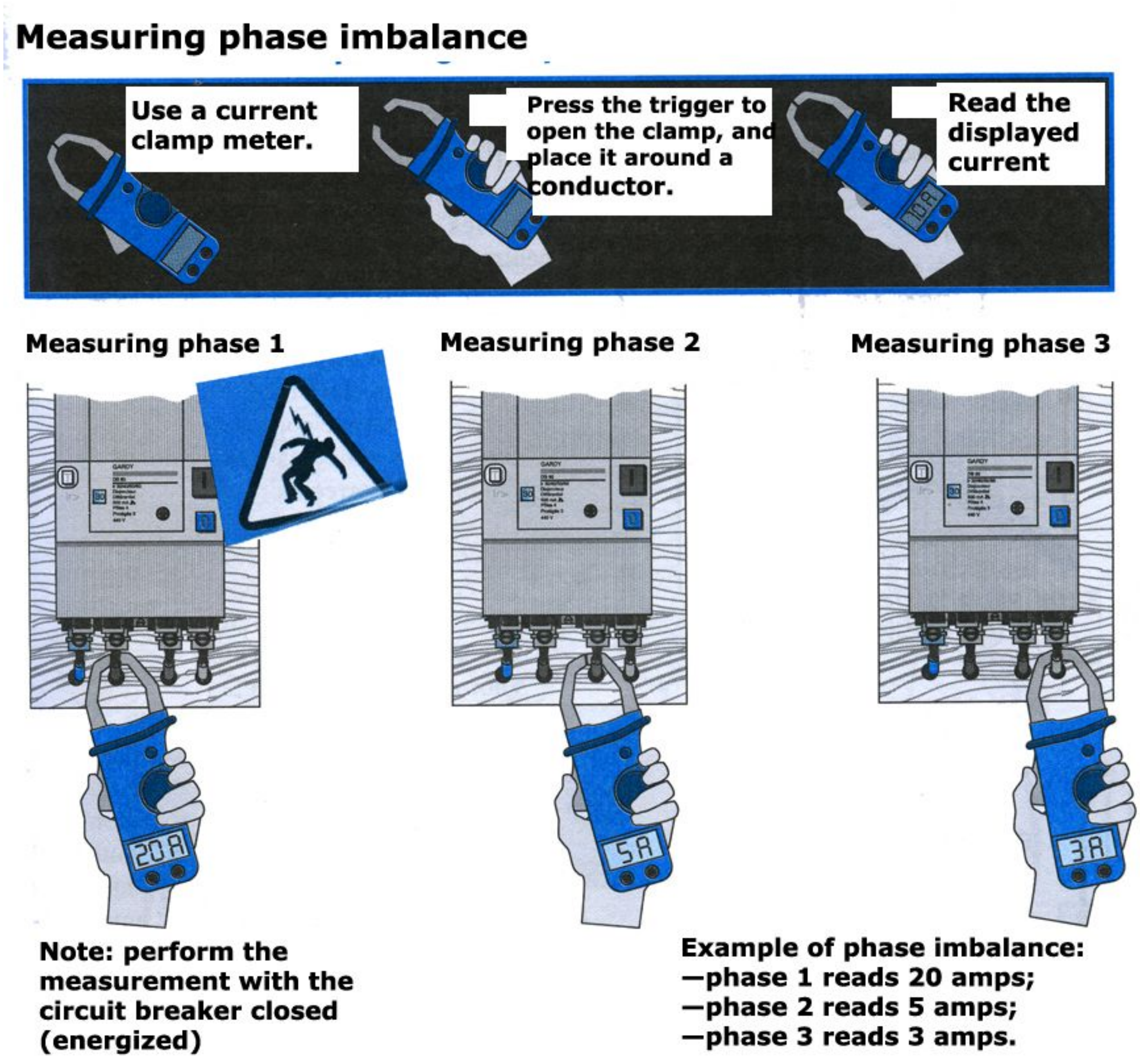
5. Device characteristics:
DB90 is the model number
s indicates that this is a selective device (designed to operate with high sensitivity 30mA RCDs). If this symbol is absent, the device is instantaneous.
Ir 15A/30A indicates the possible settings for maximum current.
Disjoncteur différentiel 500mA indicates that this is an RCBO with 500mA sensitivity.

3. PHASE BALANCING

For a good working of a three phase set up, power must be shared between all phases and should never be more than the available power per phase.
If phases are not balanced (power balanced), but without overlaod on any phase, voltage between phases (and between phase and neutral) could be desequilibrated, with a lower voltage on the more loaded phase et and a little bit less on the less loaded phase. These voltage differences will anyway remain not signifiant, if the wiring is properly sized (length and wire's section).

If one phase is overloaded (installed power is more than 1/3 of total power), the voltage difference can be more important and cause damage, and overload will cause the circuit breaker's setting off (if this one is properly designed, and thjs will cut off the full wiring).
To monitor phase balancing, we measure amperage with an ampere clamp. For this to be efficient, a maximum of consumers must be connected on, on the circuit.

Unbalancing between phases are generally due to either faulty three phase apparatus (three phased material is usually designed to respect phase balancing), or to overload of one of the single phase wiring (too many heavy load plugged on the same single phase circuit).

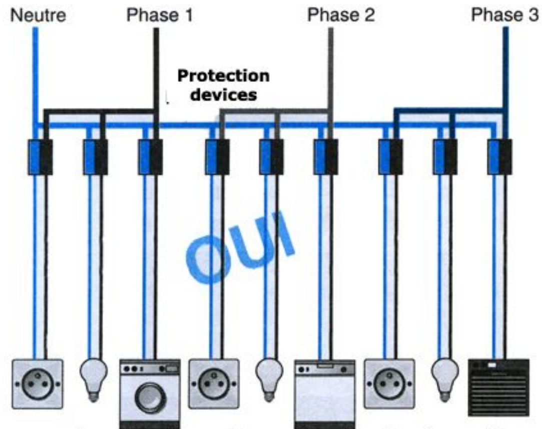


A significant difference in current indicates a phase imbalance.

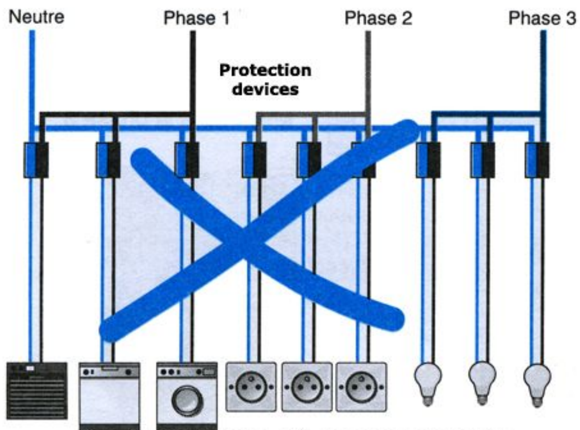
The imbalance is corrected at the distribution board, by distributing the 220V circuits more evenly—in terms of load—between the three phases.

Example:

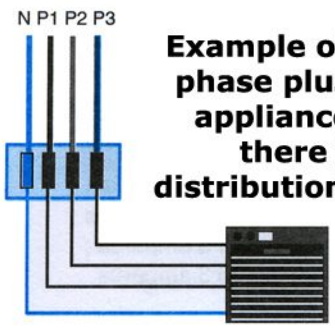
Distribution of circuits in a three-phase system



An example of good circuit distribution



An example of poor circuit distribution



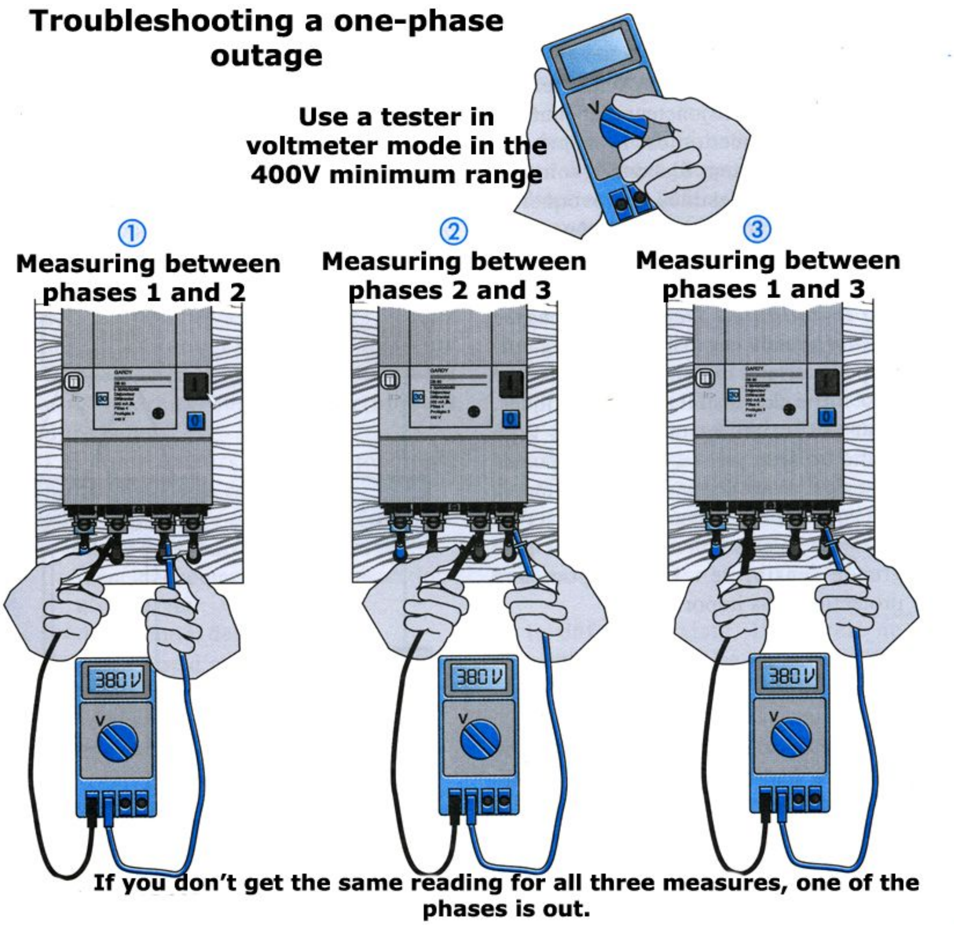
Example of a three-phase plus neutral appliance. Here, there is no distribution problem.

4. FAULTY PHASE

The power distributed from a supplier (more rarely from a generator) can be of bad quality. Indeed, according to production means and mostly wiring from local companies (often overloaded by some not very legal consumption…), the voltage available can be lower (very rarely higher) than rated voltage. In this case, voltage will be often unbalanced, and this can go up to the absence of one phase or two. .

Observable effects will be a different fonctionnement of single phase material, plugged on the differents wiring (bulbs lighting more or less, some not working material), and a bad way of working for three phased material (mostly the ones using three phased engines).

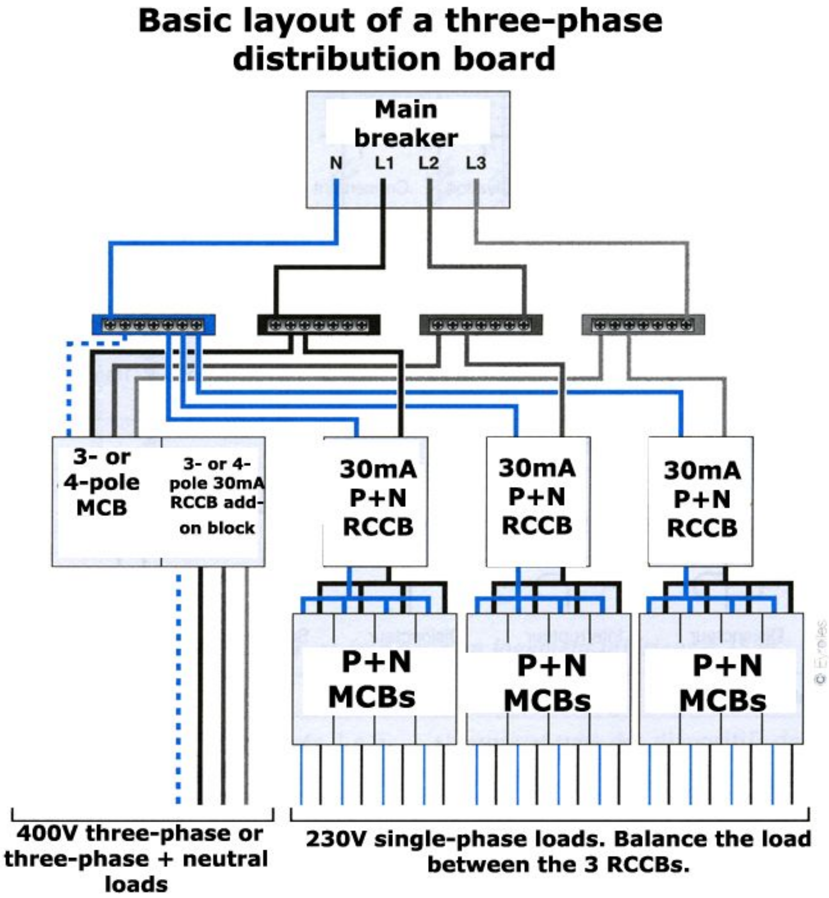
To diagnose a phase's voltage problem, measure voltage on the output of the circuit breaker, mostly voltage between neutral and each of the phases.



If at the circuit breaker level voltages are different or nil, the poblem is coming from the power supply.

5. THE DISTRIBUTION BOARD

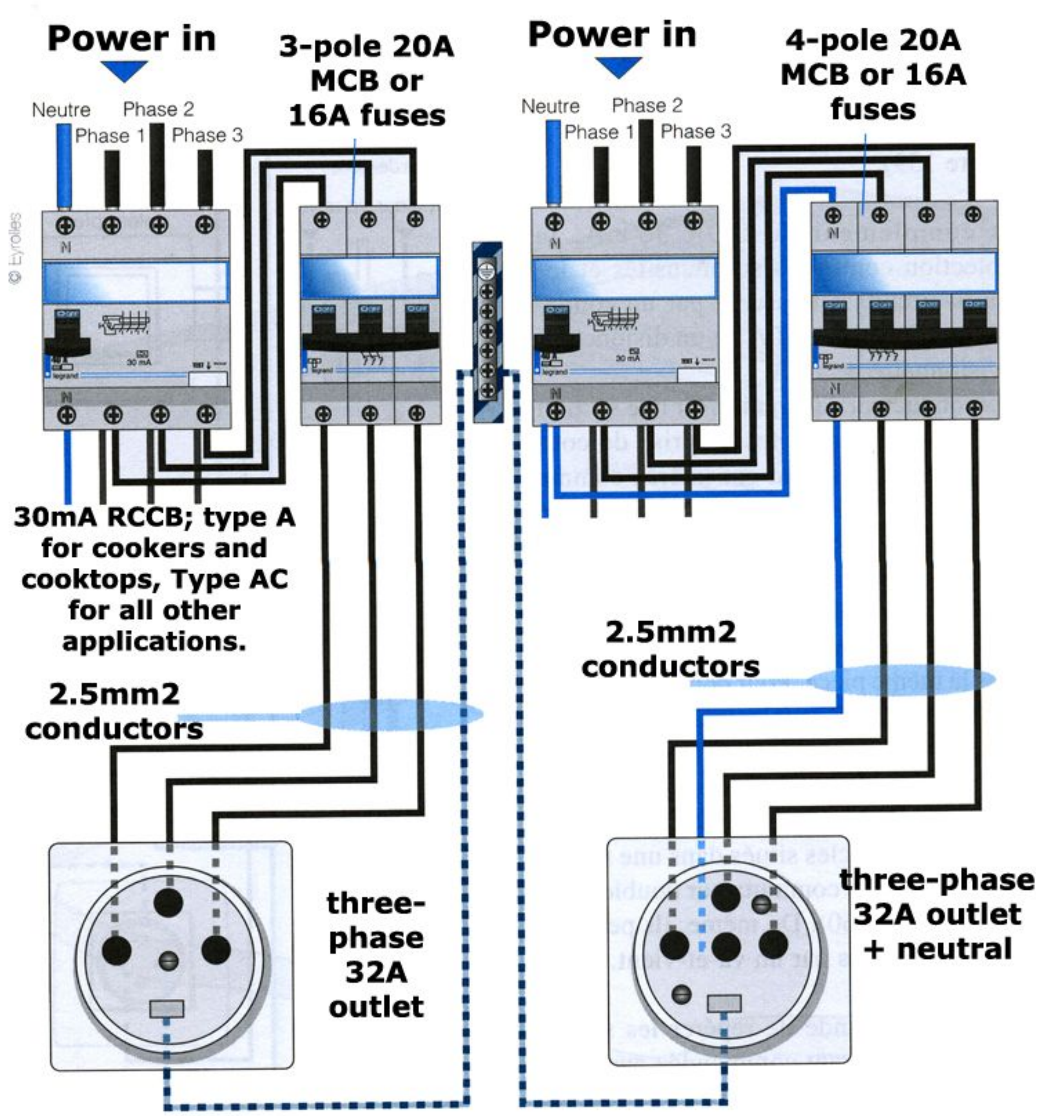
The basic wiring of a three-phase board is as follows:



Three-phase appliances are protected by three-pole devices, and single-phase appliances are distributed by sharing the loads between the three phases.

6. WIRING A THREE-PHASE 32A POWER OUTLET

The basic wiring in three-phase and three-phase + neutral systems is as follows:



Humans are protected by a 3-pole 30mA RCD, while circuits are protected from overcurrents and short circuits by a 3-pole 16A fused breaker or a 3-pole 20A MCB. For a three phase plus neutral outlet, overload and short circuit protection is provided by a 4-pole 16A fused breaker or a 4-pole 20A MCB. The cross-section of the feed wires is 2.5mm^2.

CURRENT PROTECTION AND CONVERSION

1. GLOSSARY

There are several different current conversion and overcurrent protection devices with similar-sounding names on the market.

1.1. CURRENT CONVERSION

- A TRANSFORMER converts an **AC** voltage signal of one magnitude into an **AC** voltage signal of a different magnitude. The type of current doesn't change.

Example of STEP DOWN transformers: 220VAC/15VAC and *220VAC/110VAC.*
Or 100VAC/220VAC, since there are STEP UP transformers, as well.

- A DC/DC CONVERTER converts a **DC** voltage of one magnitude into a **DC** voltage of a different, usually smaller, magnitude. Here again, the type of current doesn't change.

Example: the 24VDC/12VDC converter used in trucks.

- An ADAPTER converts the current to a different type: AC becomes DC. For example, 220VAC is converted to 7.5VDC in order to charge your mobile phone or power your pocket calculator. Both the voltage and the signal type are modified.

- On the other hand, an INVERTER or CONVERTER provides 220VAC from a DC voltage. This device is permanently connected to a 12VDC or 24VDC power supply. This allows you to work independently of grid power.
  Depending on the equipment quality, the AC signal produced will be more or less similar to the 220VAC supplied by electrical power stations. Be careful, though, because computer equipment needs a perfect signal. This means that even if there's a four-fold (or more) difference in price between the bottom-of-the-line model and one giving a perfect signal, price shouldn't be the only selection criterion.

- A (battery) CHARGER converts the **220 VAC** grid voltage to a lower **DC voltage** (13.6VDC, for example).
  Flooded lead acid batteries can be charged manually with an inexpensive charger. Solar gel and AGM batteries always need a regulated battery charger, which continually adjusts the voltage to the changing charge state of the battery. This type of charger is more sophisticated and expensive. Use of a manual charger, like those allowed for flooded batteries, will significantly reduce the life of a gel battery.

- A COMBI, as the name implies, combines several functions—it acts as both charger and inverter. Not only is the combined unit more compact, less expensive, and lighter than two separate devices—it also requires less wiring. There is no low-cost version of this product.

- INVERTERS and UNINTERRUPTIBLE POWER SUPPLIES (UPS) are used primarily for computers, to give you a very limited amount of time to save open documents and quit applications during a power outage. *These devices do not allow you to keep working during a power failure.*

1.2. EQUIPMENT PROTECTION

While there are several devices available to protect equipment, they work only with alternating current to protect equipment that runs on AC—e.g. office machines, radio communications, satellite phones, chargers, inverters—when the 220VAC voltage from the grid (or generator) is outside the generally allowed limits, or when the signal fluctuates widely and risks damaging equipment.

They are placed between the current source—that is, the grid or the generator—and the equipment.

Office equipment (such as PCs, printers, fax machines, telephone systems, etc.) and satellite communication equipment are most vulnerable to these problems.

On the other hand, incandescent lighting won't be harmed, although its brightness will fluctuate.

The nominal AC operating voltage is 230V. Energy producers claim tolerance limits of ±15%, or a useful range of 195 to 250VAC.

In many missions the grid voltage fluctuates constantly, either within or outside of this range; sometimes it's stable, but outside the range (often at the lower end, e.g. 190V).

There are three kinds of devices for protecting 220VAC equipment:

- LIMITERS:

These devices protect equipment against fluctuations in AC voltage from the grid or generator.

They allow the signal to pass as long as its amplitude remains within a pre-determined range (e.g., between 185 and 265VAC), but cut the signal off as soon as it falls outside the range.

Caution: these devices do not regulate output voltage inside of these limits.

- REGULATORS:

These devices protect equipment against fluctuations in AC voltage from the grid or generator.

They regulate the voltage, correcting it to produce an output voltage of 230VAC from any input voltage falling within a given range, e.g. 185 to 265 VAC.

They function as follows:

- within the tolerance range (i.e., for *input* voltages fluctuating between 165 and 260V), they reduce variations to produce an *output* voltage as close as possible to 230V.
- outside the regulation range: *non-guaranteed* correction, depending upon what's possible. Note that currently available models don't automatically shut off power if input voltage is outside the range.

Unlike the limiter described above, the regulator doesn't cut off output if input voltage is outside the regulated range.

This device is available in 500W, 1000W, 3000W and 5000W (5kW) models. There is no MSF model.

STABILISERS:
These combine the functions of limiters and regulators described above—that is, they maintain a *stable 230VAC output voltage*, as long as input voltage stays within the stated range—often around 200-250VAC—**AND** *cut off output outside of this range*, i.e. below 200VAC and above 250 VAC, for example.
This is the ideal protection device for office equipment.

2. DEVICES AVAILABLE THROUGH MSF

In order to have the right device in the right place, know that:

- MSF has chosen a series of products from among the different families described above. This choice is based on the quality-price ratio, using technical criteria that consider use in the field.
  We try out the equipment before making our selection, since other than price there's little to go on in choosing reliable equipment. There isn't much on the market that fits our needs.

- The selected devices might seem like overkill for your immediate needs, but experience has shown that in many cases, when you get just a charger, you end up requesting an inverter within a few months. Don't just consider your immediate needs, but also possible (and realistic) changes in your mission (e.g. telex radio upgrade, lighting, printer).

2.1. TRANSFORMER

We offer a "two-way" 220VAC/120VAC voltage converter. It can be used to run an 110V appliance on 220VAC grid voltage, or a 220VAC appliance on an 110VAC grid. It's used mainly in the Americas and in some African countries.

It's available in 800W and 1200W models. This is the maximum power rating of loads that can be plugged into the transformer, in either direction.
MSF codes: PELEVOLT10- 800W
PELEVOLT15- 1200W

2.2. 24-12 DC/DC VOLTAGE CONVERTER

A small device with low internal power consumption. There's a 12V 12A version suitable for VHF radios, and a 12V 24A version suitable for HF radios.

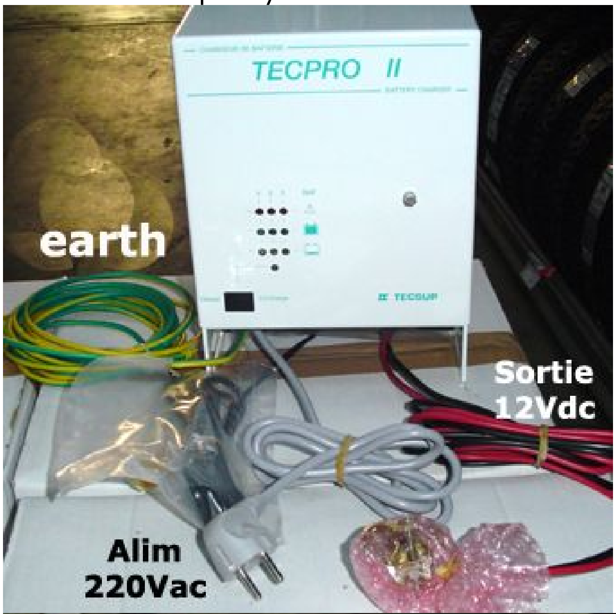
This is the most reliable solution for truck-mounted installations, and is preferred to directly connecting the transmitter to the 0-12V battery, which disrupts the charging system of the two batteries installed in series in the truck.
MSF code: PELEZBD0037

2.3. AUTOMATIC BATTERY CHARGER

It's small and comes in two versions: 25A and 60A capacity.

MSF models:

PELEBATC20- (photo)
PELEBATC60-



Old model:
PELEBATC15-
(included in VHF kits)

2.4. 300W OR 800W 12V INVERTER

Purpose: to produce 220VAC from 12VDC.
Note: this device causes interference in radio communication equipment. It has been replaced by the combi.

MSF model: PELEINVE800 (photo)
PELEINVE300
Output power: 300 or 800 watts, depending on the model.
Internal consumption: 10%.
Thus, to supply 800W to the load, the device needs 800W + 10% = 880W (or 73A at 12VDC!). *Given the high power consumption, for regular use you should plan on using several 12V batteries of the same power rating connected in parallel.*
Set-up: earth via the radio installation's earthing stake, for example.

2.5. THE COMBI: CHARGER + INVERTER

This device charges your battery using grid voltage, and supplies 220VAC even when grid power is out. It's suitable for RADIOCOMMUNICATION and OFFICE EQUIPMENT. It replaces the blue VICTRON charger/inverter. It's completely automatic and requires no handling. Wiring is permanent and there's no need to turn it on and off all the time.

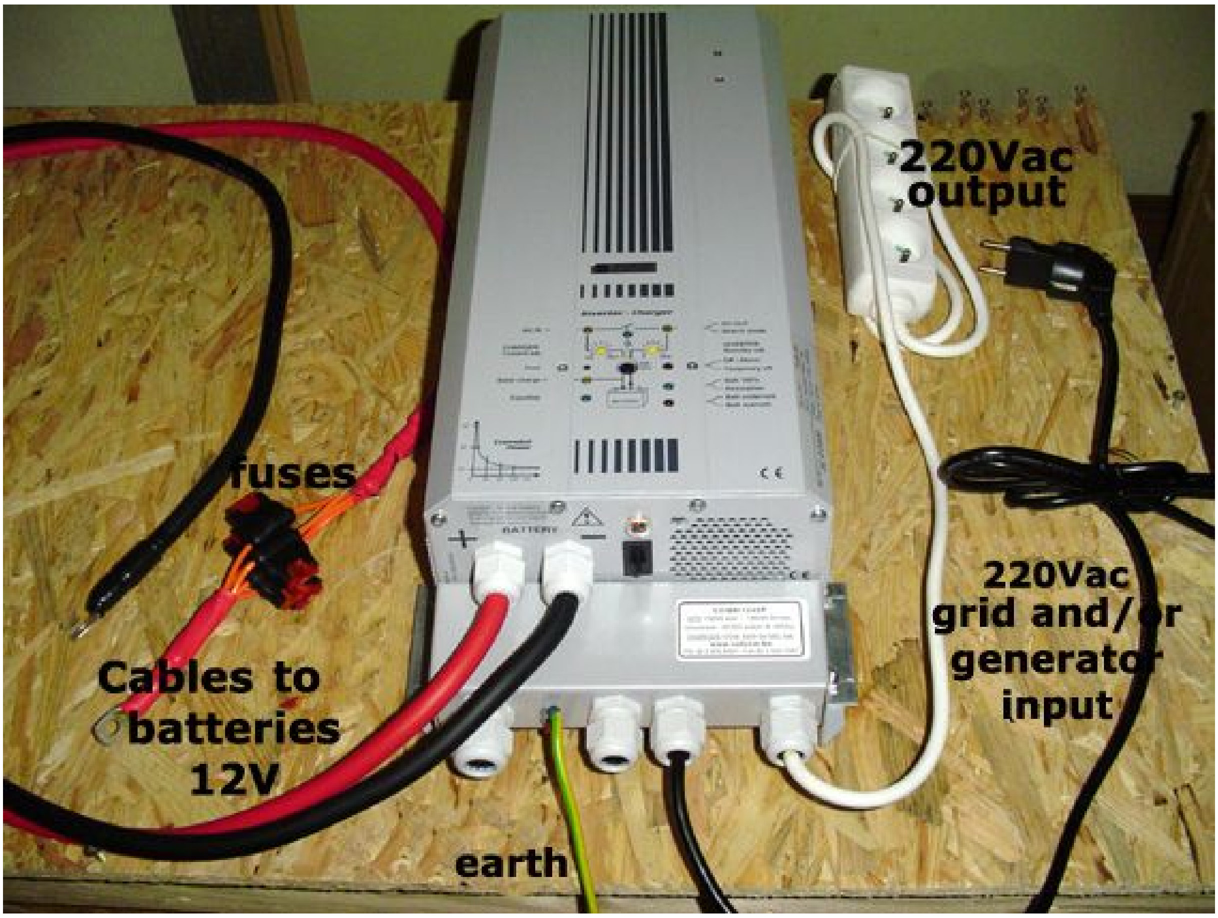
MSF code: PELEBATC45I
Model: COMBI 1245P
Inverter: Power output 1100W continuous, 1400W for 30 minutes.
Charger: 45A at 12VDC. Regulated charge for solar batteries.

Special features: This device enjoys a high level of protection against:

- reversed battery polarity,
- short circuit on the 220VAC output side of the inverter,
- overload on the output side of the inverter,
- grid voltage outside the tolerance range.

Internal consumption: 10%.
In order to supply 1100W to the load, the device needs 1100W + 15% = 1265W (or 105A at 12VDC!).
Given the very high power consumption, for regular use it's imperative to have several 12V gel batteries of the same amperage connected in parallel.

Set-up: earth via the radio installation's earthing stake, for example.



NOTE: the COMBI 1245P charger/inverter replaces the old Victron charger/inverters. It is also sent when only an inverter is requested.

Note:

The blue VICTRON charger/inverters are no longer being made, but since there are so many of them still in use in the field, it's important to describe them.

Blue VICTRON model.

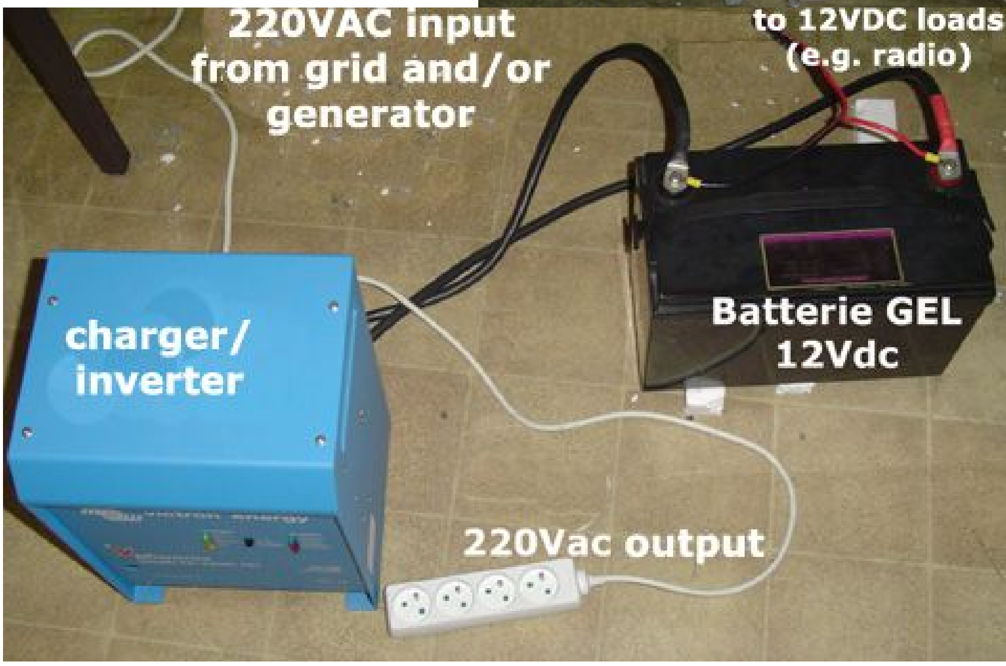
Output power: 1300W

Purpose: regulated charging of 12VDC gel batteries from the 220VAC grid. Regulation is completely automatic.

Note: this device causes mild interference in radio communication equipment.

installation : Set-up: earth via the radio installation's earthing stake, for example.

Or in a 450W version



2.6. VOLTAGE LIMITER

This device cuts off the output if the input signal is outside the range defined by the manufacturer.

There is no voltage correction within the range.

It's not suitable for office applications.

It *is* suitable for protecting older Victron charger/inverters.

The limiter's power rating is the total power of loads that can be plugged into it.

MSF model: PELEVOLL220

LANTRON (Power 2200W. Upper limit: 245Vac. Lower limit: 185VAC).

INPUT voltage:		**OUTPUT voltage:**	
220VAC	>>	220VAC	
200VAC	>>	200VAC	
185VAC	>>	185VAC	
180VAC	**>**	**0VAC**	
170VAC	**>**	**0VAC**	
185VAC	**>**	**RESET MODE**	
		MANUAL	*AUTOMATIC*
		(not reset)	
		0VAC	185VAC
200VAC	>	0VAC	200VAC
220VAC	>	0VAC	220VAC
240VAC	>	0VAC	240VAC
260VAC	**>**	**0VAC**	**0VAC**

In MANUAL mode you can only regain output equal to input by pressing the reset button on the case, provided you're within the operating range.

NOTE: MSF uses various LANTRON models (other power ratings and operating ranges).

2.7. STABILISER: LIMITER + REGULATOR

This stabilises output at 230VAC, and cuts off output when input is outside the admissible range. This is the ideal protection device for office equipment.

Consider the device’s power output, which must equal or exceed the total power required by all loads.

A 2000W stabiliser obviously can only supply 2000W, or about 9A at 220VAC.

This device is currently in development.

MSF Model: PELEZBD0145 230V/ 3000W
Cuts below 165V and above 250V
Stabilizes the output around 220V for input between 165 and 250V

CAUTION: the catalogue currently lists an item called a “Stabiliser,” code PELEVOLS150 – Power=1200W/1500VA. This is, in fact, only a voltage regulator.

It regulates within the 195.5 – 265V range, but doesn’t cut off the power supply beyond these limits.

It should eventually be replaced by the product currently under study.

3. SIZING

Once you've decided on the type of device, sizing (when there's a choice) is always based on a relatively simple calculation using the powers involved. You have to master the power formula P = U x I.

Each *load* (computer monitor, telephone system, etc.) has a data plate that details not only the manufacture code and serial number, but also its operating voltage in volts, and/or its power rating in watts, and/or the necessary current (I, in amperes).

The protection/conversion device chosen should always be capable of supplying the ***total power of all loads***.

Example: the data plate for an OKI C5300 printer says:
"220VAC – 4A"

- the printer's power consumption is therefore 220x4 = 880W.
- you want to run this printer on your 12V "radio" battery using an inverter. You will need an 880W inverter.
- The device that best matches your usage is the COMBI 1245, which provides 1100W of AC power. It will also charge your battery at 45A. The COMBI supplies an AC signal suitable for computers and other office equipment, and satisfies MSF selection criteria.

The calculation for the amount of energy needed from a battery is different, since the efficiency of the protection/conversion device must be taken into account.

4. INSTALLATION

- These devices hate dust, which—if allowed to build up—will eventually interfere with their cooling. Air intake and outflow vents and fans must be kept clear and dusted regularly. Don't place them on the ground—raise them up at least a foot or so.
- Protect them from the sun.
- Don't let the cables sit loose under furniture; secure them, making sure they're not coiled (which can cause overheating).

BATTERY: BASICS AND SIZING

1. MODELS

Battery operation and technology involve many scientific concepts. For those highly technical aspects we refer you to the MSF manual "B*atteries"*, written by MSF-Belgium's Jean Pierre Mustin (spiral bound A5 format, green cover). Here we'll settle for the layman's approach, which will take you right to the essentials and answer 99% of your questions. The remaining 1% will be answered in the above-mentioned booklet or by contacting your logistics department.

We'll confine ourselves to the two battery types most commonly encountered throughout the world:

1.1. THE CAR BATTERY

This is the conventional copper and lead battery used in vehicles, with two terminals and 6 caps allowing access to each 2 volt compartment or cell.

Characteristics:

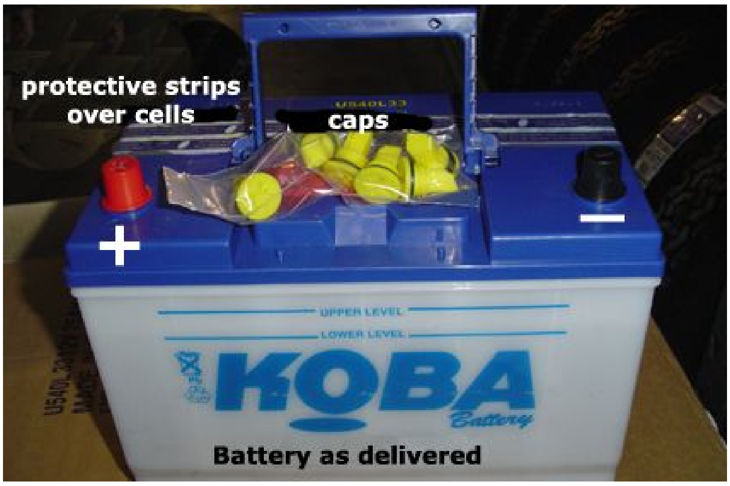
- inexpensive
- found everywhere
- charges with a basic, unregulated charger.

BUT:

- requires regular maintenance: the density of the water-acid mixture must be checked and adjusted regularly, since the water evaporates.

Uses: In vehicles, and for temporary replacement of gel batteries described below, when needed.

MSF code: PELEBATA070
12V 70Ah dry



The protective strip is removed immediately before filling the 2V cells with electrolyte.

1.2. THE GEL CELL BATTERY

Special feature: the water-acid mixture is in gel, not liquid, form.
These are recognizable by the complete absence of openings on the lid. Cables do not connect to terminals like those on flooded batteries, but to 8mm threaded pins.

Characteristics:
- more expensive to buy;
- less common throughout the world;
- not a suitable replacement for a flooded lead/acid battery in a vehicle (this would destroy it completely);
- requires a fully regulated charger.

BUT:
- no maintenance required;
- no air shipment restrictions;
- ready for immediate use upon delivery;
- ideal for solar applications;
- this type of battery has a 5-year lifespan at 20ºC. This lifespan decreases with increasing ambient temperature.

Uses:

Not to be used in a vehicle. Always suitable for radio communication and office applications.

The following equipment requires a gel battery:

- base HF and VHF radio communication devices,
- 12VDC/220VAC inverters,
- desk chargers for VHF walkie-talkies, which can work not only off of 220VAC, but also off of 12VDC via the "red and black" cord supplied with the VHF kit.
- Certain 12VDC lighting modules: fluorescent, low-consumption bulbs, etc.
- solar electric systems, which use these batteries for energy storage.

2. THE GEL CELL BATTERY

2.1. PARAMETERS

No matter what the technology, all batteries are characterized by their voltage (in volts) and capacity (in amp-hours). Autonomy is determined by capacity.
Manufacturers offer gel technology for all kinds of batteries, from the smallest to the largest, for a wide range of applications.

MSF offers only one model of gel battery: 13.8V voltage, 80Ah capacity.

MSF code: PELEBATS080
PELEBATS105
PELEBATS120

What will shorten a gel battery's life:

- *Using it at high ambient temperatures; unnecessary prolonged exposure to the sun;*
- *Using an inappropriate, non-MSF approved charger.*

What will destroy a gel battery: total deep discharge.

2.2. CHARGING AND DISCHARGING A GEL BATTERY

Unregulated charging of a gel battery will wear it out very quickly. Chargers available on the local market are not suitable.
Gel batteries can be charged using:

- one (or several) solar panels, via the voltage regulator supplied in the MSF kit,
- the COMBI 1245P, the MSF standard beginning in 2004. MSF code: PELEBATC45I
- older chargers, such as the VICTRON PALLAS1215 and 1225, and the COMBI 12450 and COMBI 12800.

Discharging a gel battery:
An "80Ah" battery should mean you've got 80Ah to use as you please. This isn't the case at all.
Totally discharging a gel battery will completely and irreversibly destroy it.

While manufacturers are even more conservative, we consider 60% of the battery's theoretical capacity, or 48Ah, to actually be available.

Thus you must make sure you never let your battery discharge completely, and recharge it sufficiently relative to how much is being consumed (see "Basic charge and discharge calculations," below).
Since the chargers selected by MSF are fully regulated, they take this specifically into account and adjust their charge accordingly, as long as you regularly supply them with 220VAC for a sufficient period.

Good to know:
As you go along using the battery without recharging it, electronic equipment (radios, etc.) will slowly start shutting themselves off, one after the other, as the voltage of the weakening battery

reaches their minimum operating threshold. This threshold is usually about 10VDC. With this kind of equipment, the risk of fully discharging the battery is practically nil.

However, an ordinary incandescent light bulb has no minimum operating voltage. A 12VDC automotive light bulb connected directly to the battery will stay on (becoming dimmer and dimmer) until the battery is completely drained, and thus destroyed. (By destroyed we mean that a charger will not even be able to raise the voltage of the battery to its 13.8V operating voltage.) You must therefore take care not to leave 12V light bulbs that are constantly on connected to the battery.

2.3. BASIC CHARGE AND DISCHARGE CALCULATIONS

The problem is simply stated, and can be summarized as follows:

- Charge:

An 80Ah battery is charged by the standard COMBI 1245P, whose output capacity is 45A. That is, it takes a bit less than 2 hours (2 hr x 45A = 90Ah) to charge the battery. If the charger has been on for only 30 minutes (because the grid has gone out, for example), the battery has received only 22.5Ah (0.5 x 45A).

Note:
If the battery is already almost fully charged, the charger, regulating its output, will have reduced the latter in such a way as to supply only what's needed to reach the battery's maximum capacity—80Ah.

- Discharge:

Let's imagine that the only loads connected to the battery are six 12V 20W light bulbs used 6 hours per day.

- At 12V, a 20W bulb draws a current of 20W/12V, or 1.6 amps.
- After 6 hours of operation this bulb will have drawn 6 hr x 1.6A, or 9.6Ah from the battery.
- With 6 bulbs, the daily consumption will thus be 6 x 9.6Ah = 57.6Ah.

Since the capacity of the charger is 45A, we'll need 57.6Ah/45A = 1.28 hours, or an hour and 15 minutes of charging, to maintain the battery level.

Reality differs from this example inasmuch as you might have several charging systems (e.g. solar and grid) and several different loads (e.g. radios, inverter, lights). Therefore, you must ensure that the average total charging capacity per day is greater than the average total consumption per day. Then make sure you have enough 12VDC battery storage capacity for the power you need (see the "COMBI" section).

2.4. ESTIMATES

2.4.1. Estimated output of different charging systems

Charging system	Amperage	Hours/day	Amp-hr/day
COMBI 1245 charger with, for example, 3 hours of 220VAC (grid or generator) per day	45A	3	135AH/d
PALLAS 1225 charger with, for example, 2 hours of 220VAC (grid or generator) per day	25A	2	50Ah/d
75Wc 12V solar panel That is, 75W/12V = 6.25A Insolation: 5 kWh/m²/day see chapter on solar installations	6.25	5 kWh/m²/day	31.25Ah/d

2.4.2. Estimated consumption of various loads connected directly to the 12V battery

Major loads			
Load	Amperage	Hours/day	Amp-hr/day
Six 12V 20W light bulbs for 2 hours/day That is, 20w/12v = 1.6A 1.6A x 6 bulbs = 9.6 A	9.6	2	19.2 Ah/d
HF Radio, 3 hours in contact mode Average 15A	15	3	45 Ah/d
HF Radio, 21 hours in standby mod Average 1A	1	21	21 Ah/d
VHF Radio, 1 hour in contact mode Average 10A	10	1	10 Ah/d
VHF Radio, 23 hours in standby mode Average 1A	1	23	23 Ah/d
VHF repeater, 7 hours in contact mode Average 8.3A	8.3	7	58.1 Ah/d
VHF repeater, 17 hours in standby mode Average 1A	1	17	17 Ah/d
Secondary loads			
SATCOM suitcase, 20 hrs. standby Average 0.4A	0.4	20	8 Ah/d
SATCOM suitcase, VOICE transmission Avg. 1A for 2 hours	1	2	2 Ah/d
SATCOM suitcase, DATA transmission Avg. 1.6A for 2 hours	1.6	2	3.2 Ah/d
Complete RADIOTELEX module (modem+OKI182 printer+Call One) 24H/24 Average 1A	1	24	24 Ah/d
Negligible loads			
VHF desk charger for walkie-talkie			NA
SWR meter: illumination			NA
CALL ONE module			NA
RADIOTELEX modem			NA

For safety reasons, we strongly recommend that you install a separate power supply system for this equipment.

2.4.3. Estimated consumption of various 220VAC loads supplied via the COMBI 1245P

NOTE: "hours of consumption" refers to the number of hours during which the device operates on the inverter, not on the grid or the generator.

Add 15% to the consumption per device to determine how much the batteries must supply.

With the COMBI (or other electronic devices) the concept of "efficiency" comes into play, because in addition to its 1000W output, the INVERTER must also supply power to its own electronics. A safe assumption would be 15%.

This means that to produce 1100W, the COMBI actually requires 1100+15%, or 1265W of battery power. In other words, 1265W/12V = 105 amps!

Since you can't discharge gel batteries more than 60%, you have 48Ah available (80Ah x 60%). Which boils down, roughly, to half an hour of inverter use at full 1100W output.

Major loads			
Load	Amperage	hours/ day	Amp-hr/day
Desktop PC without monitor 2 hours of use Max. power: 550W 550W +15% = 630W 630W / 12v = 52A	52	2	104 Ah/d
desktop PC MONITOR 2 hours of use Max. current: 0.8A x 220V = 176W 176W +15% = 202W 202W/12V= 16.8A	16.8	2	33.6 Ah/d
"240VAC/0.55A" laptop PC 2 hours of use 240x0.55= 132W 132w +15% = 152W /12V= 12.6A	12.6	2	25.2 Ah/d
OKI desktop printer Model C5300 - 230Vac, 4A Max. current during printing = 4A Printing time approx. 1hr/day 4x220=880W / 220V 880W + 15% = 1012W/ 12v= 84A	84	1	84 Ah/d
SF6800 230VAC 2.5A FAX machine Printing time approx. 1hr/day 230x2.5=575W 575W + 15%= 661W 661W/12V= 55A	55	1	55 Ah/d

1000W spot for 1 hour 1000w + 15%= 1150w/12v = 96A	96	1	96 Ah/d
1400W spot for 1 hour 1400w + 15%= 1610w/12v = 135A	135	1	135 Ah/d
3 100W bulbs for 6 hours 100w + 15% = 115w/12v = 9.6A	9.6	6	57 Ah/d
3 220V "low-consumption" 20W-90W bulbs for 6 hours 20w +15% = 23w/12v = 2A	2	6	12 Ah/d

2.5. SAMPLE CALCULATION WITH 12VDC LOADS

1. Determine which 12V loads will be connected to the battery, and how many hours per day they'll be used:

Load	Amperage	hours/day	Amp-hr/day
HF Radio, 3 hours in contact mode Average 15A	15	3	45 Ah/d
HF Radio, 21 hours in standby mode Average 1A	1	21	21 Ah/d
SATCOM suitcase, 20 hrs. in standby mode Average 0.4A	0.4	20	8 Ah/d
SATCOM suitcase, VOICE transmission Avg. 1A for 2 hours	1	2	2 Ah/d
SATCOM suitcase, DATA transmission Avg. 1.6A for 2 hours	1.6	2	3.2 Ah/d
Six 12V 20W light bulbs for 2 hours/day That is, 20w/12v = 1.6A 1.6A x 6 bulbs = 9.6 A	9.6	2	19.2 Ah/d
		Total	98.4 Ah/d

You've got to produce 98.4 amp-hours/day.

2. Determine your production

You've got a combi that supplies 45A. That is, you'll need 98.4Ah/d ÷ 45A = 2.2 hr/day, or almost 2 hours and 15 min. of charging, either on the grid or the generator.

3. Size your storage capacity

You have 80Ah gel batteries dischargeable to 60%, i.e., 48Ah useable.
Two batteries in parallel yield a capacity of 2 x 48 = 96Ah, more or less covering your needs.

2.6. SAMPLE CALCULATION WITH 12VDC AND 220VAC LOADS

You've got the standard MSF combi.

1. Determine the power ratings of your 220VAC loads and make sure that the sum is less than or equal to the capacity of the combi—that is, 1100W.

NOTE: there's no need to add 15% for this calculation. We're not calculating the amount of power the battery needs to supply the combi.

desktop PC without monitor Max. power: 550W	550W
desktop PC MONITOR Max. power: 176W	176W
1000W spot for 1 hour 1000w	1000W
	1726W

This exceeds 1100W. Don't use the PC and the spot on the combi at the same time, or use a lower power lamp.

2. Determine the daily operating time, without grid or generator power, of the devices plugged into the combi. Add the 12VDC equipment connected directly to the battery.

This time you need to add 15% to the power consumption of the 220VAC equipment to account for the efficiency of the combi.

Load	Amper age	hours/day	Amp-hr/day
desktop PC without monitor 2 hours of use Max. power: 550W 550W +15% = 630W 630W / 12v = 52A	52	2	104 Ah/d
Desktop PC MONITOR 2 hours of use Max. current: 0.8Ax220V = 176W 176W +15% = 202W 202W/12V= 16.8A	16.8	2	33.6 Ah/d
12V set-up from part 1			98.4 Ah/d
		Total	135Ah/d

You've got to produce 236 amp-hours/day.

3. Determine your production

You've got a combi that supplies 45A.

That is, you'll need 236Ah/d ÷ 45= = 5.24 hr/day, or almost 5 hours and 15 min. of charging daily, either on the grid or the generator.

4. Size your storage capacity

You have 80Ah gel batteries dischargeable to 60%, i.e., 48Ah useable.

Five batteries in parallel yield a capacity of 5 x 48 = 240Ah, easily covering your needs.

NOTE: for MSF missions it is generally preferred that you have one combi just for the radio communication system and another combi just for office equipment.

In the example above, the second combi would only have to supply 104 + 33.6 = 137.6Ah/day.

In other words, about 3 hours of charging.

You'd need three 80Ah batteries.

2.7. CONSTRAINTS AND SOLUTIONS: WHAT'S POSSIBLE

Using the COMBI in INVERTER mode:
We see that continual use of the COMBI 1245P in inverter mode (i.e. 1100W) consumes huge amounts of battery power: 1100W+15% = 1265W/12V = **105A**; that is, more than a single 90Ah battery can supply in an hour. This same combi supplies 45A to the battery when on grid power. In other words, the combi takes twice as long to charge batteries than it takes its inverter to empty those same batteries.

Conclusion:
Regular use of the COMBI 1245P in inverter mode requires:

- Using several batteries in parallel.
  For example, four batteries would yield > 80Ah x 4 = 320Ah.

- A poxerful charging:
  Significant availability of grid power, for example 8 hours at 45A (combi output) to yield 360Ah, plus a generator for when the grid is out and/or solar charging from multiple panels.

Batteries in parallel: increase energy storage capacity
Whether you use the COMBI 1245P in inverter mode or not, you can increase your energy storage capacity, and thus autonomy, by connecting more batteries in parallel: this is done by connecting positive (red) terminals to each other and negative (black) terminals to each other. The amperage is additive. The voltage remains the same—12VDC.

Given the combi's 45A charging capacity, its appetite for power in inverter mode, and the fact that batteries can't be discharged more than 60%, having two or even three batteries is strongly recommended, if not required.

2.8. CHECKING A GEL BATTERY'S CHARGE STATE

The lifespan of a gel battery is, roughly speaking, 5 years—as long as it's charged with an appropriate (MSF approved) charger. This is, of course, the manufacturer's estimate for use in industrialized countries at 20ºC, and not a formal factory guarantee.

Here are some different testing methods:

- open-circuit voltage (OCV) testing: indicative only.
  With the battery completely disconnected from the circuit, measure the voltage using a voltmeter set to VDC 20V.
  This method only gives you an indication, nothing more. You can measure 12 or 13.8V without knowing for sure whether the battery is good/can hold a charge.
  On the other hand, if the OCV is low (e.g. less than 6V), you can be fairly sure that the battery is no longer useable.

- Closed circuit voltage (CCV) testing: interesting and useful.
  Voltage is measured with a voltmeter set to VDC 20V; the battery is connected to the circuit, with *all loads connected and all charging systems disconnected.*

  The voltmeter reading is taken with a major load operating (your HF radio transmitting, for example).
  Steps:
  - Disconnect all charging systems from the battery.
  - With the HF radio off, measure the voltage, which should be about 12 or 13VDC.
  - Start transmitting with your HF radio, and speak into the microphone. As you're doing this, the voltage should drop a few volts to, say, 10V.

- Stop transmitting. The voltage should immediately return to its initial level.

Note:

There's no major risk in attempting to charge (with an MSF-approved charger) a battery that's actually irretrievably destroyed. Measure the battery voltage before and after one hour of charge to see if it's gone back up to 12 or 13V. If it has, perform a CCV test.

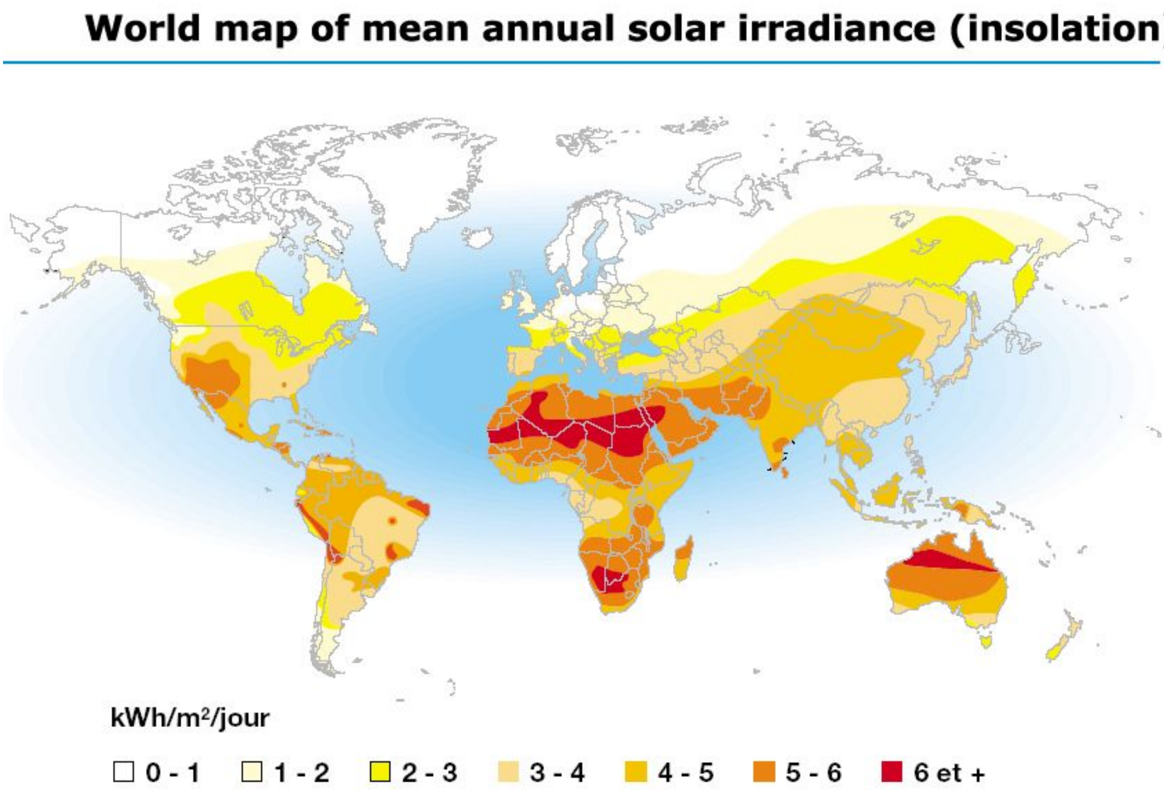
SOLAR INSTALLATIONS

1. EQUIPMENT

1.1. BACKGROUND

The production of DC electricity from sunlight is clean, quiet, requires little maintenance and is durable (provided you start with good quality materials).

The engergy produced daily by a solar panel will depend on the location's **mean daily solar irradiance**. This information is essential to size an installation: it will vary according to the season. We will consider the value of the less insolated month . It is given by the forecast services or by using the followin chart. It is expressed in KwH/m²/day



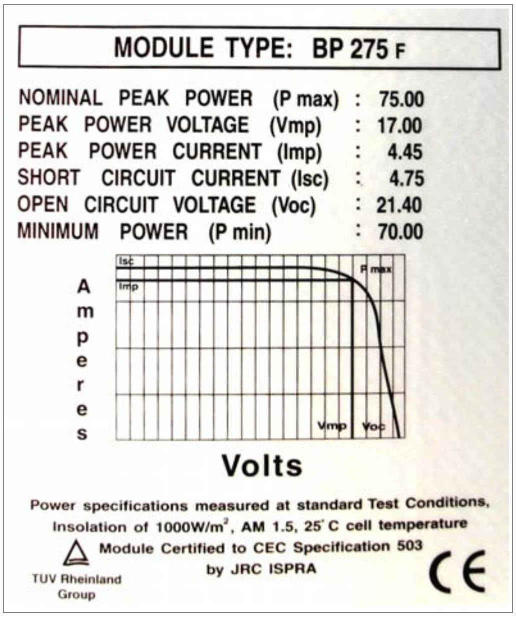
Ex.	**Niger irradiance is 6Kwh/m²/day**
	Bordeaux irradiance is 2,5Kwh/m²/day

1.2. THE PANEL

The characteristics of the panel given by the manufacturer correspond to the **STC (standard test conditions)** norm, when the **peak power** (Pmax, W_c, W_p) is established under standardized conditions:

- solar irradiance 1000W/m^2
- panel's temperature conditions: 25ºC (and, respectively). It's specified by the manufacturer.

The characteristics are usually written on the back of the panel. For example, for the MSF kit KPROKLIG70S kit:



For this panel , we can read:

Peak power	=	peak power voltage	x	peak power current
Pmax	=	Vmp	x	Imp
75Wc	=	17V	x	4,45A

The data given are:

- **short circuit current I_{sc}** – The current is directly measured at the panel without any load, the voltage is thus equal to zero.
- **peak power or rated current) I_{mp}** – The current produced under STC conditions.
- **open circuit voltage V_{oc} –** The voltage is measured directly at the panel without any load, the current is thus equal to zero in an opened circuit.
- **peak power or rated voltage) V_{mp}** - The voltage produced under STC conditions
- **nominal peak power or rated power P_{max}** – The peak power is the result of : $P_{max} = V_{mp} \times I_{mp}$

Those characteristics are the qualitative reference of the panel, mainly for purchasing. In reality , the performances of the module will depend on the real conditions of use.

In the market place, we can find panels of 80, 100, 120 Wc.

1.2.1. Influence of irradiance on the module

In reality, when the irradiance is lower than the STC irradiance (1000w/m²), the measured rated current will be lower than Imp as stated on the label of the panel and the measured rated voltage will also be lower than Vmp.

The delivered power will thus be lower than the peak power:

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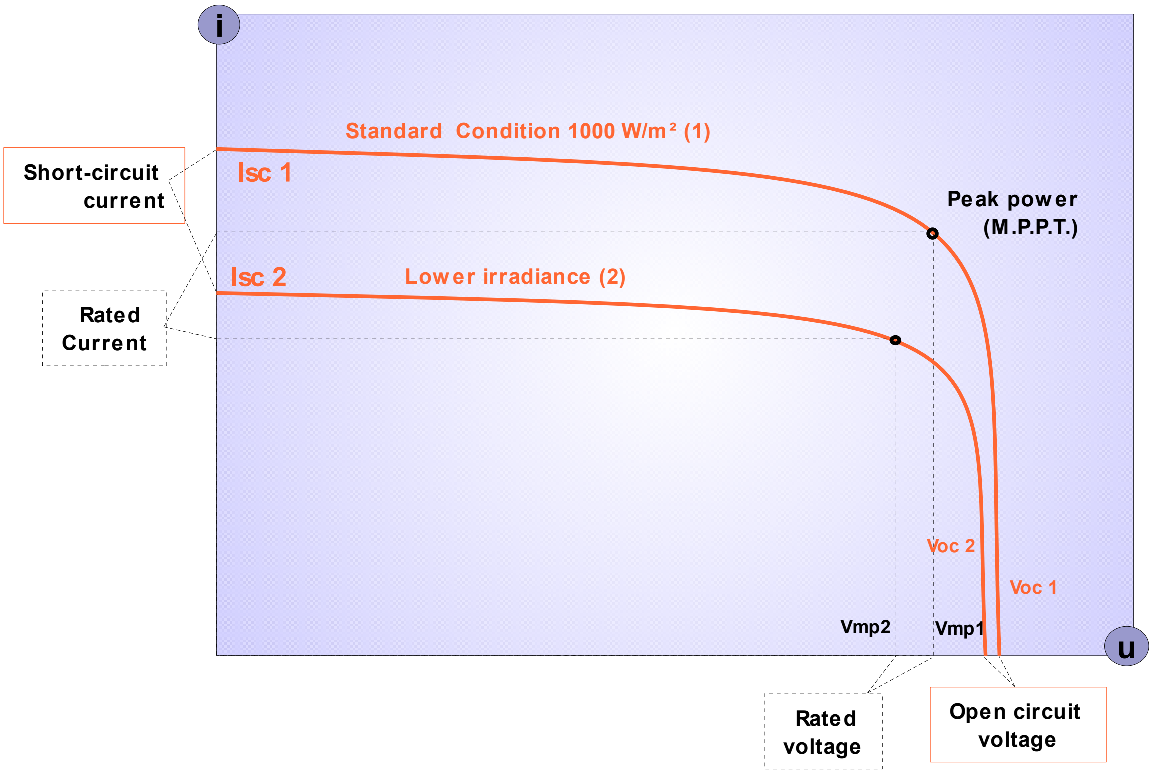


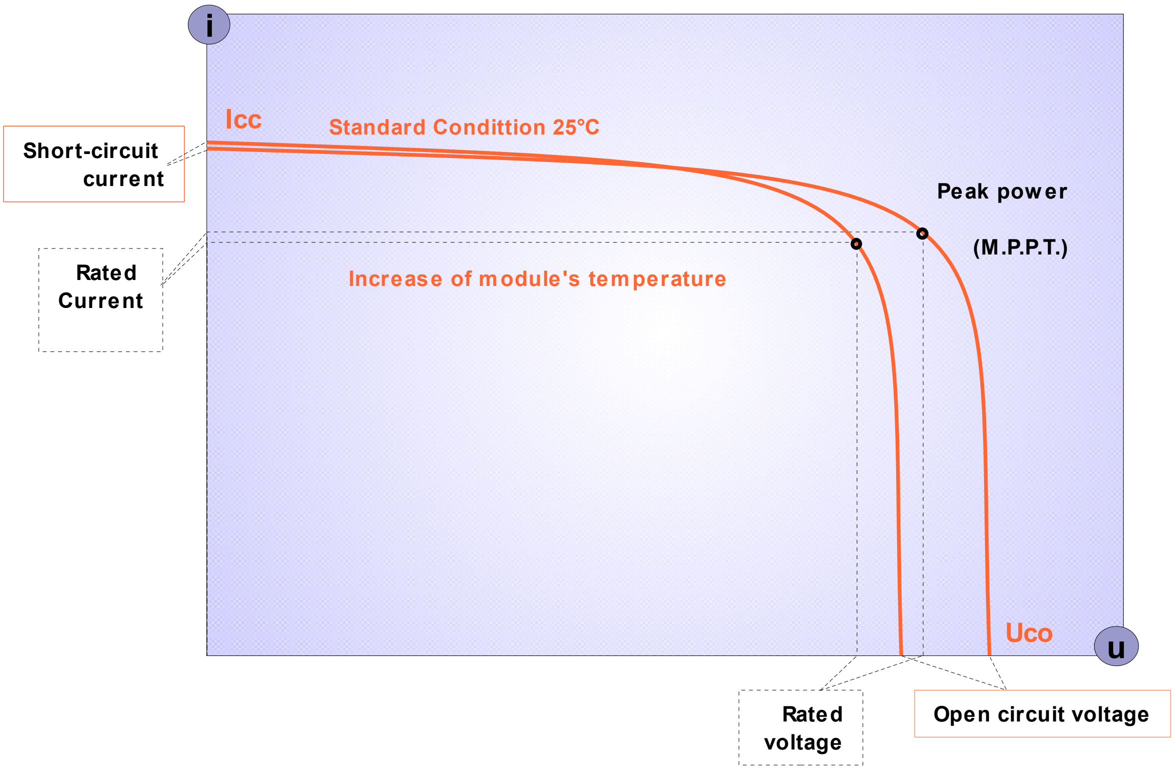
The **MPPT*** (maximum power point tracking) function of the regulator will look for the best rate voltage-current to optimize the production.

NOTE: Contrary to popular belief, a cloudy sky that hides the sun does not stop your system from operating. It's the luminosity that matters. Even with very little sunshine the panel will produce energy and its terminals will carry some voltage.

1.2.2. Influence of temperature on the module

As before, when the temperature is increasing above the STC temperature (25°c), the measured rated current will be lower than Imp as stated on the label of the panel and the measured rated voltage will also be lower than Vmp.

The delivered power will thus be lower than the peak power:



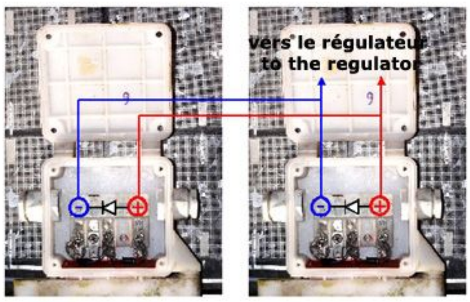
1.2.3. Performances

Both 12VDC and 24VDC systems are available. 12V systems suit our needs. 24 and 48V systems are used in power stations.

Increasing the number of panels will increase energy production. All the panels must operate at the same voltage (12VDC). 12V and a 24V panels must not be wired together.

Panels are connected to each other in **parallel**—that is, by linking together all of their POSITIVE (+) terminals, and all of their NEGATIVE (-) terminals as shown on the following picture:

Cables should be of sufficient diameter, and under no circumstances smaller than the cables supplied with the kit.



Câblage parallèle

1.3. THE REGULATOR

The regulator is an electronic unit whose job it is to control the current flow—both the current coming from the panels to charge the batteries, and the current coming from the batteries to power the loads.

It controls the charge and discharge of the battery by disconnecting the panel when the batteries are fully charged, and by cutting the power to the load when the battery is too low.

The regulator is thus at the hub of the installation.

It has a blocking diode that prevents the battery from discharging to the panel at night.

The maximum power output depends on the regulator. For the MSF kit KPROGLIG70S :

Regulator rating	Regulator power
8A	96W
12A	144W
20A	240W
30A	360W

Example: A 12A regulator can power loads totalling 144W or less.

NOTE that 12V devices that consume more than the values above should be connected directly to the battery, and not to the regulator. This is the case for radios, for example.

When connecting panels in parallel, the regulator must be slightly more powerful than the sum of all the panels connected to it. Three 75W panels (yielding 75W/17V=4.42A) will generate 13.2amps. A 20Amps regulator would be appropriate in this situation.

1.4. WIRING

In general, the cables supplied with the kit should be all you need for installation. Extending them can significantly reduce efficiency; just one extra metre can drastically reduce the power output.

Colours and conventions:
The RED (or blue) cable represents the POSITIVE pole.
The BLACK (or brown) cable represents the NEGATIVE pole.

Short cables with a large cross-section are preferred.
The table below gives the minimum diameters for wiring between the:

regulator and the panel:	about 10m,
regulator and battery:	about 1m,
regulator and junction box:	about 5m,

as a function of the regulator fuse rating:

8A	-	$6mm^2$
12A	-	$10mm^2$
20A	-	$10mm^2$
30A	-	$16mm^2$

We should add that between the battery and radio you must use the original cable that came with the radio, without cutting or extending it. From the junction box to the loads use at least $2.5mm^2$ conductors. See also the "Conductors" section. In practice, always try to reduce cable length and use large cross-sections.

1.5. THE BATTERY

NOTE: In solar systems, batteries are gel battery. See « Batteries ».

The battery is protected by the fuse of the regulator of the MSF kit.

ATTENTION, , you can find some regulators without any fuse. In this case, you will have to protect the battery with a fuse on the positive cable between the battery and the regulator.

2. SIZING

Solar systems in remote areas are easy to use but they have to be carefully designed because of intermittence of the source.

Above techical aspects, the system reliability will depend mainly on the level of the loads.

The steps to size a solar system are:

1. Calculation of load
2. Sizing of solar panel
3. Sizing of batteries
4. Selection of regulator
5. Sizing of wiring and protection

2.1. CALCULATION OF LOAD

Controlling the loads of he consumers is the key for an autonomous and reliable use of the solar panels.

Generaly speaking, any electrical load has to be efficient to receive solar power. Resistance such as heater, hair-dryer, oven, washing machine...), low performance lighting (incandescent, halogene...) or electrical tools have to be banned as a load on a solar system. Use preferably a generator for those consumers.

We have to establish an exhaustive list of all the loads: refer to chapter « Batteries »

Large 12VDC consumers will be connected straigth to the battery, others like the lighting will be connected to the regulator. Finally, 220VAC consumers will be supplied through the Combi 1245P chargeur/inverteur.

Wh (watthour) is the unit the calculate the daily need of energy.

With a Combi 1245P for 220VAC consumers, we have to consider the efficiency of the combi by adding an extra 15%.

The daily need calculated will be increased by 20% as a security measure.

Example: Office Equipment for a mission in Niger

Equipment	Power (W or VA))	Quantity	Daily hours of user (H)	Daily energy needs (Wh)
	A	B	C	A x B x C
EQUIPMENT ON THE REGULATOR				
Fluocompact litghning 20W	20	4	2	160
Power max	*20*		*S/T 12Vcc*	*160*
EQUIPEMENT ON COMBI				
Laptop Pc 230Vac / 0,55A	132	1	2	264
Printer HP 930I 230Vac/ 0,5A	110	1	0,5	55
Power max	*242*		*S/T 230Vac*	*319*
			Ccombi efficiency: +15%	*366,85*
EQUIPEMENT DIRECTEMENT SUR BATTERIE				
Radio HF en fonctionnement 12Vcc / 15A	180	1	1	180
Radio HF en veille 12Vcc / 1A	12	1	23	276
Module radiotelex complet 12Vcc/1A	12	1	24	288
Power max	*204*		*S/T 12Vcc*	*744*
			Total needs	
			Wh/j	1270,85
			Security 20%	1525,02
			Kwh/j	**1,53**

The total in Kwh/day will be used to size the solat panel. It has to be accurate.

2.2. SIZING OF SOLAR PANEL

The power to be produced by the solar panel is calculated with the following formula:

Peak power	=	Daily needs	/	Daily irradiance
Wc		Wh		kWh/m²/jour

Result will be finalised according the peak power of the available panels.

Example of Niger

Daily irradiance: 6 kWh/m²/day

Daily needs: 1525Wh (calculation of the loads)

Peak power: 1525/ 6 = 254Wc

Available Modules: **12V / 75Wc**
12V / 100Wc
12V / 120Wc

Number of solar panels required: We have to choose between :

4 X 75Wc in parallel 12V

OU 3 X 100Wc in parallel 12V
OU 2 x 120 Wc in parallel 12V

Reversly, to know the production you can expect from a known solar panel, use the following formula:

Daily production	=	Peak power	x	daily irradiance
Wh		Wc		kWh/m²/jour

Example: In a mission in Thaïlande, you have in stock a MSF kit KPROKLIG70S of 75Wc.

Ldaily irradiance is: 4 Kwh / m² / day.

Daily production = 75 Wc x 4 = 300 Wh/j

This panel will supply 300/12 V= 25Ah to the battery.

Compare to the combi 1245 which can supply 45 A, the solar panel will save ½ hour of use of the combi, ie of the generator.

2.3. SIZING OF BATTERIES

The daily needs calculated will help us to calculate the quantity of energy to store in the batteries.

The unit is the amper hour (Ah), dividing the need (Wh) by the voltage, 12V.

Example of Niger: 1525Wh of daily needs , under 12V ;

Batteries Capacity: 1525/12 = 127 Ah

Tthis battery capacity is for one day of use, it will have to be timed by the number of days of autonomy required. **Usually, We consider 3 days of autonomy for a solar system.**

Example of Niger:
127Ah for one day,
3 days of autonomy = 3 x 127= 381Ah

NOTE: the life duration of a battrey depends on the use. Therefore, it is very important to limit the discharge rate to a maximum of 20 to 40% of its capacity. A complete discharge will be fatal.

Discharge rate will interfere in the sizing: if 40% of the battery has to stay permanently, only 60% of the capacity is actually useful.

Example of Niger: if 381Ah represent the 60% of the battery 's capacity:

we need a total capcity of: 381 / 0,6 = 635Ah

Fox example with 6 batteries 120Ah PELEBATS120 in parallel.

The life duration is also linked to the outside temperature: optimum at 20°c est également liée à la température ambiante: optimale à 20°C, iti s divided by 2 at 30°c. Therefore, it is very important to prevent an exposure of the batteries to heating sources.

2.4. SELECTION OF REGULATOR

Example of Niger: Solar panel of MSF kit

Data: 75Wc Imp= 4,45A Vmp= 17V
4 solar panels in parallel will produce 4 x 4,45 = 17,8A current

-> We will choose a regulator with a 20A fuse. To be ordered to MSFLog.

2.5. SIZING OF WIRING & PROTECTION

2.5.1. Calculation

By using tables, abacus or forula give in the chapter« conductors », we can calculate the section of the wires.

Section Panels/Regulator: 10m, 12V / 20A -> abacus 12V : 25mm²

Section Regulator/Batteries: 2m, 12V / 20A -> abacus 12V : 6mm²
Section Regulator/Loads: 10m, 12V / 160W / 13A -> abacus 12V : 16mm²

2.5.2. Protection against lightning strikes

A surge protection module is required to protect the system from overlaods. Between the panel and the regulator, it has to be linked to the earth to evacuate ligthning strikes from the metallic structures of the panels.

2.5.3. Earthing

Earthing will protected people and equipment: panels, les parafoudres, combi 1245 and the negative pole of the battrey will be connected to earth.

3. INSTALLATION

3.1. SITE SELECTION:

Panels should be placed so that they aren't shaded (by trees, buildings, etc.) during the day, no matter what the sun's angle throughout the year.

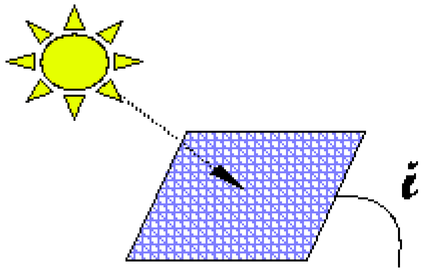
Some space will be kept between the panels and the surface supporting them in order to facilitate natural convection and limit the overheating.
Panels are fragile. Secure them to a frame or directly to the roof, to prevent the wind from carrying them away. Also secure cables along their entire course. Make sure the panels are out of the reach of children and animals. Ditto for cables.

The regulator should be placed in a dry, shaded area and well secured against chock, ideally in a closed box.

Batteries will be also protected from humidity, chocks and heating sources. At least in a well ventilated area but preferably in a secured container.

3.2. TILT

Panel tilt should equal the latitude which is a good compromise between winter and summer for a yearly production.



i = tilt.

For locations at less than 10º latitude north or south—i.e., near the equator—maintain at least a 5º tilt to allow shedding of rainwater.

Example	**Maradi - Niger: latitude 13°28mn North -> Tilt: 13°**

3.3. ORIENTATION

Panels should be oriented:

- to the south in the northern hemisphere
- to the north in the southern hemisphere.

An East / West tolerance of 45° is acceptable but a correction factor will have to be used for the calculation of the panel output:

Orientation	Correction Factor
East	0,90
North/South east	0,96
North/South	1,00
North/South West	0,96
West	0,90

example: **Maradi in Niger ; Needs: 1525Wh**

latitude of the location 13°

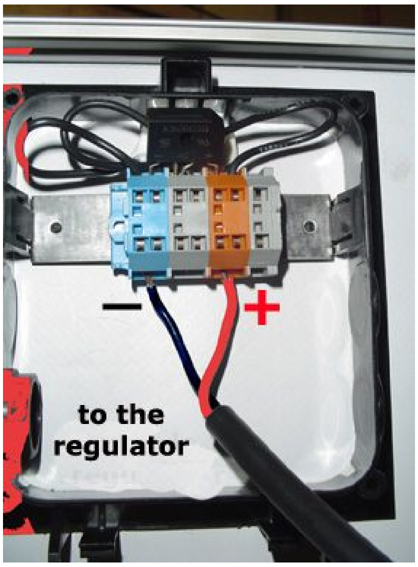
Orientation South East -> correction factor = 0,96

corrected daily needs: 1525 / 0,96 = 1588Wh

3.4. CONNECTION TO REGULATOR

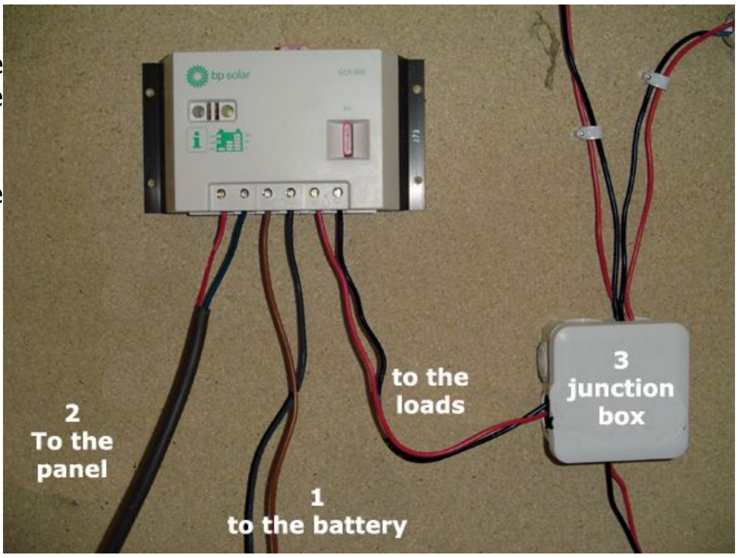
Once you've decided where to put the battery, the regulator, and the panels—according to cable lengths and the above recommendations—system components should be connected to the regulator in the following order:

1. Battery:
   - First, remove the fuse on the + cable.
   - Connect the cables to the regulator: red to the + terminal, black to the –.
   - Connect the other end of the red cable to the battery's + terminal
   - Connect the other end of the black cable to the battery's – terminal.
2. Panel:
   - Cover the panel to prevent it from producing any electricity.
   - Connect the cables to the back side of the panel. Red to red and black to...blue.
   - Connect the other ends of these cables to the regulator: + and – terminals.

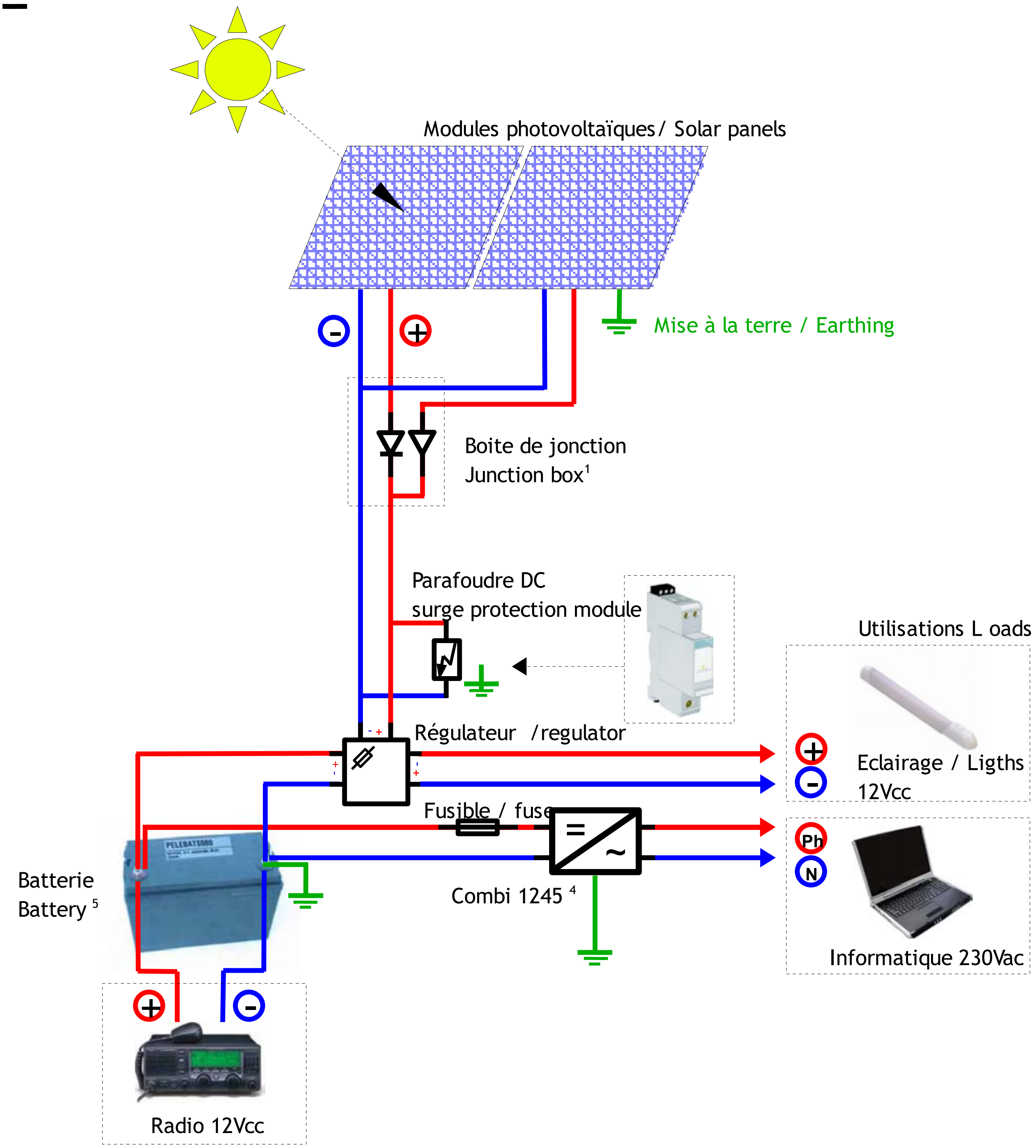


3. Loads:

- Switch all loads off, and connect the cables from the junction box to the regulator.
- Next, check all the polarities and the quality of the connections.
- Now, install the battery cable and regulator fuses.
- Remove the solar panel's protective shield.
- Switch the loads on.



3.5. INSTALLATION PLAN



[1] When using only one panel, the junction box is not necessary.

4. MAINTENANCE

Solar panels must be kept clean—otherwise, they become less efficient. Dust them regularly, and wash with water—don't use abrasives, which can scratch the glass. Make sure to clean the panels once a month, so that their output doesn't decline.

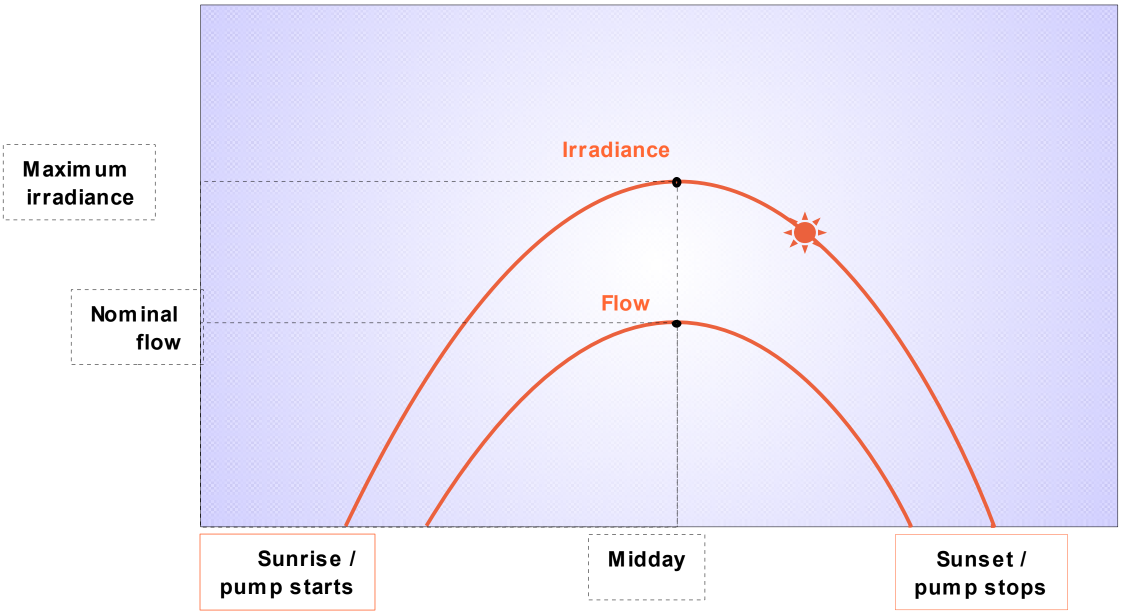
Periodically check all connections and the batteries.

5. USE FOR SOLAR PUMPING

5.1. PRINCIPLE

Solar pumping means to pump water following the race of the sun in the sky to store it in a tank and delivery it by gravity when needed. Flow rate will vary accordingly to the daily change of the irradiance:

Flow rate/ daily irradiance:



Solar pumping is the best system in arid and semi-arid areas, today's technologies are reliable and well adapted to isolated location. Electrical submersible pumps (ie. Grundfos) do not require a lot of maintenance and electrical protection devices are included. They can work under very large range of voltage, either in direct or alternating current, which will allow to connect generators to increase the flow if necessary.

Energy is supplied by solar panels sized according to the required nominal daily water flow (m3/day) depending on the capacity of the borehole.

5.2. SIZING

Solar pumping system will be sized following the 5 steps:

1. Daily water flow
2. Total Dynamic Head
3. Daily irradiance

4. Sizing
5. Installation plan

5.2.1. Daily water flow

This is the parameter to size your system. This water flow daily need, expressed in m^3/day, corresponds to the water deamnd and to the borehole capacity.

5.2.2. Total Dynamic Head (TDH)

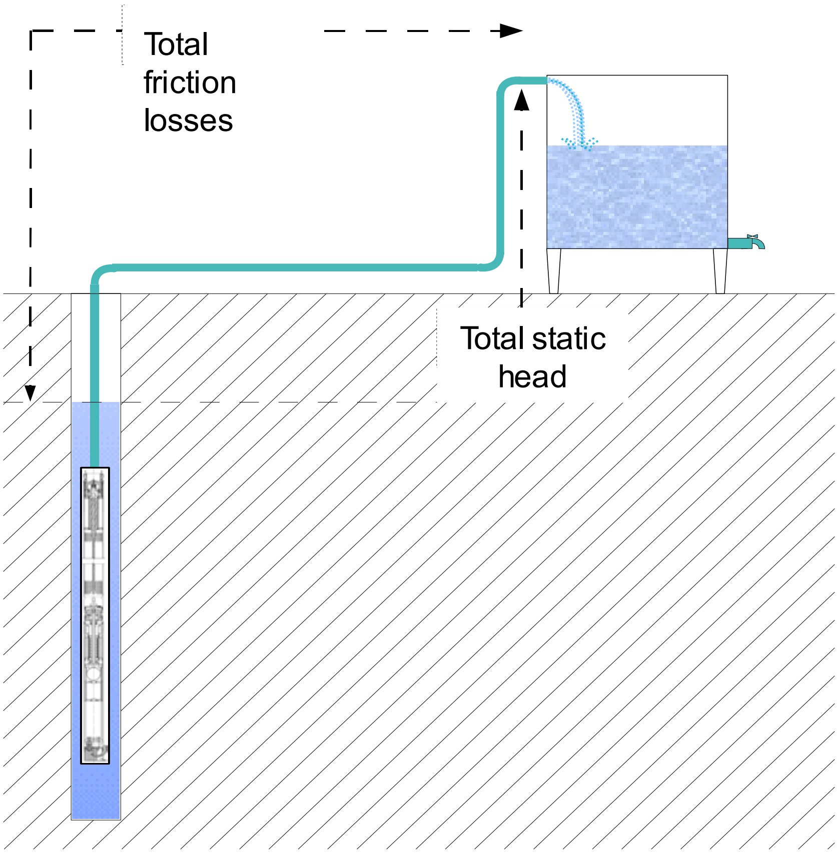
The sum of the total static head (TSH) and the the total friction losses (TFL) in the pipes is called the Total Dynamic Head. I is expressed in mCE (meter of water head).

TDH = TSH + TFL

The total static head is the vertical distance between the water surface of the tank and the water level in the borehole.

Total friction losses are the sum of the friction losses in the pipes and the friction losses generated by elbows, valvs, ... It is also expressed in mCE and vary with the diameter and the type of materials used.

For more information on hydraulic calculations, see Gravity flow guideline.



Total friction losses are estimated in the following table according to the nominal flow rate: the pump rate when the sun reaches its maximum height at midday, expressed in m3/h. We can consider that it is approximatily equal to 1/6 or 1/7 of the daily water flow.

Friction losses for 100m of pipe (in mCE) according to flow (m3/h) and diameter of pipes:

Débit en m³/h	Ø TUYAUTERIES									
	3/4"	1"	1" 1/4	1" 1/2	2"	2" 1/2	3"	4"	5"	6"
	20/27	26/34	33/42	40/49	50/60	66/76	80/90	100	125	150
1	8,0	2,1	0,5	0,2						
1,5	17,0	5,0	1,0	0,5	0,1					
2	33,0	9,0	2,0	0,9	0,3					
3		21,0	4,5	2,2	0,6	0,1				
4		32,0	7,6	3,5	1,0	0,2	0,1			
5			13,0	6,0	1,8	0,4	0,2			
6			17,0	8,0	2,5	0,5	0,3			
7			25,0	12,0	3,5	0,7	0,3			
8			33,0	14,0	4,5	1,0	0,5	0,1		
9				19,0	5,7	1,2	0,6	0,2		
10				23,0	7,0	1,5	0,7	0,2		
12				33,0	10,0	2,2	1,0	0,3	0,1	
15					15,0	3,4	1,6	0,5	0,2	
20					26,0	6,0	2,8	0,8	0,3	0,1
25					40,0	9,4	4,4	1,3	0,4	0,2
30						13,5	6,3	1,9	0,6	0,2
40						24,0	11,2	3,3	1,1	0,4
50						37,5	17,5	5,2	1,7	0,7
60							25,0	7,6	2,4	1,0
70							34,0	10,2	3,3	1,3
80								13,4	4,3	1,7
100								21,0	6,8	2,6
150									15,3	5,8
200									27,2	10,4

- Avoid the grey zone to prevent extra head losses.
- Table for metal pipe, for PVC apply a 0,8 coefficient
- For elbow, add 2 mCE for each elbow to the total length of the pipes
- For strainers, valvs, add 10 mCE per unit to the total length of the pipes

Example: Ceforlog MSF Logistique

TSH = 18m

150m of PVC pipe, 3 elbows 2'' therefore Equivalent length= 150+3x2= 156m

Daily water flow = 8m3/day

Nominal flow 8/7= 1,15 => 1,5 m3/h

Friction loss: 0,1mCE / 100m
Total friction loss TFL= 0,8 x 156 x 0,1/100 = 0,12m

TDH = TSH + TFL = 18 + 0,12 = 18,12m

5.2.3. Daily irradiance

Same calculation as in chapter 1.1 Background

Example: **Ceforlog MSF Logistique in Mérignac:** 2,5 kWh/m²/day

5.2.4. Sizing

The size of the solar panel required will be calculated using the followin formula:

$$\text{Solar power} = \frac{\text{Daily water flow} \times \text{Total Dynamic Head} \times 2{,}725}{\text{Daily irradiance} \times \text{pump efficiency}}$$

Pump efficiency – It is the electrical power used dividing the hydraulic power given, a technical parameter of the pump given by the manufacturer. This power efficiency will vary according to the water flow and will be at its maximum for the nominal flow. Therefore, the pump has to be siezed according to the nominal flow (1/6 or 1/7 of the daily water flow).

Example: **Ceforlog** **Daily water flow: 8m³ /day**

TDH: 18,12m

Irradiance: 2,5kWh/m²/day

Power efficiency ~ 0,60

Solar pôwer $= \frac{8 \times 18{,}12 \times 2{,}725}{2{,}5 \times 0{,}60} = \underline{263\text{Wc}}$

=> 3 solar panels of 100 Wc each

Nominal flow rate ~ daily water flow (8m³/j) / 7 => 8/7 = 1,15m³/h

With those calculations, MSF Logisitique can choose the best system according to your needs, for example in this case, a Grundfos SQFlex 1.2-2 pump (1,2m³/h – 2 stages)

This pump has the following solar characteristiques:

SOLAR MODULE GF 101

Electrical Data

(Above specification at STC: Insol 1000W/m², Am 1.5, Cell T 25°C)

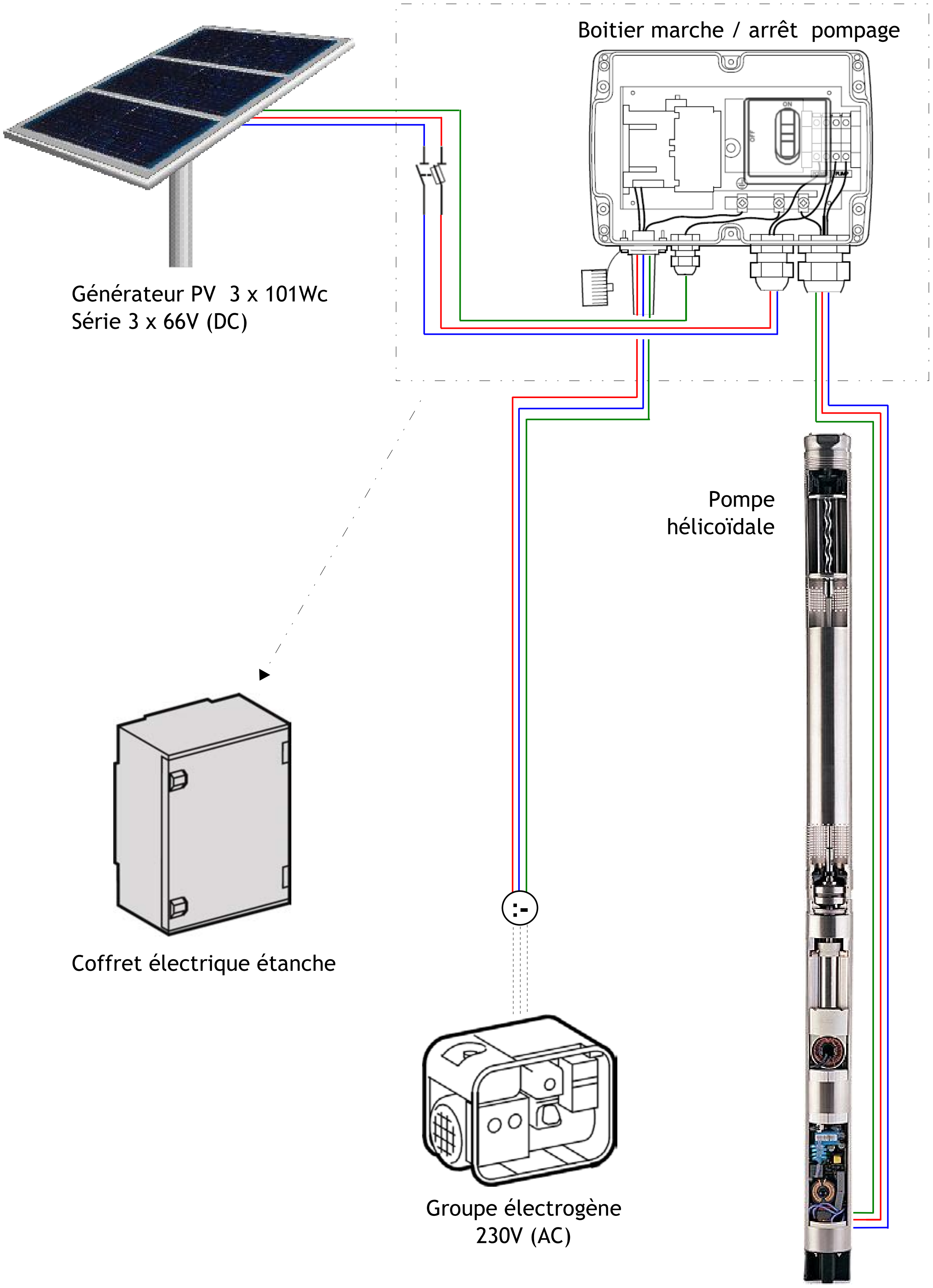
Rated Power (P_{MAX}):	101 Wp
Tolerance of the rated output power:	+/- 5%
Rated Voltage (V_{MPP}):	66 V
Rated Current (I_{MPP}):	1,53 A
Open Circuit Voltage (V_{OC}):	86,5 V
Short Circuit Current (I_{SC}):	1,65 A
Max System Voltage (V_{DC}):	600 V (US NEC Rating) 600 V (IEC Rating)

The pump accepts alternating current voltage from 90 to 240 VAC (courant alternatif) and direct current voltage from 30 to 300 VDC

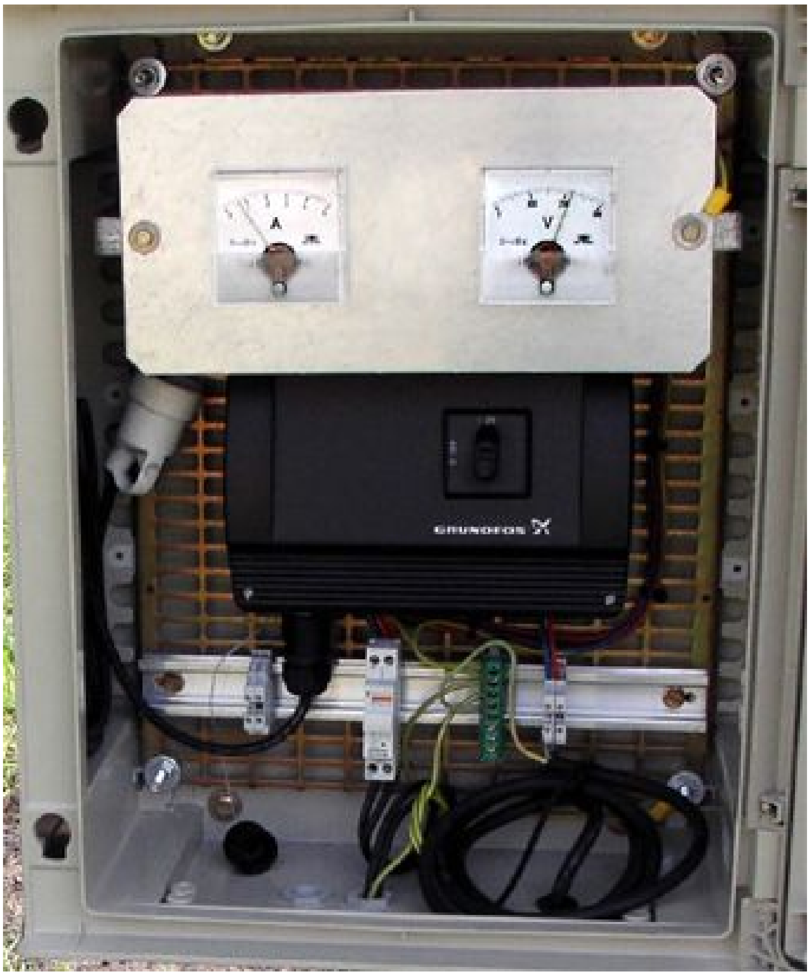
In serial, the modules will produce:
=> 3 x 66V = 188 VDC

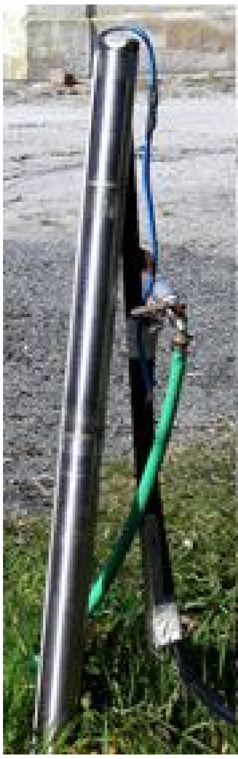
Grundfos is providing the pump with its adapted solar panels.

5.2.5. Installation plan



5.2.6. In reality





6. FREQUENTLY ASKED QUESTIONS

6.1. CAN I SAVE THE COST OF A REGULATOR?

NO: The regulator's job is to protect the battery, which otherwise would be charging constantly, even when already full. This would drastically reduce the life of the battery.

6.2. I ABSOLUTELY MUST EXTEND THE CABLE BETWEEN THE PANEL AND THE REGULATOR BY A FEW METRES. CAN I DO THIS, AND IF SO, HOW?

It can be done, but the new cable will have to have a larger cross-section. An increase in length must be compensated by an increase in cross-section (and thus diameter). This can be done either by using a larger cross-section cable, or by coupling other, longer cables in parallel to yield double or triple the original cross-section.

Measure the result with a voltmeter:

If you read 13.8V at the battery terminals and 13.4V at the end of the cable supplied in the kit, you've got to have at least 13.4V at the end of your new "homemade" cable, otherwise you've reduced the efficiency of your installation.

6.3. CAN I CONNECT LOADS DIRECTLY TO THE BATTERY?

Technically, yes, but then the battery would no longer be protected against total discharge. To clarify: if you leave a bulb burning for too long, nothing will prevent your battery from discharging below the point of no return, and it will be irreversibly destroyed— you won't be able to recharge it.

On some panels you will find a small black cylindrical piece between the + and – terminals: this is the blocking diode that prevents accidental back feeding of energy from the battery to the panel, in case you've "forgotten" to install a regulator.

GENERATOR SETS AT MSF

1. 800VA/650W, 220V SINGLE-PHASE PETROL MODEL

Code MSF: KPROKGEN6P – Generator kit

2. OLD 4.2KVA/3.3KW DIESEL MODEL

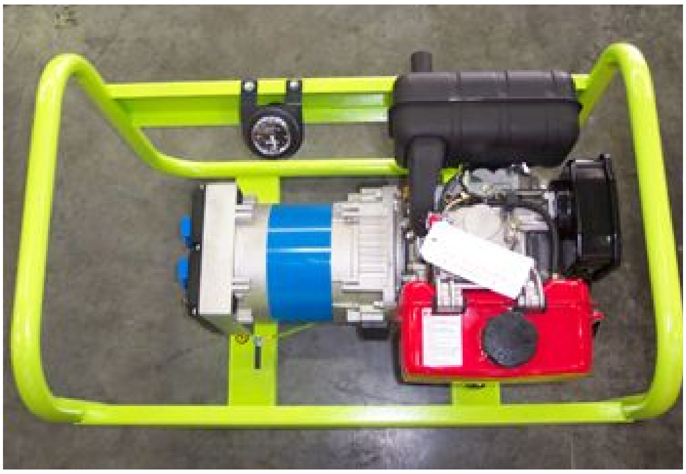
Code MSF: KPROKGEN45D – Generator kit

This older model has been replaced by the two models below.

3. NEW 3.8KVA/3KW, 220V SINGLE-PHASE, 50HZ DIESEL MODEL

3.1.1. description

MSF code: MSF: PELEGEND03Y



3.1.2. Distribution

We have the following 25A RCCB for use with these three generators in the field. It should be connected between the generator and the loads:

MSF code: PELEBOAR02P

Three 16A 2-PIN outlets are available, for a maximum power of 3500W.

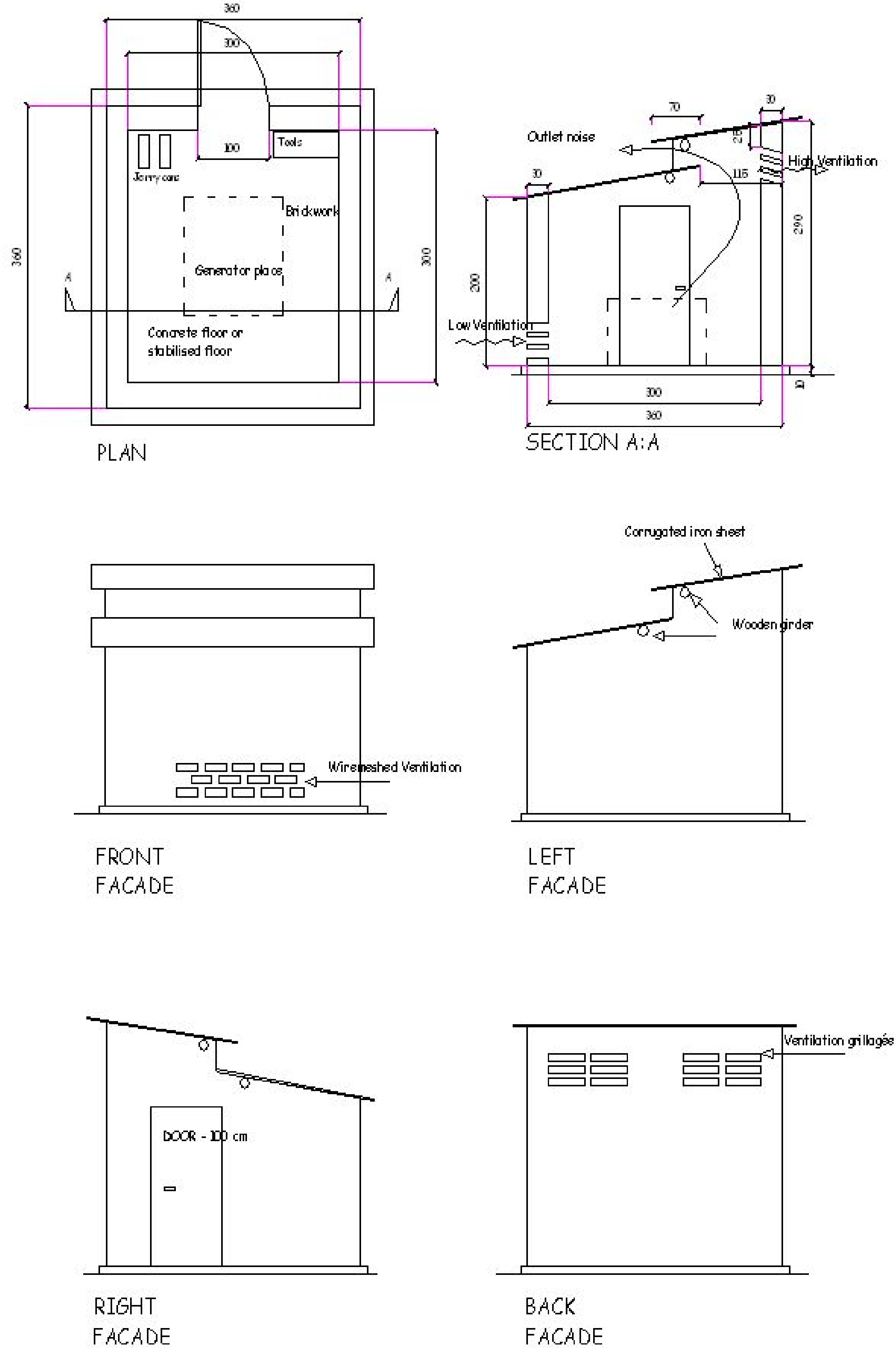
This model can be used outdoors.

CAUTION: the RCD will only protect against insulation faults if the generator is correctly earthed.

This device does not protect against overloads and short-circuits.

3.1.3. Setup

Do not forget to connect te generator to the earth. Example de cabine:



3.1.4. Maintenance

This generateur, 3000 Round/minute (RPM) has to follow this maintenance services program:

- Service A: every 100 hours
  - clean engine
  - change engine oil
  - drain fuel filter of water sediment
  - clean air filter

- Service B: tevery 200 hours
  - service A
  - change fuel filter
  - replace oil filter

- Service C: every 400 hours
  - service B
  - change air filter

4. NEW 6KVA/4.8KW SINGLE-PHASE DIESEL MODEL

4.1.1. description

MSF code: PELEGENDO5S
MSF kit: KPROKGEN05S.

This model is silenced and protected against bad weather: it can be very quickly setup outside.

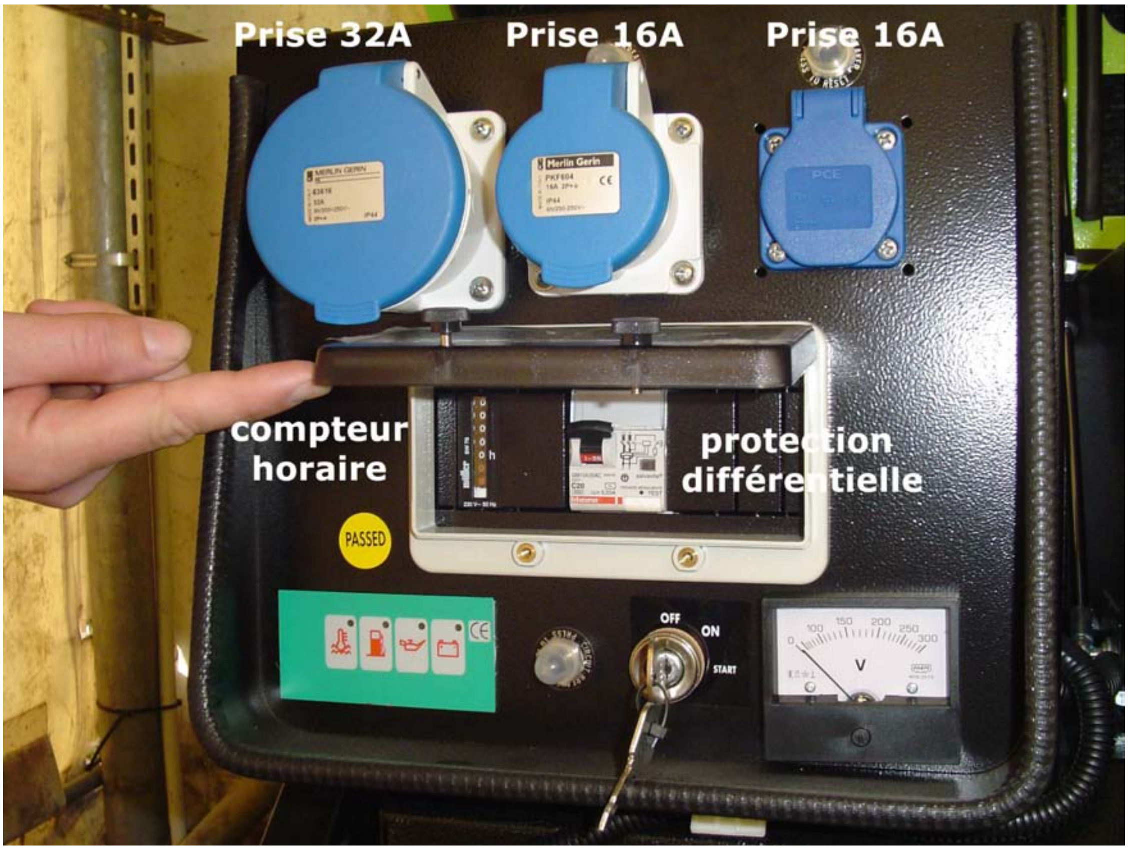
It has an hour counter, residual current protection against insulation faults, and three 220VAC outlets:

- 32A,
- 16A industrial,
- 16A household,

Each of the outlets is protected against short-circuit and overload by an MCB of equivalent current rating.

Remember, the RCD only works if the generator is properly earthed.

The 32A outlet can be used to connect the distribution panel (code PELEBOAR03P).



4.1.2. distribution

At the distribution panel (PELEBOAR03P) you can hook up to three 16A 3-pin industrial outlets and one 10A household outlet.

Each outlet is protected from short-circuit and overload by its own MCB: three 16A and one 10A.

We prefer that MSF cable reels (each with three 16A 3-pin outlets and 40m of H07RN F3G2.5 cable) be used to hook up to the three 16A 2-PIN outlets on the panel.

Thanks to the outlets, the cable reels cannot be connected in series. They can be used, for example, to connect low voltage 2x23W lights.

These lights can be controlled with a switch, and offer three 16A 2-pin outlets. They come with 5m of cable and may be installed outdoors.

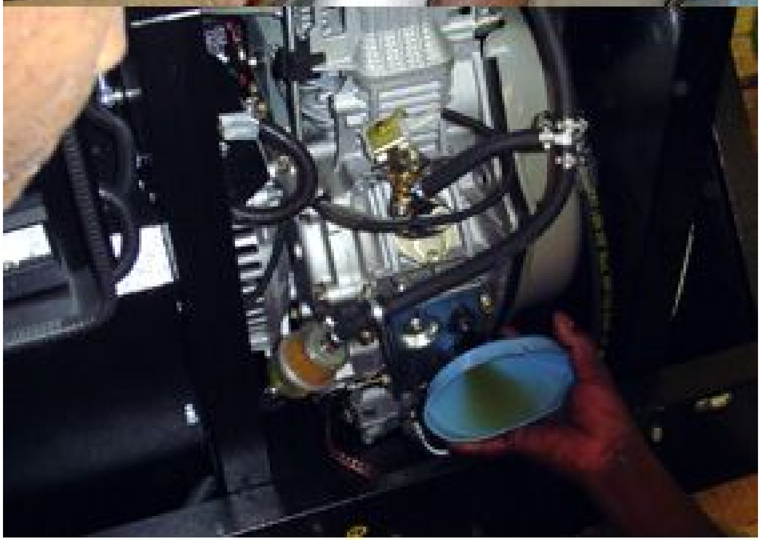
See the "Lighting circuits" section.

All this equipment is included in the 6kVA, single-phase electric distribution module (KPROLIGED), available only with the 6kVA generator.

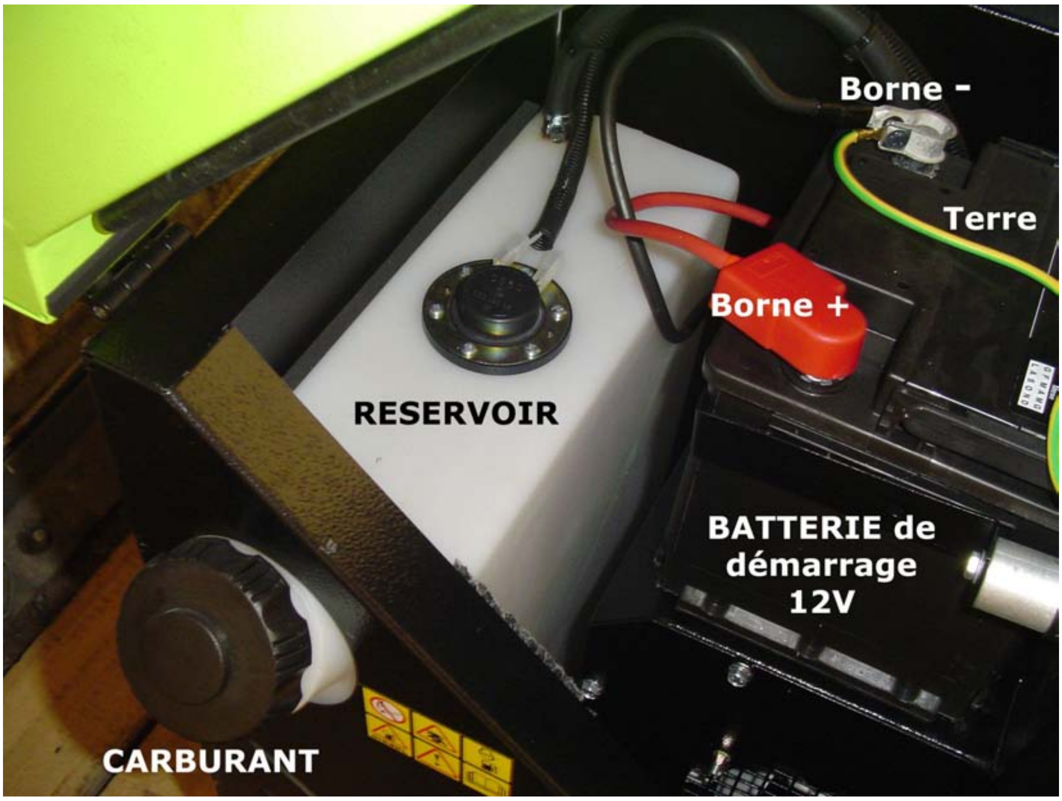
4.1.3. start-up

Fill the fuel tank :

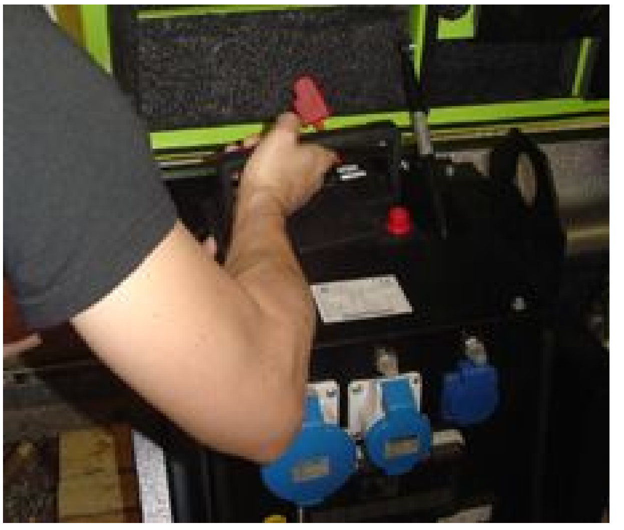
Fill the oil tank:



This model is equipped with an electric starter with 12V battery:

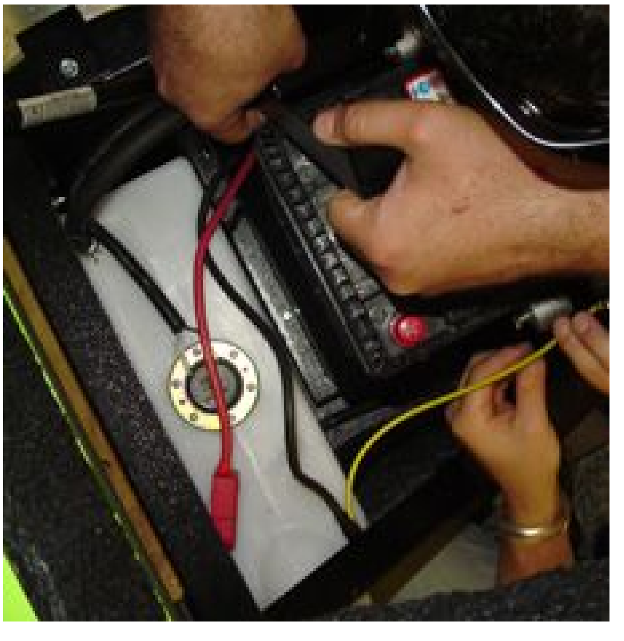


The batteriy is not filled when you receive the generator: after removing the battery from its location,



Fill it with electrolyte,

put it back with all its connections.



To start the engine, you have to turn the ignition key when you hear the fuel pump running.

4.1.4. Maintenance

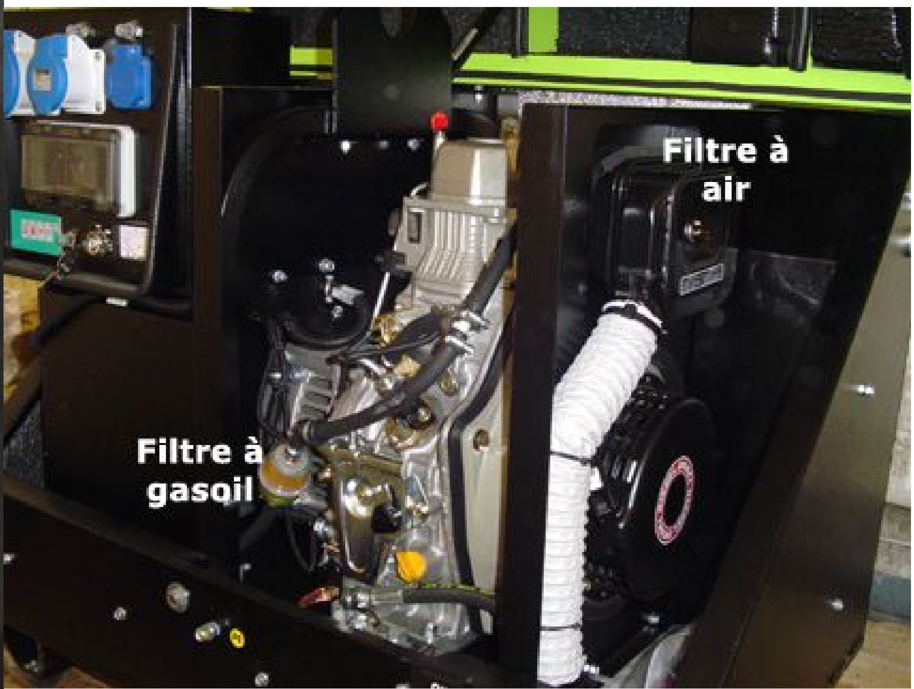
This generateur, 3000 Round/minute (RPM) has to follow this maintenance services program:

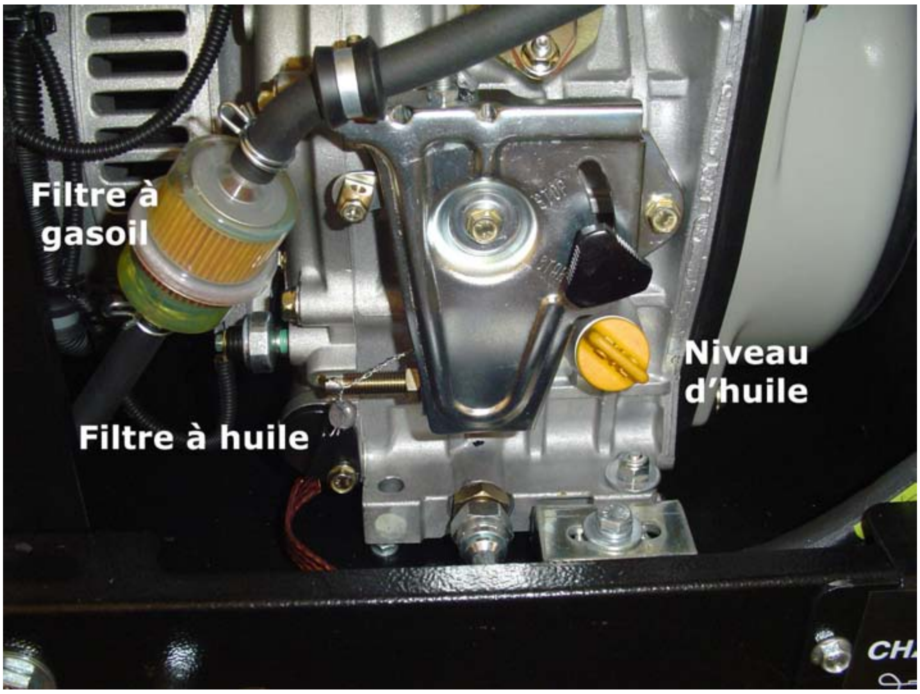
- Service A: every 100 hours
  - clean engine
  - change engine oil
  - drain fuel filters of water sediment
  - clean air filter

- Service B: tevery 200 hours
  - service A
  - change fuel filters
  - replace oil filter

- Service C: every 400 hours
  - service B
  - change air filter

ATTENTION, this generator is equipped with 2 fuel filters:





To ease the oil drainage, the generator has a drainage pipe: