SCOOPE Saving Cooperative Energy

# Utilities and Horizontal Energy Efficiency

## Webinar nº 11

circe RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION

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# Energy efficiency in lighting systems

1. Energy efficiency in installations
2. Improvement of installed equipment
3. Installation of energy saving devices
4. Switch on and switch off devices.

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# Energy efficiency in lighting

**Lighting**: the measure of the power of electromagnetic radiation related to visible light.

**Luminous flux**: objective measure of the useful light emitted by a light source.

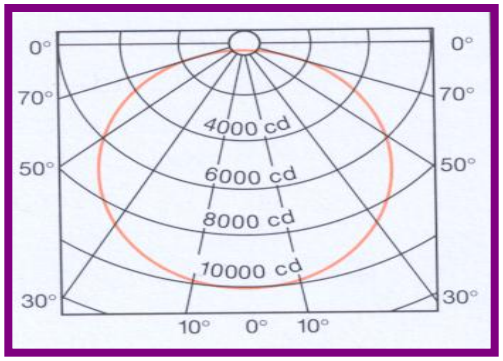
*Symbol:* $\Phi$

*Units*: lumen (lm)


**Luminous intensity:** the flux that is radiated by a light source in a determinate direction.

*Symbol: I*

*Units: candela (cd)*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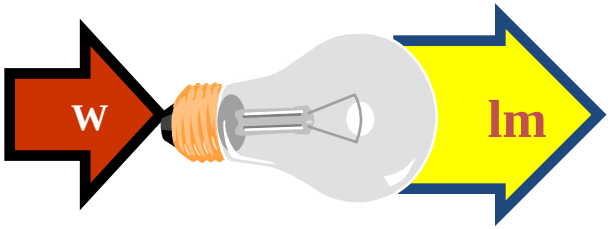
# Energy efficiency in lighting

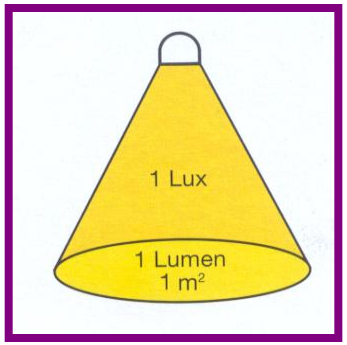
**Luminous efficacy:** It is the ratio of luminous flux to power (usually electric power)


*Units*: lm/W




**Illuminance:** Relationship between the luminous flux (lumens) and the area.

*Units:* lux (lx) = 1lx = 1lm/m$^2$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# Energy efficiency in lighting

## Lamps classification

- Ligh emiting diode (LED)
- Thermoresistence
  - incandescent
  - halogen
- Gas discharge
  - fluorescent pipe
  - compact fluorescent
  - High intensity discharge






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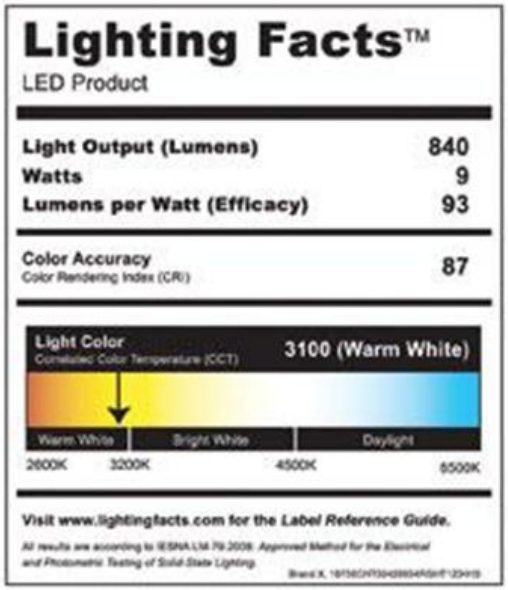
# Energy efficiency in lighting

## Luminous Efficacy and Luminous Efficiency

***Light bulb label***




PHILIPS

Energy efficiency compared

| Technology | Luminous efficacy (lm/W) | System efficiency (%) |
|---|---|---|
| Incandescent | 12 | 4 |
| Halogen | 24 | 8 |
| Compact fluorescent | 54 | 18 |
| Fluorescent tube | 96 | 32 |
| Inorganic LEDs | 70-120 (150) | (50) |
| Organic LEDs | 64 (150) | (50) |

The luminous efficiency is expressed as a value between zero and one.

*1 corresponding to an efficacy of 683lm/W*

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# Energy efficiency in lighting

## VEEI: Energy Efficiency Value in Lighting systems

The energy efficiency of the lighting system in a particular zone is determined by the VEEI value ($W/m^2$) for each 100 lux. Ratio of the lighting density in an area.

$$VEEI = \frac{P \cdot 100}{S \cdot E_m} \quad [W/m^2]$$

P, the total power of light taking into account the auxiliary devices (W)
S, illuminated surface ($m^2$)
Em, horizontal average of illuminance (lux)

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# Energy efficiency in lighting

## Improvement of installed equipment

Lamps

Ballast or reactance

Luminary

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# Energy efficiency in lighting

## Improvement of installed equipment

**Profits:**

1.- Power installed is reduced with the same amount of illumination

Mercury vapour 250 W → high pressure sodium 150 W

Mercury vapour 125 W → high pressure sodium 70 W

2.- Lifespan is higher, so it reduces the cost of replacing the lamps

Mercury vapour 10.000 h → high pressure sodium 20.000 h

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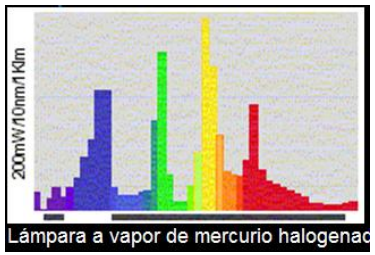
# Energy efficiency in lighting

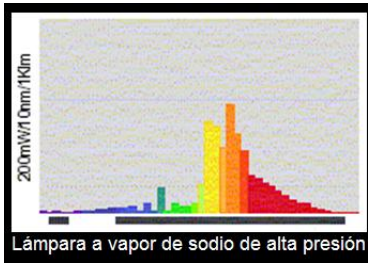
## Improvement of installed equipment:

### Problems:

1.- The quality of the light can be worse because the color index is not the same and depends on the type of lighting

Mercury vapor > 50 → high pressure sodium  25




2.- It is necessary to install auxiliary devices

Ballast and starter

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# Energy efficiency in lighting

## Improvement of installed equipment:

Replacement of electromagnetic ballasts by other electronic devices.


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# Energy efficiency in lighting

## Improvement of installed equipment: replace the ballast

**Problems:**

- Operation problems in high temperatures.
- Because there are electronic components in them, it is necessary to remove the heat to ensure operating temperatures below 70ºC

## Improve of installed equipment: replace luminary

**Profits**

- Improve energy efficiency in the lighting system by directing the lighting flow to the area that needs lighting
- With the use of high efficiency reflectors it is possible to reduce the electrical power of the lamps
- It includes systems with IP protection that improve maintenance operations

**Problems**

- It is necessary to adapt the system (support)

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# Energy efficiency in lighting

## Installation of saving devices:

To obtain energy savings in lighting systems it is possible to install equipment that reduces the lighting flow and the hours of operation.

- Lighting flow regulators
- Dual level line installation
- Regulated electronic ballasts

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# Energy efficiency in lighting

## Installation of saving devices: lighting flow balancers

This device reduces the input voltages in the lamps for a certain time. It is possible to achieve energy savings up to 40%.

The lower voltages may vary depending on the type of installations, but due to the safety conditions, it is recommended to discharge lamps following these values:

- Nominal value: 230 V
- Reduced value in sodium: 184 V
- Reduced value in mercury: 207 V

Due to voltage losses in the line, it is not recommended to adjust theses values too much.


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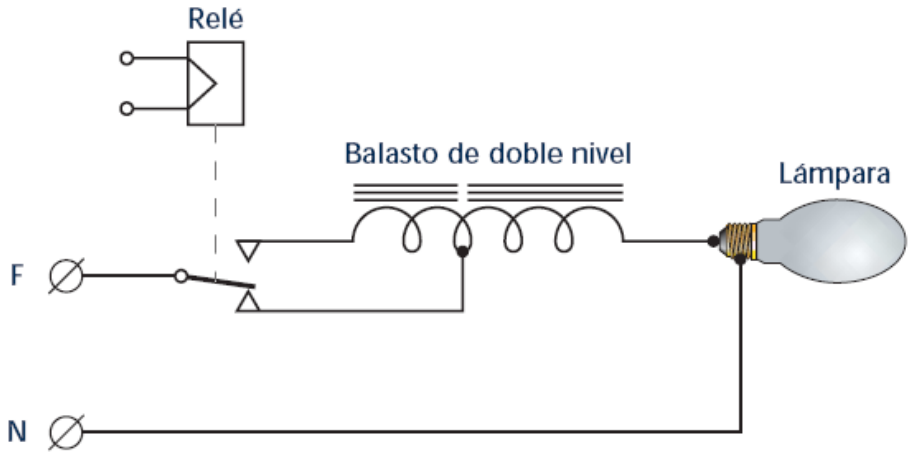
# Energy efficiency in lighting

## Installation of double level of ballasts in each lamp

The function is very easy, the system allows adjusting the level of illumination and a regulator must turn on or off each one.




The energy consumption is very low

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# Energy efficiency in lighting

## Installation of double level of ballasts in each lamp

**Profits:**

- There are very high energy savings
- It is an economical system, but only in the case of a dual level line installation

**Problems:**

- A double line level is required at each point of light
- It reduces power factor, so an auxiliary capacitor is needed
- Devices that can turn the line on and off are required (clock, photocell)

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# Energy efficiency in lighting

## Lighting system with LEDs

**Characteristics:**

- Efficiency: very high, around 90 lm/W
- Lifespan: Long (100.000 -50.000 h)
- Cost reduction in operation and maintenance
- Colour: High spectrum of colours
- IRC: high RA = 80
- It is recommended for installations that have too many switches on and off (e.g. cooling chambers)

**Applications**

- Traffic lighting
- Information displays
- Low power outdoor lighting
- All applications for indoor lighting (lamps, pipes)

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# Energy efficiency in compressed air

In a standard installation, it is possible that compressed air consumes approximately 10 % to 20% of electricity consumption. In most of the industrial installations, this is a horizontal installation related to the production processes.

No optimized installations loses an average of a 30% of the energy used during its life. For this reason, energy savings could be high.


In LCC analysis, the highest percentage of the costs of these systems, is the consumed energy.

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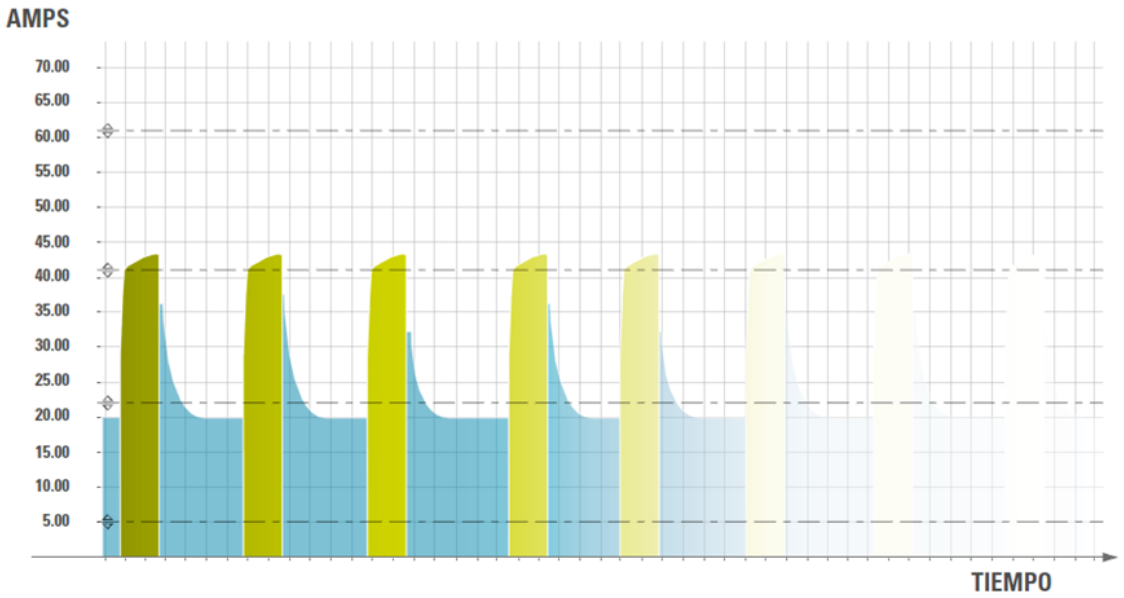
# Energy efficiency in compressed air

## Operation compressor All/Nothing (Loading and unloading)




**Compressor working**

- **Load.** The compressor demands nominal power and injects the nominal flow into the compressed air circuit.
- **Unload.** The compressor demands between 30 and 20 % of nominal power without injecting compressed air into the circuit.

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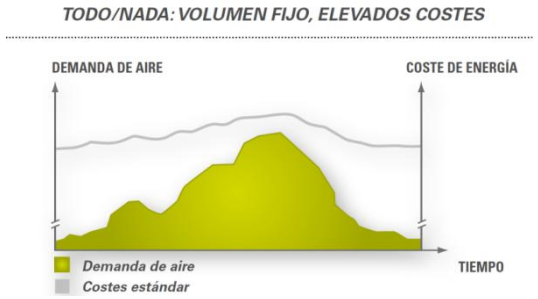
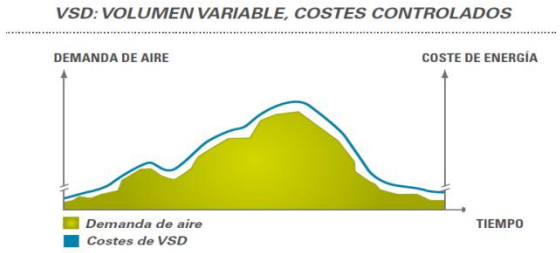
# Energy efficiency in compressed air

## Variable Speed Compressor

A compressor without variable speed can only control its pressure by loading or unloading.
For this reason, these compressors, in periods of demand, consume an average of 30% of energy without producing compressed air.




**Proposed Improvement:**
The installation of a variable speed compressor will allow to control periods of variable demand and reduce the energy consumption.

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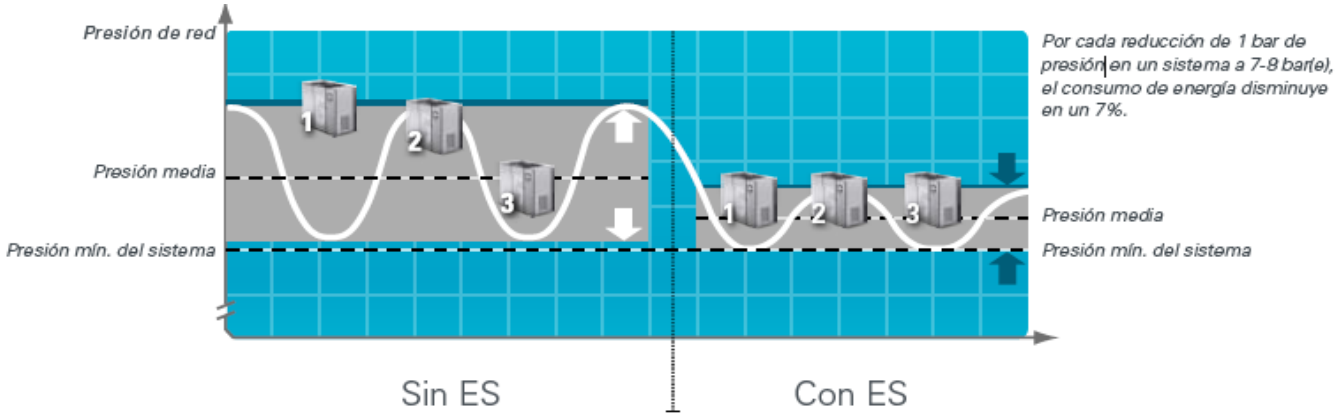
# Energy efficiency in compressed air

## A control System

An automatic control is very important if there are several compressors in the same installation

**Advantages:**

- Management priorities, giving preference to the most efficient compressors and adapting the workload.
- Possibility of programming different pressure points.
- Fix a reduced pressure band. (For each 1bar of pressure reduced in a system of 7-8 bar, the energy consumption decreases 7% ).

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# Energy efficiency in compressed air

## General improvements

- Detection of air leaks in compressed air net and creation of a leak control and maintenance plan.
- Divide the air compressor net into different production areas.
- Set the adequate working pressure. (A 20% reduction in pressure produces a 15% reduction in energy consumption in the air compressor).
- Heat recovery: The heat removed can be recovered to produce energy savings.

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# Measurements Devices

- Lux Meter
- Thermographic camera
- U-Value Meter
- Combustion Gas Analyzer - Flue Gas Analyzer
- Grid Analyzer

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# LUX METER

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# Lux Meter

**The Lux Meter allows the measurement of luminous flux (lumen) per unit area ($m^2$) that provides a lighting value in lux, the illuminance level.**


European Standards exist covering minimum lighting levels depending on the activity.

- **EN 12464-1** Lighting of work places – Indoor work places
- **EN 12464-2** Lighting of work places – Outdoor work places
- **EN 15193** Energy Performance of Buildings – Energy requirements for lighting
- **EN 12193** Sports lighting level

However, the standards also specify that sometimes "more" is required depending on the situation.

| 3 | Offices | | | |
|---|---|---|---|---|
| Ref. no. | Interior type, task or activity | $E_m$ | $UGR_L$ | $R_a$ |
| 3.1 | Performance of work, copying, etc. | 300 | 19 | 80 |
| 3.2 | Writing, typing and reading, data processing on a PC | 500 | 19 | 80 |
| 3.3 | Technical drawing | 750 | 16 | 80 |
| 3.4 | CAD workstations | 500 | 19 | 80 |
| 3.5 | Conference and meeting rooms | 500 | 19 | 80 |
| 3.6 | Reception desks | 300 | 22 | 80 |
| 3.7 | Archives | 200 | 25 | 80 |

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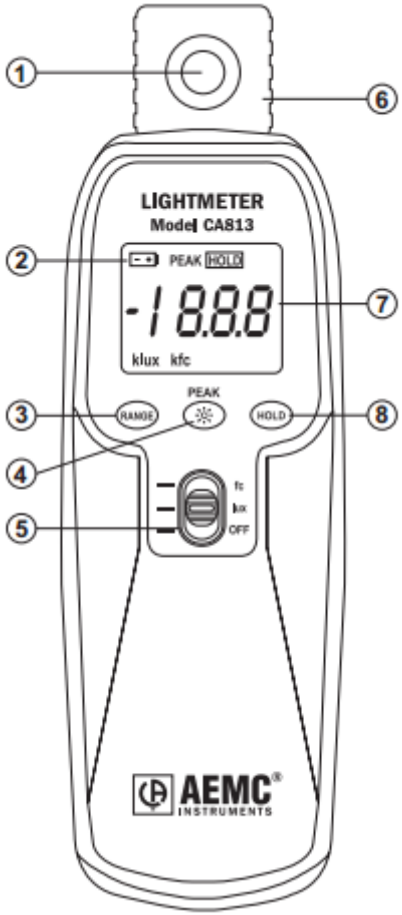
# Components of a Lux Meter


1. Sensor – Silicon photodiode
2. Low battery indication
3. Range selector
4. Peak function (813) or max function (811)
5. Measures of foot-candles or lux or off (power selector)
6. Removable sensor for remote reading
7. Display
8. Hold function

The lux meter must be calibrate by an authorised laboratory

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# THERMOGRAPHIC CAMERA

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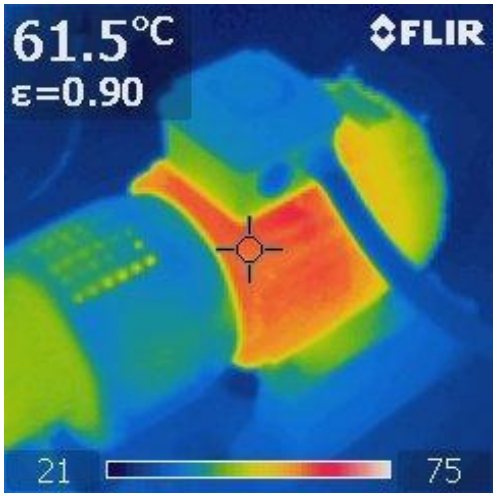
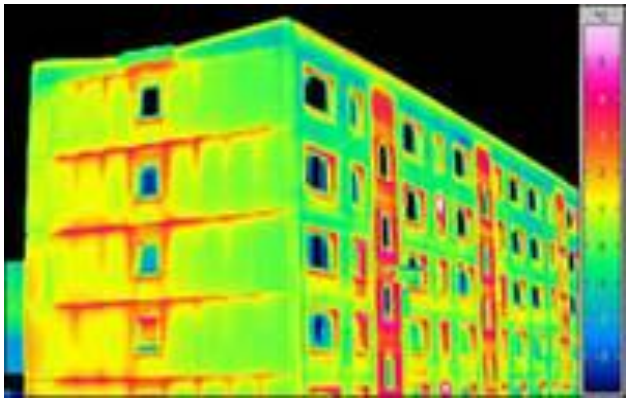
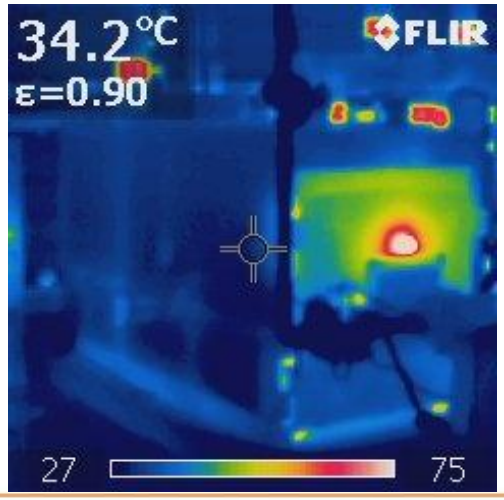
# Thermography



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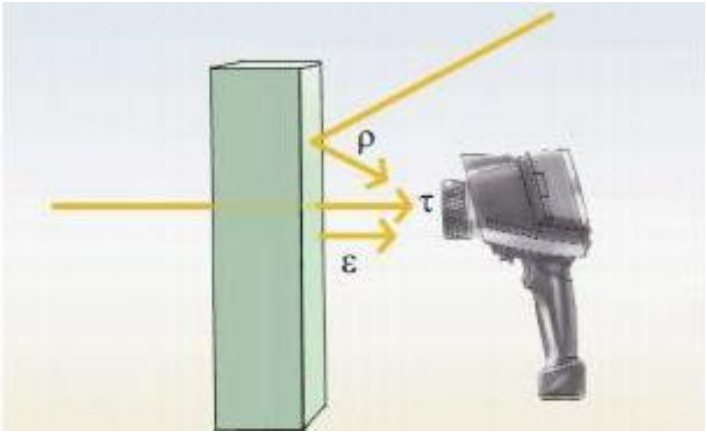
# Thermography basis




$\varepsilon + \rho + \tau = 1$

**Emission + Reflection + Transmission = TEMPERATURE**

Every object whose temperature is higher than absolute zero (0 Kelvin = -273,15ºC), sends out infrared radiation, which is invisible by humans.
In order to know the superficial temperature, is necessary to take into account these parameters:

- **Emissivity (ε)**, is the measurement of the capacity, which one material has, to send out (spread) infrared radiation.
- **Reflection (ρ)**, is the measurement of the capacity's object to reflect the infrared radiation. (Polished surfaces reflect much more than those irregulars or the same material without polish).
- **Transmission (τ)**, is the measurement of the capacity's material to transmit the infrared radiation.

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# Parameters to configure a thermographic camera

The configuration of a thermographic camera is possible depending on the characteristics of the surface. It is necessary to define the emissivity and reflection of the material.

Most of the thermographic camera's software have included a material data base.

| Material (temperatura del material) | Emisividad |
|---|---|
| Aluminio, bobinado (170 °C) | 0.04 |
| Aluminio, no oxidado (25 °C) | 0.02 |
| Aluminio, no oxidado (100 °C) | 0.03 |
| Aluminio, muy oxidado (93 °C) | 0.20 |
| Aluminio, muy pulido (100 °C) | 0.09 |
| Algodón (20 °C) | 0.77 |
| Hormigón (25 °C) | 0.93 |
| Plomo, rugoso (40 °C) | 0.43 |
| Plomo, oxidado (40 °C) | 0.43 |
| Plomo, gris, oxidado (40 °C) | 0.28 |
| Cromo (40 °C) | 0.08 |
| Cromo, pulido (150 °C) | 0.06 |
| Hielo, liso (0 °C) | 0.97 |
| Hierro, esmerilado (20 °C) | 0.24 |
| Hierro, decapado (100 °C) | 0.80 |
| Hierro, laminado (20 °C) | 0.77 |
| Yeso (20 °C) | 0.90 |
| Cristal (90 °C) | 0.94 |
| Granito (20 °C) | 0.45 |

| Material (temperatura del material) | Emisividad |
|---|---|
| Caucho, duro (23 °C) | 0.94 |
| Caucho, blando, gris (23 °C) | 0.89 |
| Hierro fundido, oxidado (200 °C) | 0.64 |
| Madera (70 °C) | 0.94 |
| Corcho (20 °C) | 0.70 |
| Radiador, negro, anodizado (50 °C) | 0.98 |
| Cobre, deslustrado (20 °C) | 0.04 |
| Cobre, oxidado (130 °C) | 0.76 |
| Cobre, pulido (40 °C) | 0.03 |
| Cobre, enrrollado (40 °C) | 0.64 |
| Plásticos: PE, PP, PVC (20 °C) | 0.94 |
| Pintura, azul en lámina de aluminio (40 °C) | 0.78 |
| Pintura, negra, mate (80 °C) | 0.97 |
| Pintura, amarilla, 2 capas en lámina de aluminio (40 °C) | 0.79 |
| Pintura, blanca (90 °C) | 0.95 |
| Mármol, blanco (40 °C) | 0.95 |
| Ladrillo (40 °C) | 0.93 |
| Latón, oxidado (200 °C) | 0.61 |
| Pinturas al óleo (cualquier color) (90 °C) | 0.92 a 0.96 |
| Papel (20 °C) | 0.97 |
| Porcelana (20 °C) | 0.92 |
| Arenisca (40 °C) | 0.67 |
| Acero, galvanizado (200 °C) | 0.52 |
| Acero, oxidado (200 °C) | 0.79 |
| Acero, estirado en frío (93 °C) | 0.75 a 0.85 |
| Arcilla, cocida (70 °C) | 0.91 |
| Pintura de transformador (70 °C) | 0.94 |
| Ladrillo, mortero, cal (20 °C) | 0.93 |
| Zinc, oxidado | 0.1 |

There are also cameras with automatic regulation

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# Keep some ideas in mind


Adjustable colour scale according to the measurement range



It is important to take a photograph

Focusing the camera and fit the measurement distance. Avoid radiation from the sun, lights, etc. they can provide disturbances

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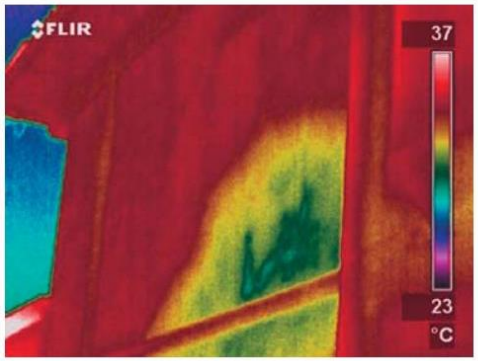
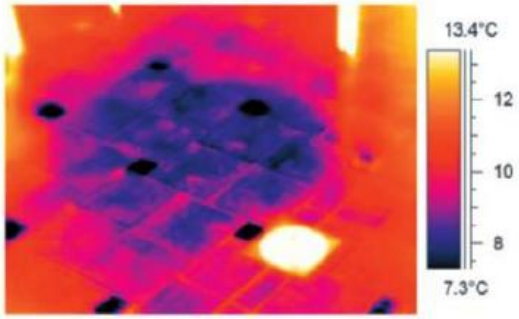
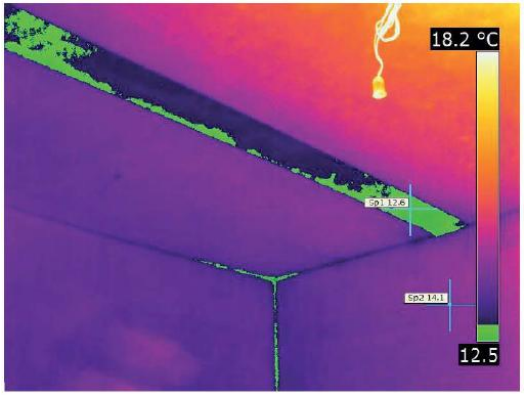
# Why thermography is useful?




**Termites detection**




**Humidity detection**




**Condensations**


**Infiltration detection**

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# U-VALUE METER

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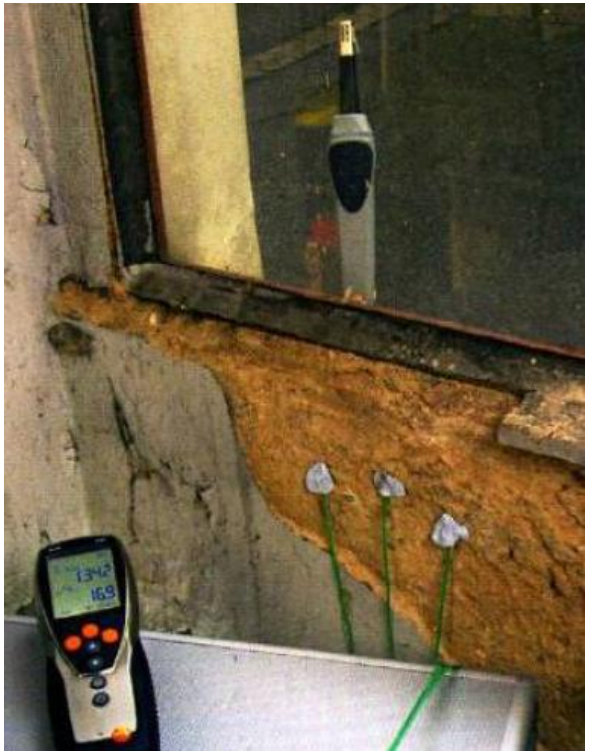
# U-Value Meter



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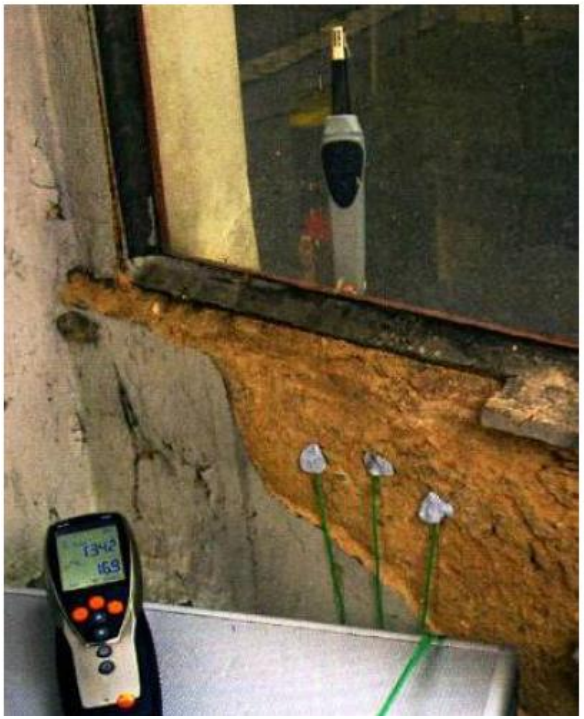
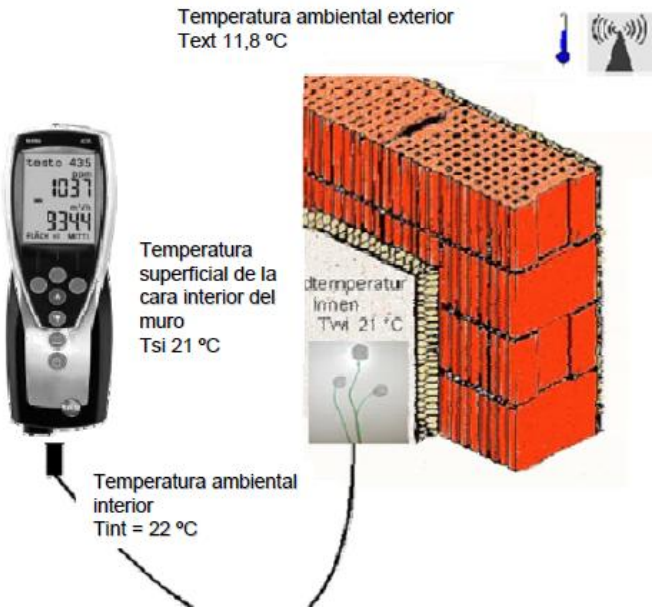
# Thermal transmittance

The **Thermal transmittance** or **U-Value**, is the rate of transfer of heat through one square metre of a structure, divided by the difference in temperature across the structure. W/m$^2$K.



$$U = \frac{(Ti - Tsi)\, h_{ci}}{(Ti - Te)} \quad [W/m^2K]$$

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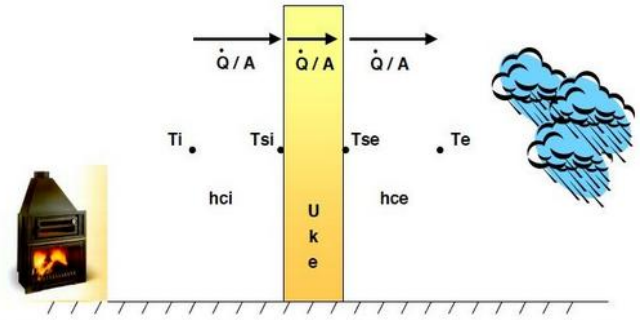
# Basis of calculation




$$U = \frac{(Ti - Tsi)\, h_{ci}}{(Ti - Te)} \quad [W/m^2K]$$

- The thermal transmittances of most walls and roofs can be calculated using ISO 6946.
- For most ground floors it can be calculated using ISO 13370.
- For most windows the thermal transmittance can be calculated using ISO 10077 or ISO 15099.
- ISO 9869 describes how to measure the thermal transmittance of a structure experimentally.

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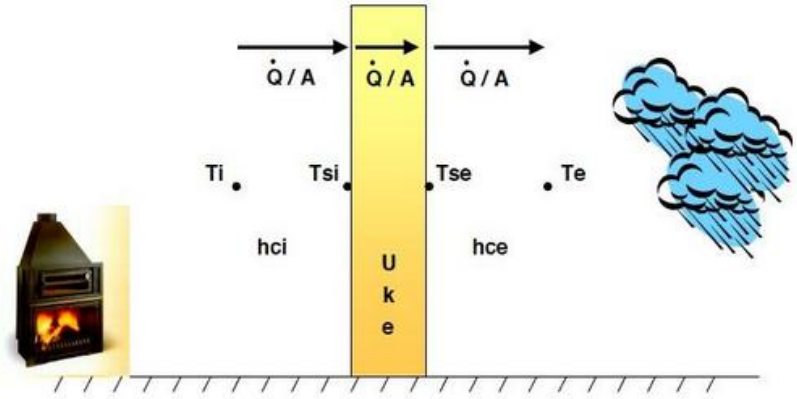
# Basis of calculation




Flujo de calor ambiente - pared

$Q/A = (Ti - Tsi)\ hci$

Indoor conditions

Flujo a través de una pared

$Q/A = U\ (Ti - Te)$

Heat flux through the wall

$$U\ (Ti - Te) = (Ti - Tsi)\ hci$$

$$U = \frac{(Ti - Tsi)\ hci}{(Ti - Te)} \quad [W/\ m2K]$$

*U-Value meter equation*

- **Q/A:** The rate of heat and surface [$W/m^2$]
- **e:** thickness [m]
- **k:** heat conductivity [W/mK]
- **hci:** indoor convection coefficient [$W/m^2K$]
- **hce:** external convection coefficient [$W/m^2K$]
- **Ti:** indoor temperature [ºC]
- **Tsi:** indoor surface temperature [ºC]
- **Te:** outdoor temperature [ºC]
- **Tse:** outdoor surface temperature [ºC]
- **U:** U-Value of transfer of heat [$W/m^2K$]

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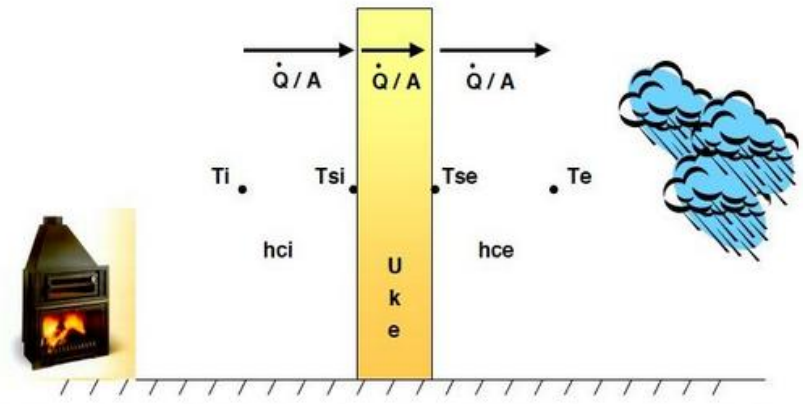
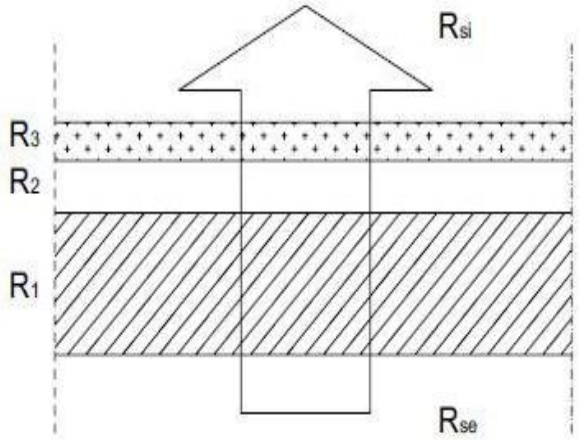
# Basis of calculation




$$U = \frac{1}{R_T}$$

**Thermal Resistance:**

$$R_T = R_{si} + R_1 + R_2 + \cdots + R_N + R_{se}$$

[$m^2K/W$]

**R = e (m)/k** [W/Mk]

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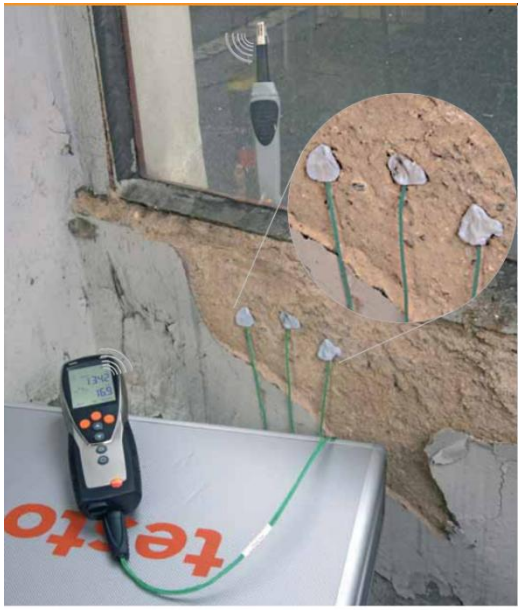
# How is the measurement?

**ISO 9869** describes how to measure the thermal transmittance of a roof or a wall by *using heat flux meters*. These heat flux meters usually consist of thermopiles which provide an electrical signal.

For most wall and roof constructions the heat flux meter needs to monitor heat flows continuously for a period of 72 hours to be conform the ISO 9869 standard.




The external conditions influence:

- The difference in temperature between the inside and outside of the building is at least 5°C.
- The weather is cloudy rather than sunny
- There is good thermal contact between the heat flux meter and the wall or roof being tested.
- The monitoring of heat flow and temperatures is carried out over at least 72 hours.
- Different spots on a building element are measured or a thermographic camera is used to secure the homogeneity of the building element.

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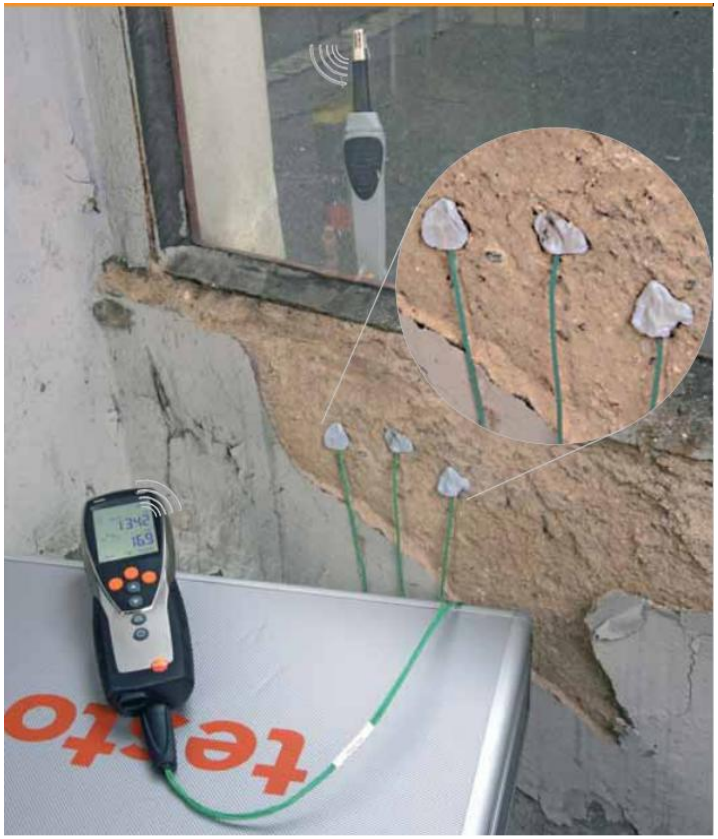
# U-Value Meter

## Testo 635-2 U-value set and thermohygrometer




Wireless measurement data transmission via radio;
Both indoors and outdoors temperature measurements can be carried out simultaneously;
To calculate the U-Value is possible thanks of three sensors or thermopiles in contact with the wall. These sensors measure the indoor conditions;
The U-Value Meter registers all the values and calculates the U-Value;
This equipment measures both temperature and humidity.

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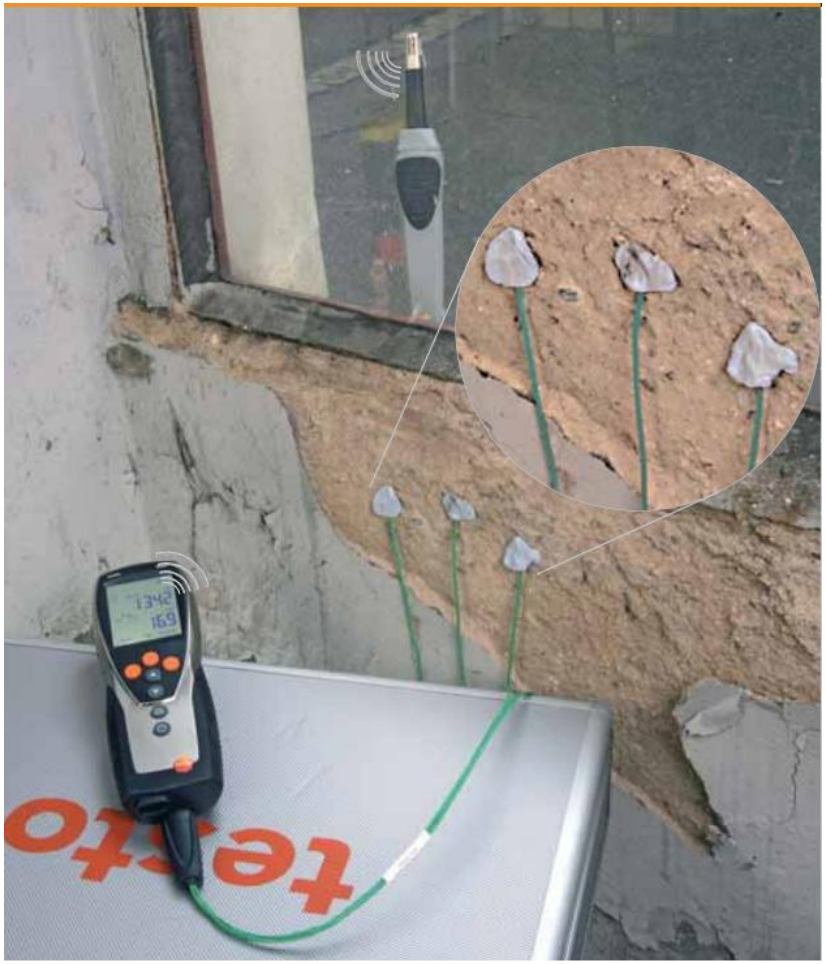
# U-Value Meter

**Testo 635-2 U-value set and thermohygrometer**




The difference in temperature between the inside and outside of the building is at least **15°C**;

Measurement in stable zones of the walls; Avoid thermal bridges and unions;

The external surface should be protected from the snow, wind, rain or sun radiation;

Indoor temperature should be constant during the measurement period.

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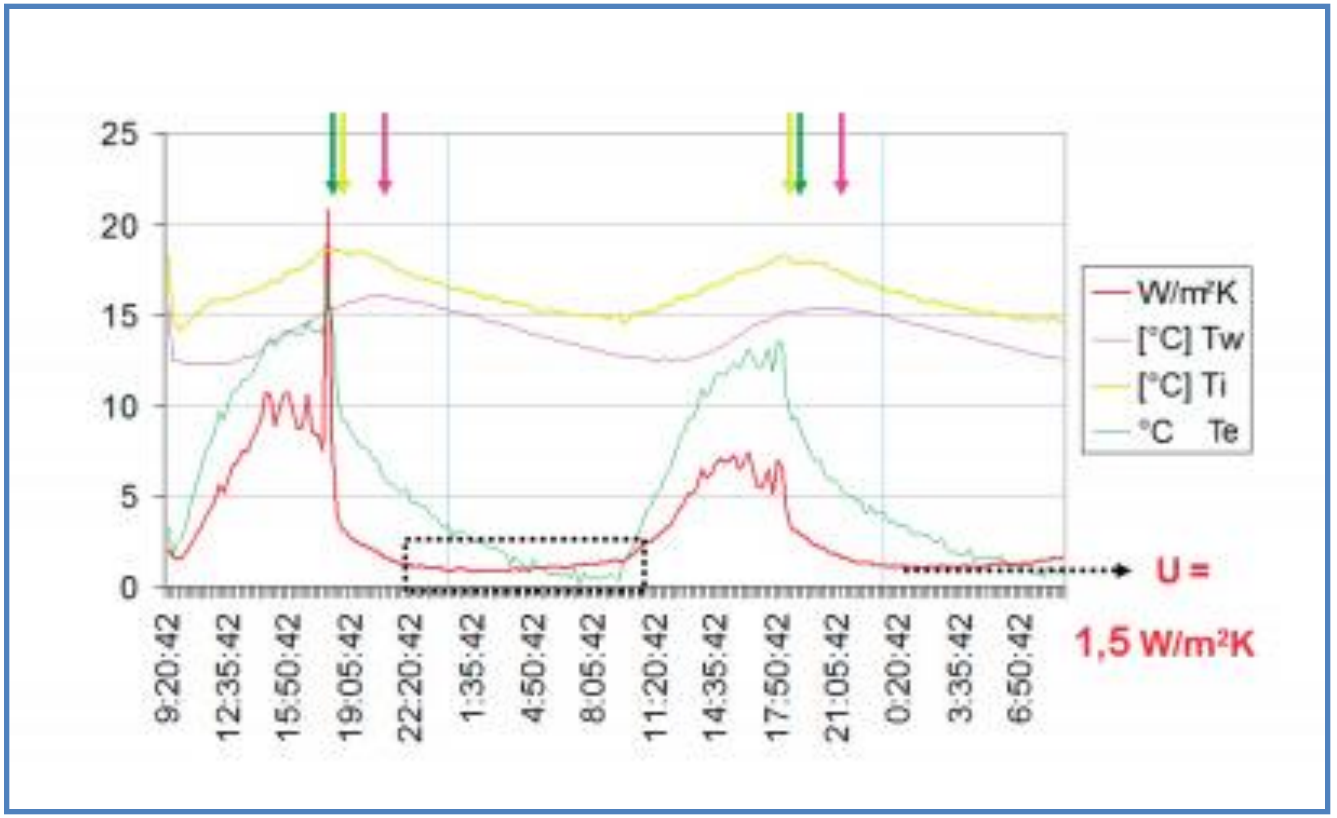
# The Results

It is important to know how to analyse the results, because the value fluctuates a lot during the measurement period.

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# Combustion Gas Analyser
# Flue Gas Analyser

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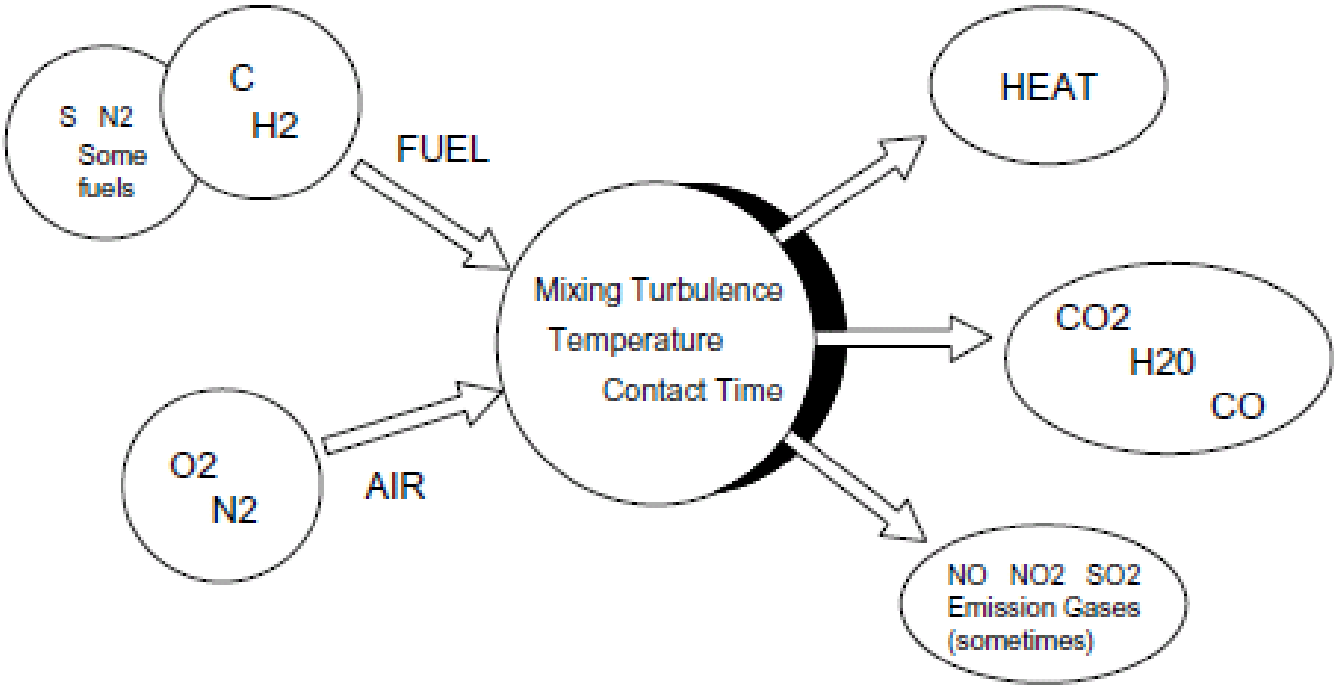
# Combustion reaction in a boiler

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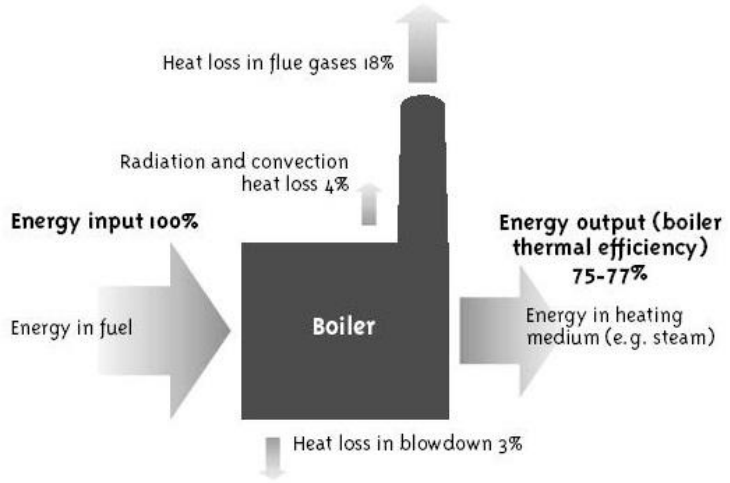
# Energy Efficiency of a Boiler

To verify the energy performance of a boiler:

- Direct Method $\eta = \frac{\dot{m} \cdot c_p \cdot \Delta T}{F \cdot PCI}$
- Indirect Method: The evaluation of the different losses in a boiler




- Heat loss in flue gases
- Bad fuel combustion
- Radiant and convection losses
- Heat loss in blowdown

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# Energy Efficiency of a Boiler

- Heat loss in flue gases
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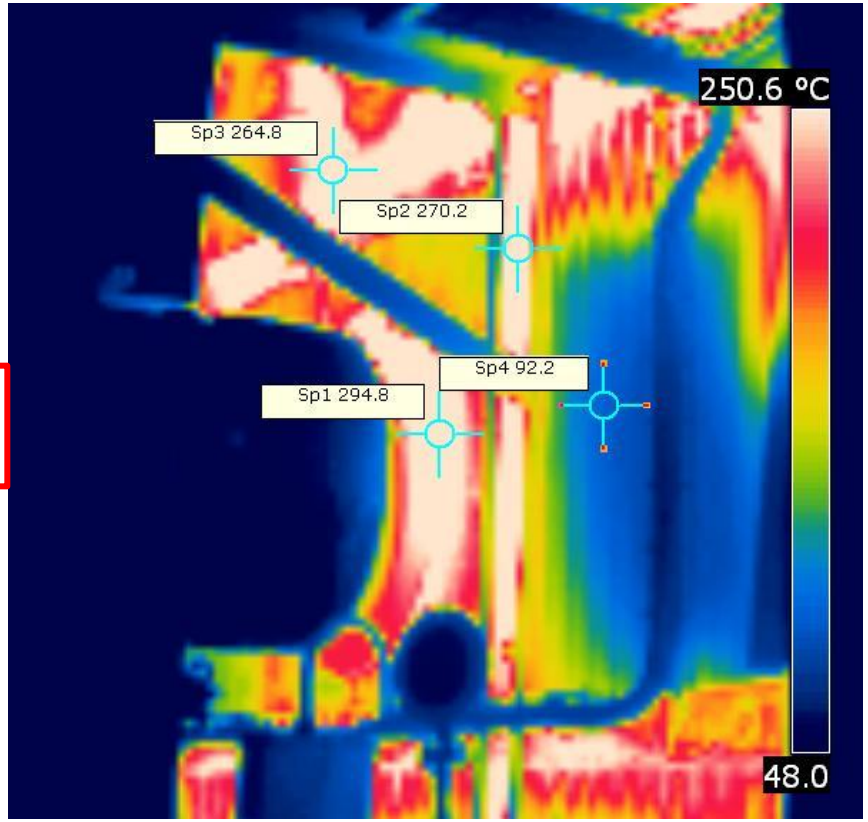


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# Flue gas analyser

The combustion efficiency is measured by the combustion gas analyser.

- Heat loss in flue gases
- Bad fuel combustion
- Radiant and convection losses
- Heat loss in blowdown

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# Flue gas analyser

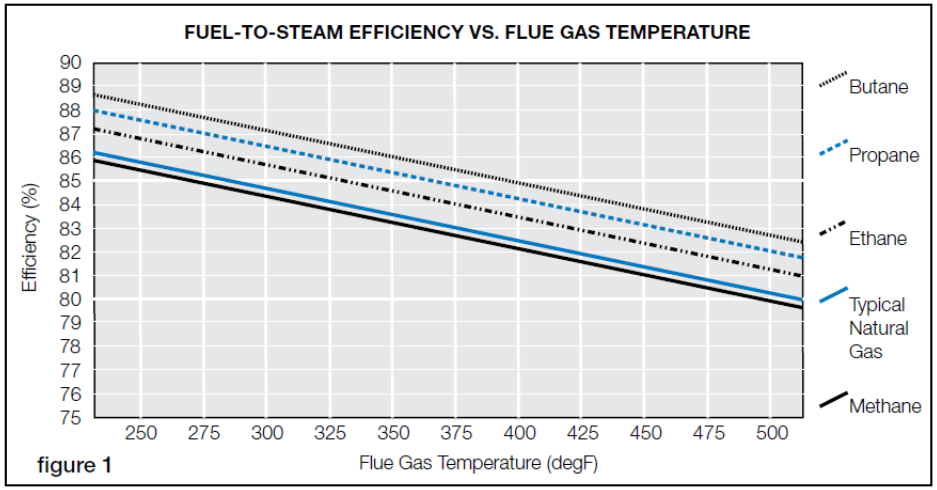

figure 1

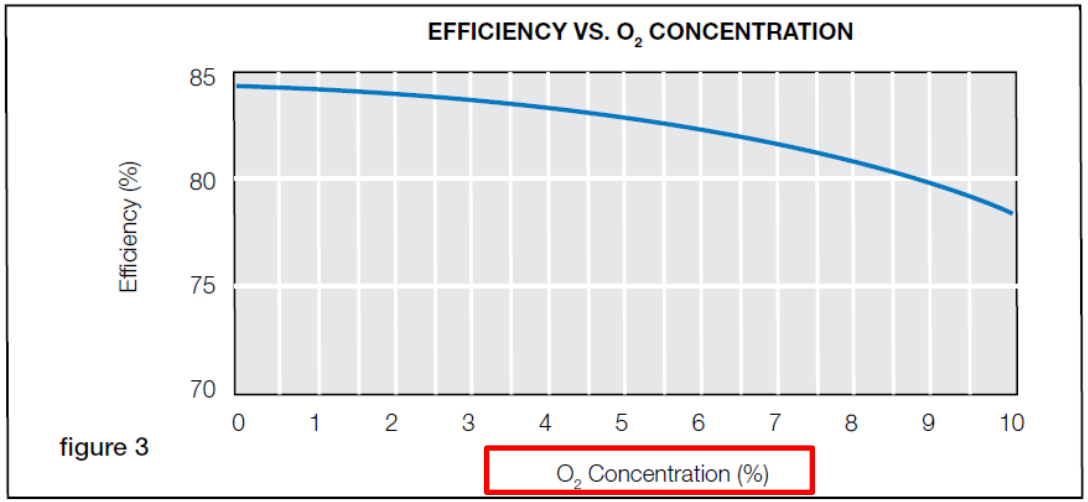

figure 3

Seasonal changes in temperature and barometric pressure can cause the excess air in a boiler fluctuate 5%-10%.

$O_2$ represents percent oxygen in the flue gas. Excess air measured by sampling the $O_2$ in the flue gas. If 15% excess air exists, the oxygen analyser would measure the $O_2$ in the excess air and show a 3% measurement.

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# Flue gas analyser

The combustion gas analyser, measures, display, store and print combustion efficiency, $O_2$, CO, $CO_2$, along with all of the necessary temperature, draft, and pressure measurements.

| | | |
|---|---|---|
| 25.11.2009 | | 13:29:28 |
| Combustible: | | Gasoleo C |
| O2ref.: | | 3.0% |
| CO2max: | | 15.5% |
| 255.8 | °C | Temp.Gas.com |
| 14 | ppm | CO corregido |
| 7.0 | % | O2 |
| 9 | ppm | CO |
| 1.50 | | Lambda |
| 10.33 | % | CO2 |
| 12.6 | % | qA |
| ----- | mbar | Tiro |
| 27.0 | °C | TA |
| 46.0 | °C | Punto rocío |
| 74 | ppm | NO |
| 87.4 | % | REN |
| ----- | ppm | COamb |
| ----- | ppm | CO2amb |
| 78 | ppm | NOx |
| ----- | kg/h | Q. co. |
| ----- | bar | Pres. Com. |
| Número de opacidad | | |
| | | _ _ _ |
| Promedio : | | ----- |
| Oleod | | --- |

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# GRID ANALYZER

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# Grid analyzer

An analyzer allows you to measure all the necessary parameters: voltage, current and power parameters for a complete diagnosis of an electrical installation. It provides captures and records of all the parameters, transients, alarms and waveforms simultaneously to have a complete knowledge of the installation or equipment under study with a simple and easy use.

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# Grid analyser

## How to switch on the analyzer?

1. *The analyzer has two different kinds of connection:*
   - Connection to the network: to charge the intern battery of the equipment for being allowed to use it in the field.
   - USB connection to PC: to download the information registered from analyzer to the computer.
2. *There are several sorts of sensor you can use depending on what you need to measure:*
   - You have 4 current inputs where you have to connect the current sensors. The most important ones are:
     - Clamp meter for measuring moderate intensity (up to 400 A) in AC, no cables very large section. You have 4 voltage inputs where you have to connect the voltage sensors.
     - Amflex for measuring high intensity (up to 6.000 A) in AC, cables of very large section.
     - Clamp meter DC: for measuring intensity in direct current.

You have 4 voltage inputs where you have to connect the voltage sensors.

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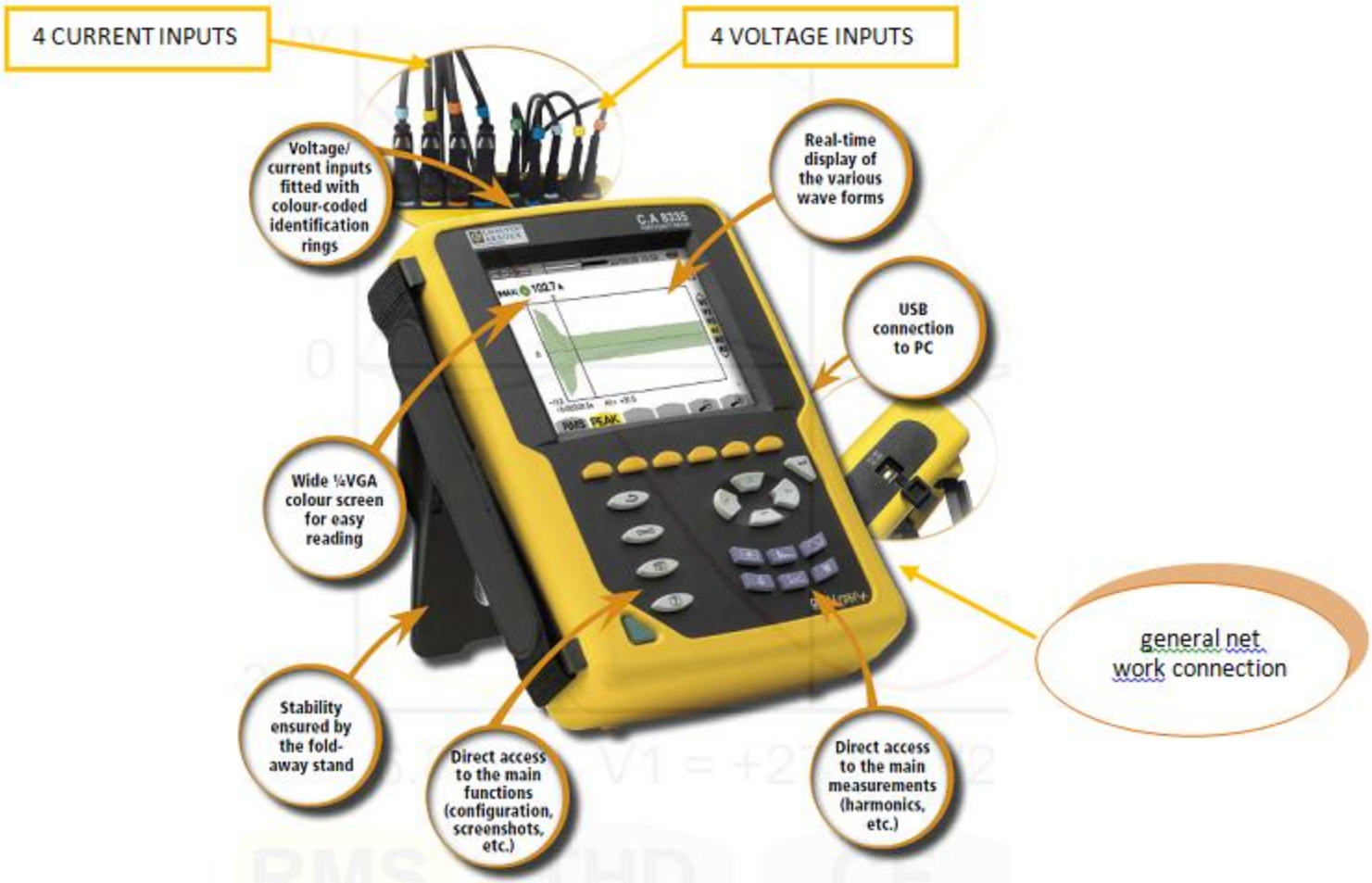
# Grid analyser

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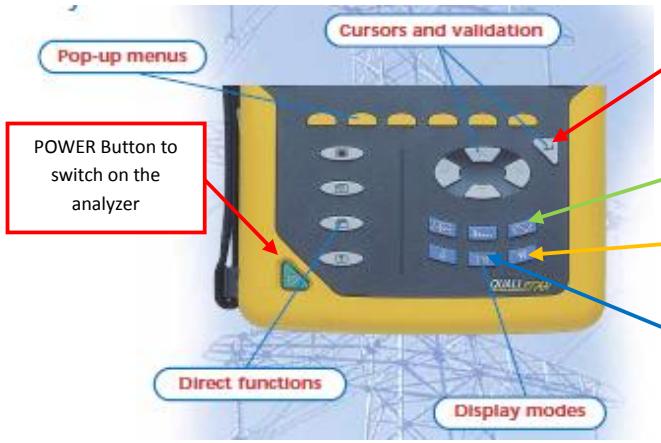
# Grid analyser

## Configuration parameters




ENTER button to confirm and access to the different menus

GRAPH button to show the value of measurements

POWER button

RECORDING button

POWER Button to switch on the analyzer

**Image 1.- Keyboard**

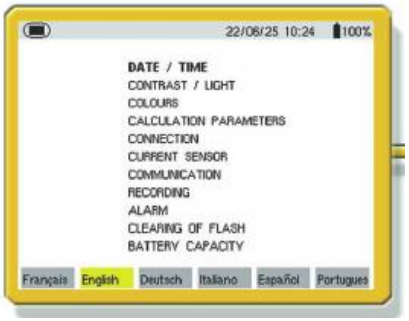



**Image 2.- SETUP Screen**

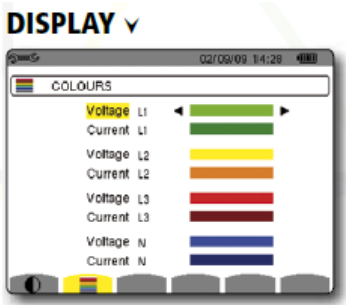



**Image 3.- Colours display**

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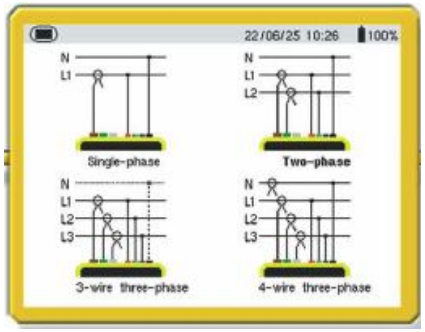
# Grid analyser

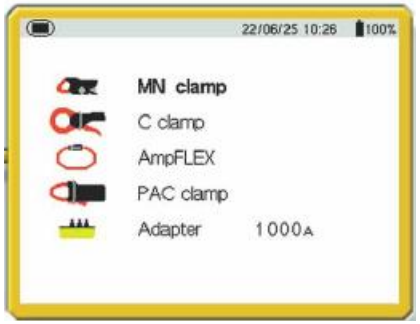
Within the SETUP Screen you can modify the following basic parameters:

- **DATE/TIME**: Adjust if is necessary the time and the date of the instrument. To know when a certain event happens when you analyze the data in the whole period of measurements.




- **COLOURS**: Select different options about the colour assigned to the power lines in both current and voltage.

- **ELECTRICAL CONNECTION**: This is one of the most important steps. You have to choose the type of electrical configuration you need to make according to the kind of installation you have: a single-phase or triphasic voltage measure. The selected option is displayed in bold, if you wanted to change it you will have to use the cursors to choose other one.




- **SENSORS AND RATIOS**: After selecting the net configuration of your installation, made in the previous item, you have to select the sensors that you have connected to the analyzer.

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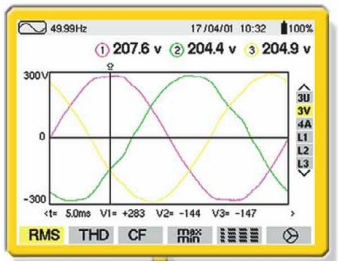
# Grid analyser

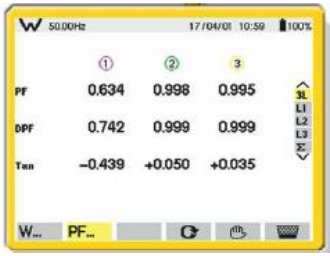
**“GRAPH” button**: You can check the different voltages measure which appear in the right side of the screen. Obviously, if the network configuration was single-phase you will only have one value of voltage. In this mode, three types of representations are possible: graphic, table and vector:

- 3U: Line voltage
- 3V: Phase voltage
- 3A: Current
- L1, L2 and L3: The three power lines with all the values measurable.
- N: neuter line





**“POWER” button**: You can check the power and energy, and check if you have installed in the right direction the current clamp meters, too. There is an arrow drawn in the current clamp indicating the direction in which the clamp should be placed, which is in the current flow. If you had negative values in one or more of the lines, you will have to change the direction of the clamp of each line which has negative value.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# Grid analyser

**Saved data:**

To save the data you have just recorded it is necessary to either turn off the analyzer or wait until the recording is finished. Before the process is considered complete, restart the machine and check that the recording is performed.

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# WP3 -
# DIAGNOSIS TOOL

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# AUTODIAGNOSIS TOOL

## 1º STEP: Identify process, systems, and equipment.

## 2º STEP: Do an inventory of electric equipment and thermal equipment

### Electric equipment:

a) Identify the equipment and the associated process (pumping, ventilation, drives…)
    a) Engines
    b) Lighting
    c) Heat pump
    d) Chiller
    e) Cold compressor
    f) Evaporators, condensators

b) Identify the electric characteristics: Power, demand current, voltage, power factor, operation regime.

c) To know how many hours operate ?

d) Load Factor

a) Maintenance program

b) Consumption if it is possible (meter or grid analyzer)

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# AUTODIAGNOSIS TOOL

## Thermal equipment:

a) Identify the equipment and the associated process
    a) Boilers
    b) Dryers
    c) Burners
b) Identify the thermal characteristics: Power, demand , kind combustible, exhausted gas temperatures,
c) To know how many hours operate?
d) Load Factor
a) Maintenance program
b) Consumption if it is possible (meter and flue combustion analyzer)

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# Thank you for your attention!

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**Gema Millán**

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circe
RESEARCH CENTRE
FOR ENERGY RESOURCES
AND CONSUMPTION

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