ZAPPITEC Series 1200 Conductivity Meter User Manual

mod 1201 (meter)
mod 1210 (probe)
mod 1211 (probe)

Contents

1 Introduction

The ZAPPITEC Series 1200 Electrical Conductivity Meter for non-magnetic metals takes advantage of the latest technological advances to provide an equipment that does not require special training, allowing non-destructive, quick and precise measurements.

The Series 1200 provides plug-and-play probes that can be individually calibrated, allowing true 100% up-time by having a spare probe.

1.1 Series 1200 description

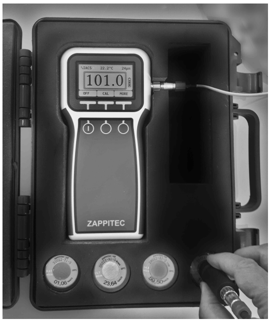

Figure 1: Meter model 1201 showing case and standard blocks

Figure 2: Probe model 1210

The Series 1200 consists of a meter (e.g. 1201) and one or more probes (ex. 1210, 1211). The meter (1201) includes a case, cable and 4 conductivity standard blocks. Table 1 below shows the main components of Series 1200:

Table 1: Series 1200 current members

Model	*Description*
1201	Meter, includes 4 conductivity standard blocks.[1]
1210	Probe 10mm diameter, 60kHz
1211	Probe 8mm diameter, 60kHz

[1] Does not include probes, which should be ordered separately

Probes can be replaced on the spot.

They work immediately after connection in a plug and play fashion: no user intervention is needed.

The main advantage is that this allows the customer to choose the probe that is ideal for their measuring conditions and the option of having spare probes.

Calibration is specific to the probe: there is no need to send back the instrument for calibration.

1.2 Electrical Conductivity

Electrical conductivity is a property of solids that describes their capacity to transmit electrical current. The higher the conductivity, the lower are the energy losses in a current-carrying conductor.

Measurements are usually made in **%IACS** units, an acronym:

" % of ***I***nternational ***A***nnealed ***C***opper ***S***tandard"

In this unit the standard annealed copper is by definition 100 %IACS at $20\,^{\circ}\mathrm{C}$, while very pure copper can reach 102.7 %IACS.

Conductivities are normally standardized at $20\,^{\circ}\mathrm{C}$ (293K or 68°F) to allow easy comparison between different metals. When the ambient temperature is not $20\,^{\circ}\mathrm{C}$, the Series 1200 will automatically correct the reading to $20\,^{\circ}\mathrm{C}$, using a standard with conductivity and thermal coefficient similar to the part being measured. The conductivities of some pure metals are shown in Table 2.

Table 2: Conductivity of some pure metals at $20\,^{\circ}\mathrm{C}$

pure metal	*Conductivity in %IACS*
Silver (Ag)	108.6
Copper (Cu)	102.7
Gold (Au)	77.9
Aluminium (Al)	65.1
Zinc (Zn)	29.2

Zappitec can optionally supply conductivity meters with the default unit set to SI units (International System of Units), MS/m (**M**ega **S**iemens per **m**eter). Conductivity is usually expressed using the greek letter sigma (σ) and units can be converted using the following formulas:

$$\sigma_{(\%IACS)} \times 0.58 = \sigma_{(MS/m)}$$

and

$$\frac{\sigma_{(MS/m)}}{0.58} = \sigma_{(\%IACS)}$$

where

$\sigma_{(\%IACS)}$ — Conductivity value in %IACS
$\sigma_{(MS/m)}$ — Conductivity value in MS/m

Another less frequently used conductivity unit is the $\frac{m}{\Omega \cdot mm^2}$ (meter per ohm millimeter squared)- which is equivalent to (MS/m).

The resistivity is the reciprocal of the conductivity and is symbolized by the greek letter rho (ρ).

Common resistivity units are:$\mu\Omega \cdot m$ (micro-ohm meter) which is the inverse of MS/m and $n\Omega \cdot m$ (nano-ohm meter). To convert, use the formulas:

$$\frac{1.724}{\rho_{(\mu\Omega \cdot m)}} = \sigma_{(\%IACS)}$$

and

$$\frac{1.724}{\sigma_{(\%IACS)}} = \rho_{(\mu\Omega \cdot m)}$$

and

$$\frac{1724}{\sigma_{(\%IACS)}} = \rho_{(n\Omega \cdot m)}$$

where

$\sigma_{(\%IACS)}$ — Conductivity in %IACS
$\rho_{(\mu\Omega \cdot m)}$ — Resistivity in $\mu\Omega \cdot m$
$\rho_{(n\Omega \cdot m)}$ — Resistivity in $n\Omega \cdot m$

Our website provides a calculator to convert between those units. Access it at:

zappitec.com/calculator

2 Principle of Operation

The Series 1200 probes generate a high-frequency magnetic field which induces eddy currents in the bulk of the sample to be tested. There is no real electrical contact between the probe and the sample, allowing measurements through thin oxides or lacquer and paint layers.

A simulation of the relative intensity of the magnetic field generated by the probe is shown in Figure 3. This field is restricted to a circular area 10mm in diameter. For this reason the sample does not need to have a flat surface larger than 10mm.

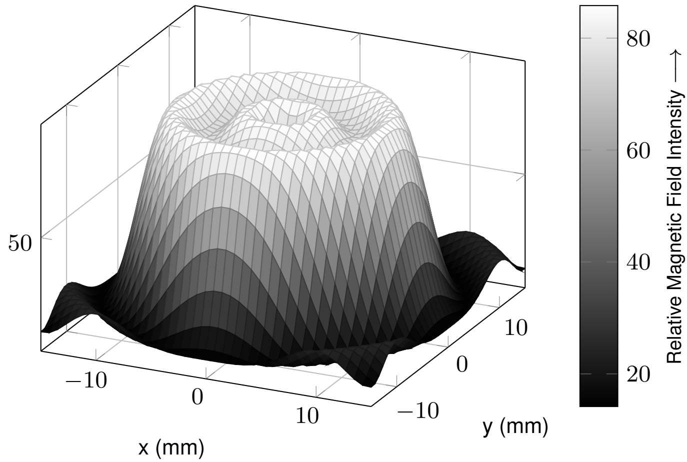

Figure 3: Magnetic field intensity generated by probe

The minimum thickness measurable by the 1210 and 1211 depends on the depth of penetration of the eddy currents and can be determined from Table 3 or Figure 4. Thinner materials can be measured by stacking several plates together provided there is no gap between them. Tightly packed sheet rolls can be measured as well. Precision will be slightly compromised.

Table 3: Minimum thickness measurable by 1210 and 1211 probes

Metal	*Conductivity (%IACS)*	*Minimum thickness*
Copper, copper alloys	65-100	1.0 mm
Aluminium,alloys	45-65	1.2 mm
Brass,Bronzes	20-45	1.8 mm
Lead, Tin	8-20	3.0 mm

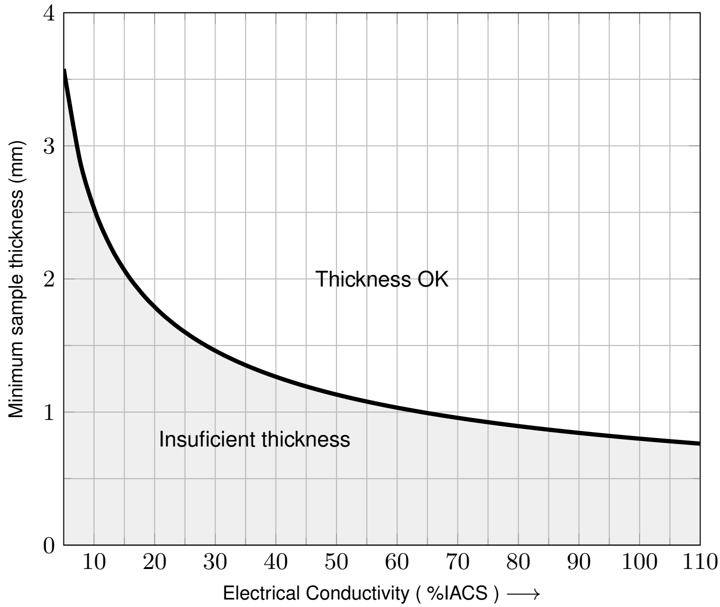

Figure 4: Minimum sample thickness versus conductivity @ 60kHz

3 Operating Instructions

3.1 General description

The ZAPPITEC Series 1200 Conductivity Meter offers the following features which set it apart from other equipments in the market:

Plug-and-play probes
Probes for series 1200 are ready to use as soon as plugged in and the calibration is stored in the probe itself. Once the probe is connected the instrument will show probe details, including last calibration date. Spare probes allow continuous availability of the conductivity meter, even during calibration cycles.

Automatic Calibration
Four conductivity standards are shipped with the meter. Their values are recorded in its non-volatile memory. To calibrate, just place firmly the probe against the standard and press “CAL”. The instrument can only be calibrated with the standards shipped with the meter.

Low power consumption
The series 1200 is powered by 4 AA alkaline batteries, dispensing with chargers. The auto shut-off system extends battery life.

Simplicity of operation
Turn the equipment on. Place the probe on the selected standard and press “CAL”. Place the probe on the sample to be measured.

The 1201 meter is conditioned in a impact resistant case for protection in industrial environments. It is shipped with four conductivity standards, the values of which are stored in the equipment’s memory. The individually calibrated standards are required to operate the equipment.

The frontal panel of the 1201 has three push-buttons. Their functions are context sensitive, according to the mode of operation. A high visibility liquid crystal screen is readable even under direct solar light. The AA batteries should be replaced by new ones when an empty bat indicator appears on the screen.

3.2 Measuring procedure

To obtain accurate results, we recommend the following procedure:

1. The surfaces to be measured must be flat and larger than 10mm in diameter for probe mod. 1210 or 8mm in diameter for probe mod 1211. The thickness of the sample should be above the minimum recommended in Figure 4.
2. The equipment must be calibrated with the standard which has a conductivity closer to the conductivity of the sample to be measured.
3. The standards and the sample to be measured must be at the same temperature within 0.5 $^{\circ}$C. If that's not the case, place the standard over the sample and wait some minutes to allow the temperatures to equalize before measurements.
4. Use only the standards shipped with your instrument, identified with the corresponding serial number.

Once the above has been assured, proceed to the measurements:

1. Turn on: if the equipment is off, press "(I)". The meter model and serial number will appear on the display. Press any key to continue. The equipment will then scan and find a connected probe. The display will then show the probe model, serial number, frequency, diameter and calibration date, as shown in Figure 5 below. Press OK to continue. If no probe is connected the display will show "PROBE DISCONNECTED".
2. Calibrate: place the probe firmly on the appropriate standard shipped with the equipment. Press "CAL" immediately. The value will be adjusted to the value engraved on the standard used.
3. Measure: place the probe firmly on the sample to be measured. The value on screen is the conductivity of the sample already corrected to the value at $20\,^{\circ}\mathrm{C}$, even if the ambient temperature is different.

To measure again, repeat the procedure from item 2.

For successive measurements of several samples which are at the same temperature, it’s possible to skip calibration and simply measure as shown in item 3.

Please verify calibration periodically (item 2.) to guarantee measurements are correct.

Calibration uses only one standard at a time. Use the standard which has conductivity closer to the sample to be measured.

Example: To measure copper, use the copper standard shipped with the 1201. For measurements in aluminium or aluminium alloys choose the aluminium standard which has the closest conductivity to the part to be measured.

The 1201 will turn itself off automatically after 10 minutes from latest measurement to save battery. It’s possible to turn off the equipment at any moment, pressing the “OFF” button.

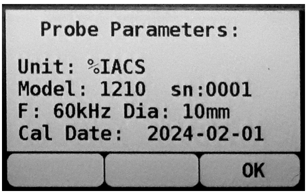

Figure 5: Meter screen showing connected probe parameters

3.3 Other functions

3.3.1 Main Screen

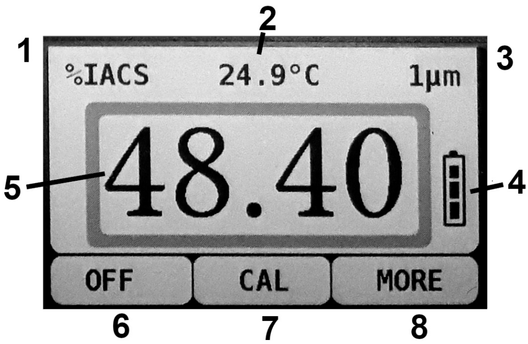

Figure 6: Meter screen - Normal Operation

1. Conductivity Unit, either %IACS or MS/m
2. Approximate probe temperature (always in °C)
3. Lift-off in µm (approximate). Useful to evaluate thickness of paint. When not measuring conductivity, this position indicates the probe frequency in kHz.
4. Visual battery indicator.
   Replace batteries immediately when depleted.
5. Electrical Conductivity value measured in the unit indicated in *1.*
6. Turn off the instrument
7. Calibrate (see 3.2 Measuring Procedure)
8. More functions

3.3.2 More Functions

By pressing "MORE" in the main screen (Figure 6), the menu in Figure 7 below is reached.

Figure 7: Meter Screen - More Functions

The menu can be navigated with the arrows and the option is selected by pressing "SEL".

Start Recording
: By selecting this, normal operation changes to record mode, the "OFF" button being replaced by "MEM" as shown in Figure 8

Stop Recording
: Exits record mode, the "MEM" button becomes "OFF" again.

Read Stored Values
: Read and navigate through the conductivity values stored in the device (Figure 11)

Change Unit
: Allows to change from %IACS to MS/m and vice-versa. After power down the unit changes back to the instrument's default.

Return
: Returns to normal operation without any changes

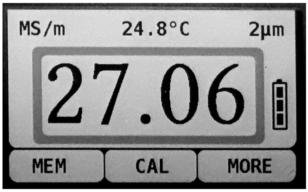

Figure 8: Meter Screen - Record Mode

3.3.3 Memory

Figure 8 shows the screen in normal operation when in record mode. By pressing "MEM" the display will show the memory position where the value is stored, as shown in Figure 9.

Figure 9: Meter Screen - Storing Value

To read the stored values, just press "MORE" and then select "Read Stored Values" as shown in Figure 10 below.

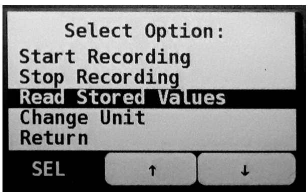

Figure 10: Meter Screen - Select Read Stored Values

The stored values will then be shown as in Figure 11. Up to 60 values can be stored in memory. If more than 12 values are stored, go to next page by press "NEXT". If no value was stored yet, you will see "NO DATA LOGGED" on the display.

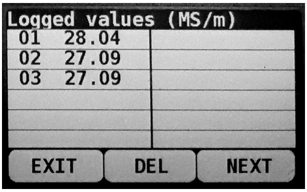

Figure 11: Meter Screen - Read Logged Values

By pressing "DEL" all stored values will be deleted.

3.4 Instrument care and warnings

Take special care of the standards shipped with the instrument. They are necessary for correct calibration.

Use only the standards supplied with the equipment.

Do not use on hot, dirty or wet surfaces.

Do not use abrasives, sandpaper or solvents to attempt to clean the probe. For cleaning use only a clean, dry cotton cloth instead.

Do not place the probe near magnets, magnetic fields or magnetized parts.

If you have a policy requirement to certify/calibrate your probes periodically, ZAPPITEC can supply this service. By having a spare probe you may send one for calibration while using the other to allow for zero down-time.

4 Applications

4.1 Evaluation of purity of metals

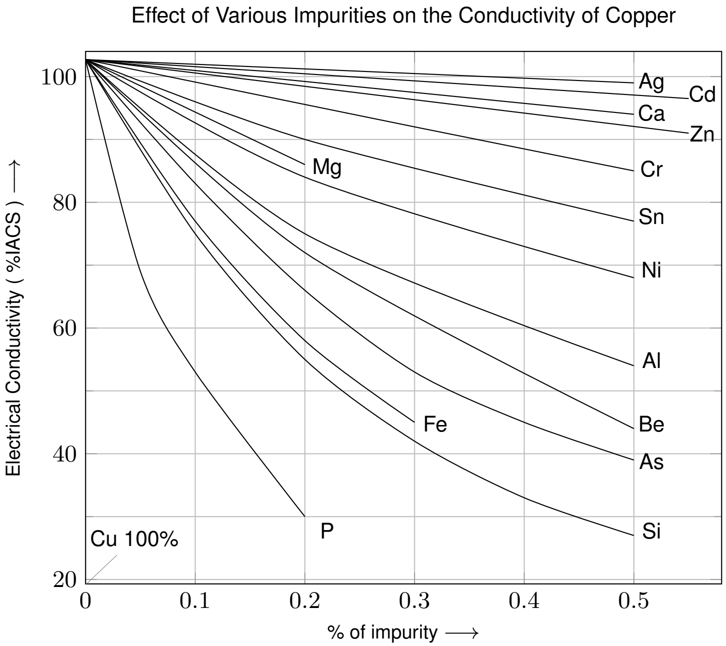

Figure 12: Influence of various elements on the conductivity of copper

Small quantities of impurities added to pure, high conductivity metals distort the cristal lattice interfering with the flow of electrical current. For this reason conductivity tends to decrease, allowing convenient evaluation of the degree of purity of the sample tested.

As an example we can mention pure copper, which has a conductivity of 102.7 %IACS at $20\,°\mathrm{C}$. We show in Figure 12 the relationship between conductivity of copper and concentration of impurities. Each element affects the conductivity in a different way. Phosphorus (P), for example, has a big influence: one part in 1000 of phosphorus in copper reduces the overall conductivity of the resulting alloy by 50%, when compared with pure copper.

Figure 13 shows the influence of impurities on silver (Ag), which has a conductivity of 108.6 %IACS at $20\,°\mathrm{C}$ when pure.

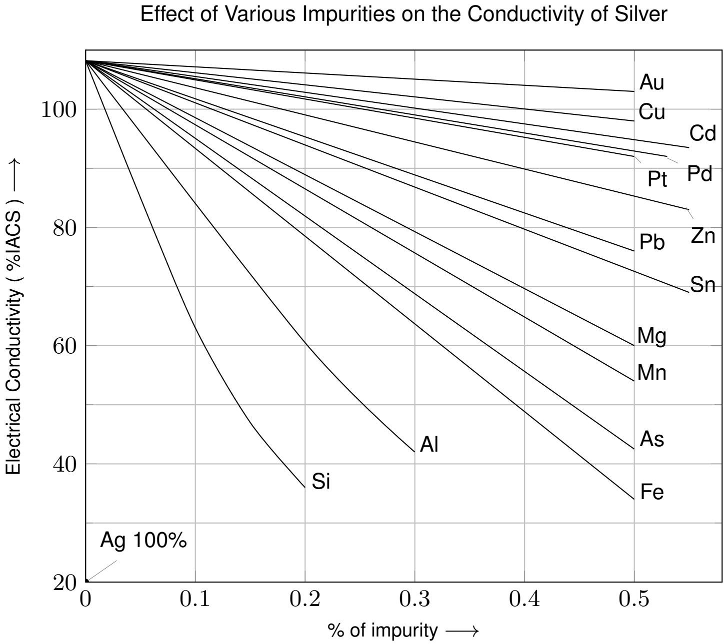

Figure 13: Influence of various elements on the conductivity of silver

4.2 Determination of composition of binary alloys

In some binary alloys, the conductivity changes continuously as the composition varies. Some examples are shown in the following plots. Figure 14 shows how conductivity changes as nickel content is increased in copper-nickel alloys.

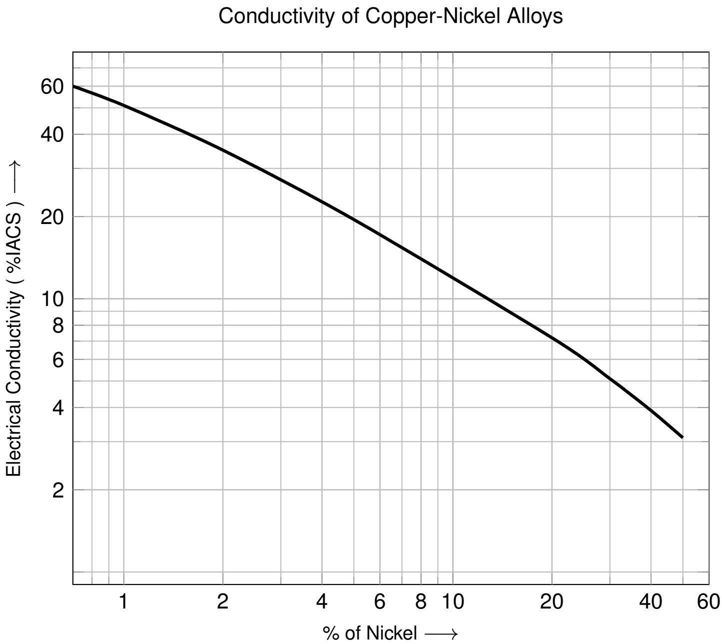

Figure 14: Conductivity of binary copper-nickel alloys

The influence of the addition of magnesium on aluminium's conductivity can be seen in Figure 15.

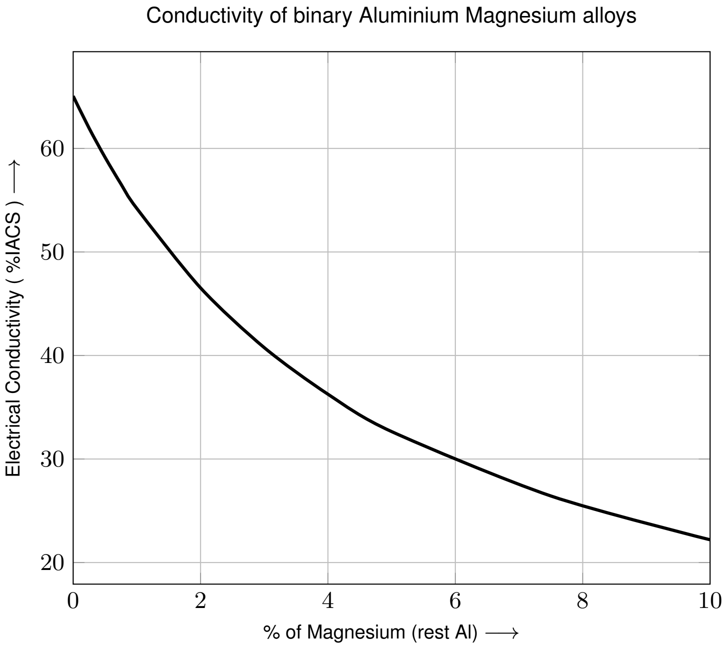

Figure 15: Conductivity of binary aluminium-magnesium alloys

The composition of tin-lead alloys can be estimated with a single conductivity measurement. Figure 16 shows the conductivity dependence on the alloy composition for this system.

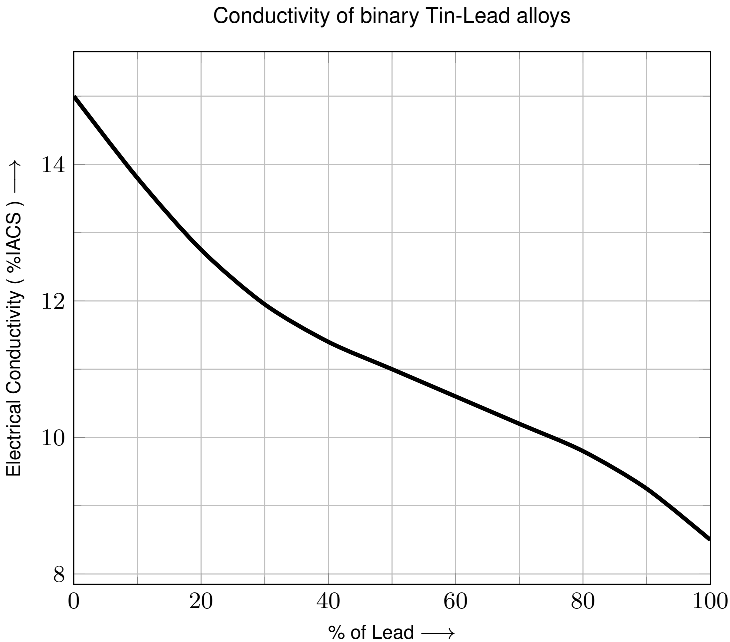

Figure 16: Conductivity of binary tin-lead alloys

4.3 Degree of cold work and heat treatment

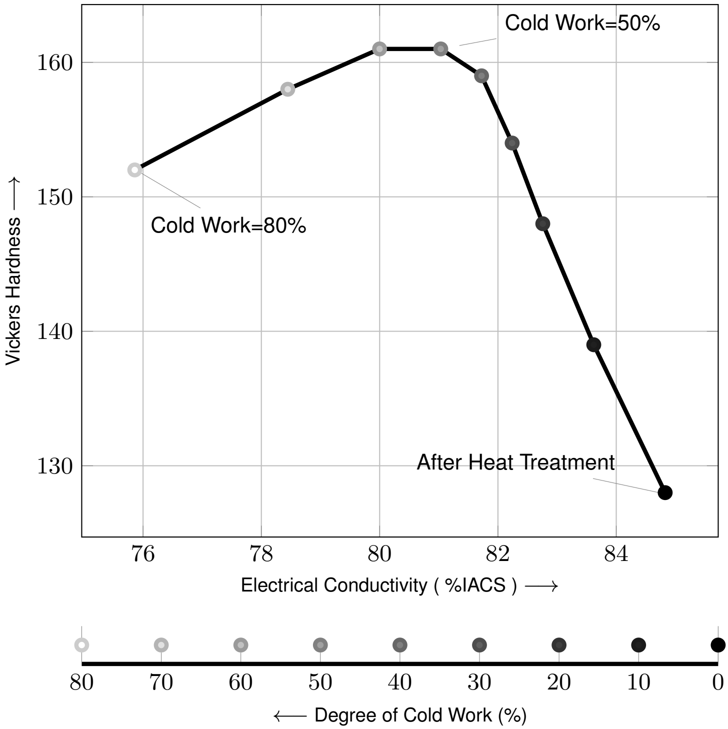

Figure 17: Hardness and conductivity during cold form in CuCr 0.6% alloy

Another important application of the Conductivity Meter is the evaluation of the degree of thermal treatment in special alloys.

The Series 1200 Conductivity Meter allows for the verification of the degree of heat treatment and cold work in copper-chromium, copper-beryllium and various aluminium alloys. In Figure 17 the conductivity and hardness variations according to the degree of cold work in a copper-chromium 0.6% alloy. It's also possible to verify the progress of heat treatment or estimate thermal damage in parts made of aluminium alloys which have been exposed to temperatures above specifications. The latter application is commonplace in the aerospace industry.

4.4 Thermal Conductivity Measurement

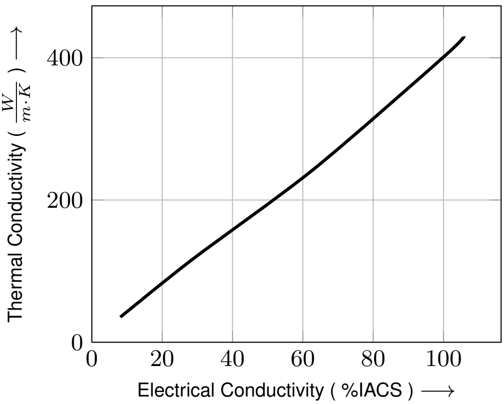

Figure 18: Relationship between thermal and electrical conductivity in metals

The thermal conductivity in metals is approximately proportional to the electrical conductivity. It is thus possible to determine thermal conductivity without measuring it directly as shown in Figure 18. It is also possible to use the following formula to estimate the thermal conductivity from the electrical conductivity:

$$(\frac{W}{m \cdot K}) = 400 \times (\%IACS)$$

where $(\frac{W}{m \cdot K})$ is the thermal conductivity in Watts per meter-Kelvin

5 Specifications

5.1 Meter model 1201

All Series 1200 components are compatible.

Display:	High resolution LCD display
Memory:	up to 60 conductivity values
Power supply:	4×AA alkaline batteries

5.2 Probe model 1210

Measuring Range:	1.0 - 110 %IACS	0.6 - 64 MS/m
Frequency:	60kHz
Diameter:	10mm

5.3 Probe model 1211

Measuring Range:	1.0 - 110 %IACS	0.6 - 64 MS/m
Frequency:	60kHz
Diameter:	8mm

Resolution for probes 1210 and 1211 is:

0.1 %IACS (65-110 %IACS)
0.05 %IACS (30-65 %IACS)
0.02 %IACS (10-30 %IACS)
0.01 %IACS (1.5-10 %IACS)

6 Ordering information

Product	Model n.	Description
1201 meter	1201	Meter, 4 stds, cable and case
1210 probe	1210	10mm probe, 60kHz
1211 probe	1211	8mm probe, 60kHz
1299 cable	1299	1.3m cable for Series 1200

The default unit is %IACS. If you prefer the instrument/probes default unit to be MS/m, simply add a "M" to the end of the model number.

Example: 1201M, 1210M, 1211M, etc. will display values in MS/m

Example: 1201, 1210, 1211, etc. will display values in %IACS