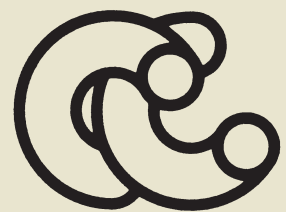


Wieland



CUPROCLIMA®

Quality Standard
for ACR Copper Tubes
in LWC

Wieland

cuproclima® is a protected tradename for high-quality seamless copper tubes in level-wound coils (LWC) supplied to manufacturers of heat exchangers for the air conditioning and refrigeration (ACR) industry.

This document describes the product requirements and delivery form of the tubes for such an end use. The specification has been established in view of the special manufacturing requirements of the ACR industry. As such it covers the main national and international standards.

It should be pointed out that the cuproclima® specification supports the new European Pressure Equipment Directive 97/23/EC.

Of course, the production sites of Wieland-Werke AG have been certified according to DIN EN ISO 9001 : 2000 for copper tubes. The quality system of Wieland-Werke AG has been approved by the auditing company Bureau Veritas.

| Edition | Revision | Date |
|----------------|-----------------|-------------|
| 1 | 0 | May 2002 |
| 1 | 1 | June 2003 |
| | | |
| | | |

1.1 Melting and casting of round billets

Tube manufacturing starts with a round billet of about 360 kg. A round billet is a cut length of cylindrical casting.

In the manufacture of billets, the melting and casting process can be either in heats or continuous.

1.2 Hot extrusion of shells

Shells are produced on an extrusion press by piercing and extruding the billets. For this purpose, the billets are preheated to about 900 °C. To prevent the oxidation of the inner and outer surfaces of the shell, a special technique is used.

1.3 Cold working

The final dimension of the tube is reached by drawing (bull blocks, spinner blocks) or combination of rolling (tube reducer) and drawing.

1.4 Level winding and eddy current testing

After drawing the tubes are level wound. The eddy current tester is linked to the level winder. Whilst the tube is being level wound, it is simultaneously 100 % eddy current tested.

1.5 Annealing

To achieve the final temper the tubes are annealed. The annealing is performed in a protective atmosphere (including other conditions) to eliminate oxidation and ensure a clean inside/outside surface.

1.6 Packaging

After the annealing, the tubes shall be packed in such a way that damage during transport and storage is avoided.

1.7 Super clean quality

On request, copper tubes are also available with particularly high inside cleanliness in the so-called super clean quality.



1.8 Quality control

The purpose of quality control during the manufacturing process is to identify at the earliest possible stage any defect deleterious to the final product and to stop such material from proceeding in the process. For that purpose, the product itself, the manufacturing parameters as well as the machinery, equipment and tooling at the different stages are submitted to permanent controls as specified in the QAM and the documented procedures.

2.1 Scope

The purpose of this specification is to define the chemical, geometrical, mechanical and other characteristics of seamless round copper tubes used in the manufacture of heat exchangers for air conditioning and refrigeration equipment and the procedures used to test these characteristics.

These tubes are supplied in LEVEL-WOUND COILS in an annealed temper and with appropriate packaging.

2.2 General statement

When tubes are ordered according to this cuproclima® specification, the requirements listed in items 2.3 - 2.7 shall apply. This specification covers among others the following standards (latest editions):

| | | | | |
|------|---------------|------------------|----------|---|
| ASTM | B 68 B 743 | C 12200 (DHP) | (USA) | light annealed soft annealed |
| EN | 12735-2 | Cu-DHP | (Europe) | Y040 light annealed Y035 soft annealed |

2.3 Definitions

- Seamless tube: a tube produced with a continuous periphery at all stages of the production;
- Coil: a length of tube wound into a series of connected turns (without cardboard reel);
- Level-wound coil (LWC): a coil in which the tube is wound into layers parallel to the axis of the coils such that successive turns in a given layer are next to one another (without cardboard reel);
- Cardboard reel: Type of packaging for LWC made of cardboard material. To use for customers without coil adapters in decoiling operation.
- The term “unaided eye” as used in this specification means that the use of corrective spectacles to reach normal vision are permitted.
- Local defects: a discontinuity localised in a very short length of the tube (holes, cracks, dents, inclusions, etc.)
- Longitudinal defect: a non-local discontinuity which involves a certain length of the tube.

2.4 Order specification

Order specification shall include the following information:

- Copper tubes according to cuproclima® quality standard
- Total quantity (kg) of each item
- Material designation (deoxidized high residual phosphorus copper)
- Temper (light or soft annealed)
- Dimensions (outside diameter x wall thickness)
- Maximum coil weight
- Type of packing (without or with cardboard reel)
- Special requirements (e.g. maximum cardboard reel or coil dimensions, sealing of the tube ends, mill test certificate, etc.)

2.5 Specification and requirements

2.5.1 Material

The tubes are made of phosphorus deoxidized copper.

The chemical composition shall meet the requirements of table 2.

2.5.2 Temper

Tubes are normally supplied in "light annealed Y040" temper. They can also be supplied in "soft annealed Y035" temper.

Respective mechanical properties and grain size shall meet the requirements of table 3.

2.5.3 Dimensions and tolerances

The tubes are defined by

- the outside diameter (d)
- the wall thickness (t)

2.5.3.1 Recommended sizes

Cuproclima recommends the sizes in table 4.

Other sizes can be supplied upon agreement.

2.5.4 Surface quality

The inner and outer surfaces of the tubes shall be clean and smooth.

The maximum permissible residue on the inner surface of the tube measured in specific cleanliness tests (ASTM B 743 or comparable) is 25 mg/m². On request, the ends of each coil shall be closed to prevent any contamination of the inner surface.

2.5.5 Mechanical integrity

2.5.5.1 Drift expanding

No crack, break or tearing of the metal shall be visible to the unaided eye after a specific drift expanding test.

The outside diameter of the tube shall be expanded by 40 %.

2.5.5.2 Eddy current testing

After the final draw, the tubes shall be 100 % tested in an eddy current testing unit. Signals indicating possible defects on the tube surface trigger a colour marking at the point concerned for subsequent removal by the end user. The marking shall not deform the tube (usually black marks). The permissible number of black marks shall comply with the values given in table 7. This number is proportional to the coil weight.

2.5.6 Conditions of delivery

2.5.6.1 Delivery form

The tubes can be delivered either in bare coils or on cardboard reels.

Common range of bare coils and cardboard reel sizes are given in table 8. Precise figures for weights and dimensions are obtainable from the manufacturer.

2.5.6.2 Weight tolerance

If the nominal weight of the coil is indicated in the order, no coil shall weigh less than 70 % of the nominal weight per shipment and a maximum of 20 % of the coils shall have this minimum weight.

Example:

Shipment of 10 LWC, nominal weight 150 kg:
No coil shall weigh less than 105 kg (70 % of the nominal weight) and a maximum of 2 coils (20 % of the coils) shall weigh 105 kg.

2.5.6.3 Packing and labeling

For transportation the coils are stacked on pallets one above the other.

They shall be packaged in such a way that they are protected from any damage under normal transportation, storing and handling conditions. Each coil shall be provided with a label giving at least the following information in a legible and permanent form:

- tube dimensions
- coil net weight
- number of eddy current black marks
- lot identification number

Each pallet shall be provided with a label with at least the following information:

- manufacturer
- customer
- shipping address
- order number
- dimensions and temper
- total gross and net weight

2.6 Test procedure

This item describes the testing of the final product.

2.6.1 Number of tests

The number of tests on final product is given in table 9.

2.6.2 Retests

Retests may be performed if only one specimen per property out of a batch of 15 tonnes maximum fails. In that case, four additional samples from different coils of the same batch shall be taken. The results on all these additional samples have to meet the requirements. Otherwise the entire batch shall be rejected.

If the result of more than one specimen fails to meet the requirement for a specific property, the entire batch shall be rejected.

2.6.3 Test methods

2.6.3.1 Methods of analysis

The chemical composition shall be determined by chemical or spectrographic methods according to ASTM E53, E62, E478 or ISO 1553 and ISO 4741.

2.6.3.2 Tensile test

The tensile test shall be carried out according to EN 10002-1.

2.6.3.3 Grain size definition

The grain size shall be determined according to the ASTM standard E112 (comparison procedure or linear intercept procedure). For quality control during the manufacturing process other appropriate methods may be used.

2.6.3.4. Cleanliness test

To perform the cleanliness test according to ASTM B743 or EN 723, a section from the outside end of the coil, not less than 1.5 m long, is used. The inside of the tube is washed with a suitable solvent. The residue remaining after evaporation of the solvent shall be determined.

For the routine quality control, other methods may be used.

2.6.3.5 Drift expansion test

This test shall be carried out according to ISO 8493, using a conical mandrel having a 60° included angle.

2.6.3.6 Eddy current testing

After the final draw, the tubes shall be passed through an eddy current testing unit adjusted to provide information on the suitability of the tube for the intended application. For this purpose, testing procedures shall detect both local and longitudinal defects.

2.6.3.6.1 Local defects

Testing shall follow the procedures of ASTM Practice E 243 Item 7.1.2b or EN 1971, except for the determination of the "end effect".

The calibration tube used to adjust the sensitivity of the unit shall be selected from a typical production run and shall be representative of the purchase order.

The artificial defects used when calibrating the unit shall be a set of three holes, each drilled radially through the tube wall in each of three successive transverse planes at 0–120 and –240 degrees (table 10, Fig. 2). The holes shall be spaced to provide signal resolution adequate for interpretation.

Alternatively, a calibration tube with one hole may be used. In this case the calibration tube shall be passed through the eddy current testing unit three times at 0–120 and –240 degrees (see EN 1971 – item 5).

The diameters of the drilled holes are given in table 10.

As an alternative, the E. C. test and calibration of the equipment shall follow the procedure of DKI-Werkstoffblatt No. 781 class A.

2.6.3.6.2 Longitudinal defects

Longitudinal defects can be detected by summing up, in a specific tube length, a certain number of signals smaller than those defined in item 2.6.3.6.1.

Calibration of the testing unit for this purpose shall be done in such a way that all defects that could be harmful to the end use, according to the manufacturer's experience, shall be detected.

Other appropriate methods with the same sensitivity may be used.

2.6.3.7 Tolerances on outside diameter

Tolerances on the outside diameter are given in table 5.

The average outside diameter

is defined as half of the sum of any two outside diameters normal to each other in the same cross-section.

$$d_{aver} = \frac{d_{max} + d_{min}}{2} \text{ (mm)}$$

The roundness tolerance refers to the deviation of the tube cross-section from the circular form.

The percentage roundness is defined as follows:

$$\text{roundness tolerance} = \frac{d_{max} - d_{min}}{d_{aver}} \times 100 \%$$

where:

d_{max} = maximum diameter (mm)
 d_{min} = minimum diameter (mm)
 d_{aver} = average diameter (mm)

2.6.3.8 Tolerances on wall thickness

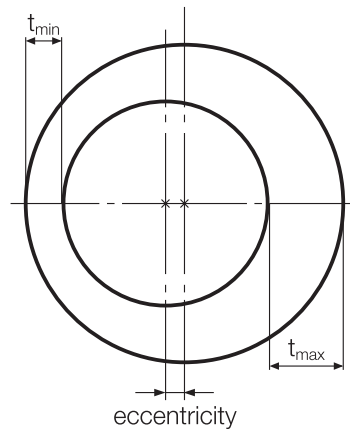
The wall thickness tolerances are given in table 6.

The **average wall thickness** is defined as half of the sum of maximum and minimum wall thickness at any cross-section of the tube.

$$t_{aver} = \frac{t_{max} + t_{min}}{2} \text{ (mm)}$$

Eccentricity (mm) is defined as follows:

$$\text{eccentricity} = \frac{t_{max} - t_{min}}{2} \text{ (mm)}$$



where:

t_{max} = maximum wall thickness (mm)

t_{min} = minimum wall thickness (mm)

at any cross-section of the tube.

Non-uniformity of wall thickness

(%) refers to the deviation of the maximum and/or minimum wall thickness from the average wall thickness.

$$\text{NUWT} = \frac{t_{max} - t_{min}}{t_{max} + t_{min}} \times 100 \%$$

Note:

The dimensions are determined with commercial measuring equipment.

2.7 Mill test certificate

Upon request, a mill test certificate shall be supplied identifying the shipment and giving the test results of the final product according to this specification.

Table 1

Description of quality control within the manufacturing process

| Manufacturing stage | Parameters to be controlled | |
|------------------------------------|---|--|
| | on product | on equipment |
| Melting and casting | <ul style="list-style-type: none"> ● chemical composition ● dimensions ● quality of surface and of cut ends | <ul style="list-style-type: none"> ● melting and casting temperature ● cooling parameters ● casting speed |
| Hot extrusion | <ul style="list-style-type: none"> ● dimensions incl. eccentricity ● surface quality | <ul style="list-style-type: none"> ● heating parameters ● tool quality |
| Cold working | <ul style="list-style-type: none"> ● dimensions ● surface quality | <ul style="list-style-type: none"> ● tool dimensions and quality ● lubrication |
| Level winding including ec-testing | <ul style="list-style-type: none"> ● dimensions ● surface quality ● quality of defect marking ● number of defects | <ul style="list-style-type: none"> ● tool quality ● adjustment and proper functioning of EC and marking devices |
| Annealing | <ul style="list-style-type: none"> ● surface quality ● inner surface: visually on a cross cut coil or/and by cleanliness test | <ul style="list-style-type: none"> ● time ● temperature ● atmosphere |
| Packaging | <ul style="list-style-type: none"> ● quality of packaging | |

Table 2

Chemical analysis

| Standard | Material designation | Cu (+ Ag) % min. | P % | Bi % max. | Pb % max. |
|-------------|----------------------|------------------|-------------|-----------|-----------|
| cuproclima® | CU-DHP | 99.90 | 0.015–0.040 | 0.001 | 0.003 |
| ASTM | C 12200 | 99.90 | 0.015–0.040 | – | – |
| EN 12735-2 | CU-DHP | min. 99.90 | 0.015–0.040 | – | – |

Table 3

Mechanical properties and grain size

| Temper | | proof*) stress, $R_{p0.2}$ N/mm ² | Tensile strength R_m min. N/mm ² | Elongation A min. % | Average grain size mm |
|------------------|------|--|---|---------------------|-----------------------|
| Light annealed | Y040 | 40–90 | 220 | 45 | 0.015–0.035 |
| EN 12735-2 | Y040 | 40–90 | 220 | 40 | 0.015–0.040 |
| Soft annealed**) | Y035 | 35–80 | 210 | 48 | 0.030–0.060 |
| EN 12735-2 | Y035 | 35–80 | 210 | 40 | 0.030–0.060 |

*) $R_{p0.2}$ values are affected by test specimen preparation but shall always meet the above requirements.

***) Only on special request, but wall thickness minimum 0.5 mm.

Table 4

Recommended sizes

| O.D. inch | Wall inch mm | .011 | .012 | .014 | .016 | .018 | .020 | .025 | .028 |
|--------------|--------------------|------|------|------|------|------|------|------|------|
| | | 0.28 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 0.63 | 0.70 |
| 5/16 | 7.94 | ● | ● | ● | ● | | | | |
| 3/8 | 9.53 | ● | ● | ● | ● | | ● | | ● |
| 1/2 | 12.70 | | | ● | ● | | ● | ● | ● |
| 5/8 | 15.87 | | | | ● | ● | ● | ● | ● |

Table 5

Tolerances on outside diameter

| | Nominal diameter range (mm) | | | | | Wall thickness range (mm) |
|-----------------------|-----------------------------|--------------------|---------------------|---------------------|---------------------|---------------------------|
| | from 6.00 to 9.52 | over 9.52 to 13.00 | over 13.00 to 16.00 | over 16.00 to 22.00 | over 22.00 to 28.00 | |
| Average diameter (mm) | ±0.04 | | ±0.05 | ±0.05 | – | t ≤ 0.40 |
| | ±0.04 | | | ±0.05 | ±0.08 | t > 0.40 |
| Roundness (%) | 4.0 | 5.0 | 7.0 | *) | – | t ≤ 0.40 |
| | 3.5 | 4.0 | 6.0 | *) | *) | 0.40 < t ≤ 0.70 |
| | 3.0 | 3.5 | 5.0 | *) | *) | 0.70 < t ≤ 1.00 |
| | | | | *) | *) | 1.00 < t ≤ 1.20 |
| | | | | *) | *) | 1.20 < t ≤ 1.50 |
| | | | | *) | *) | 1.50 < t ≤ 2.00 |

*) Upon agreement

Table 6

Tolerances on wall thickness

| | Nominal wall thickness range (mm) | | | | | | | | | | Nominal outside diameter range (mm) | |
|---|-----------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------------------------|---------------------|
| | from 0.25 to 0.30 | over 0.30 to 0.35 | over 0.35 to 0.40 | over 0.40 to 0.50 | over 0.50 to 0.63 | over 0.63 to 0.80 | over 0.80 to 1.00 | over 1.00 to 1.20 | over 1.20 to 1.50 | over 1.50 to 1.80 | | over 1.80 to 2.00 |
| Max. permissible deviation at any *) point (mm) | ±0.025 | ±0.030 | ±0.030 | ±0.040 | ±0.050 | ±0.060 | ±0.070 | ±0.080 | ±0.090 | ±0.100 | ±0.110 | |
| Tolerances on average wall thickness (mm) | ±0.01 | | ±0.015 | | ±0.020 | | ±0.025 | ±0.030 | ±0.035 | ±0.05 | ±0.05 | from 6.00 to 9.52 |
| | ±0.01 | | | ±0.015 | | | ±0.020 | ±0.030 | ±0.035 | ±0.05 | ±0.05 | over 9.52 to 13.00 |
| | ±0.01 | | | | ±0.015 | | ±0.020 | ±0.030 | ±0.035 | ±0.05 | ±0.05 | over 13.00 to 16.00 |
| | ±0.01 | | | | | ±0.015 | ±0.020 | ±0.030 | ±0.035 | ±0.05 | ±0.05 | over 16.00 to 28.00 |

*) Includes eccentricity

Note: Nominal diameter x nominal wall thickness in table 6 are reference values and shall be defined upon agreement!

Table 7

Permissible number of eddy current black marks per coil.

The number is proportional to the coil weight, reference coil weight = 100 kg.

| OD - | Wall thickness | Ø Testhole | Max. number of black marks per 100 kg coil | Max. number of black marks per min. 5 t order | | |
|-------------|-------------------|---------------|---|---|--------|--------|
| | | | | Nominal coil weight | | |
| mm | mm | mm | | 100 kg | 150 kg | 300 kg |
| 6.00– 9.53 | <0.35 | 0.4 | 3 | 1.5 | 2.3 | 4.5 |
| 6.00– 9.53 | ≥0.35 | 0.6 | 3 | 1.0 | 1.5 | 3.0 |
| 9.54–20.00 | all | 0.6 | 3 | 0.8 | 1.2 | 2.4 |
| 20.01–28.00 | all | 0.7 | 3 | 0.8 | 1.2 | 2.4 |

The max. number of black marks per coil is calculated on the basis of the nominal coil weights (proportional to the reference coil weight of 100 kg). The maximum number of eddy current black marks remains constant within the permissible deviation from the nominal weight.

| Usual nominal coil weights kg | Permissible deviation from nominal weight per 1 coil kg | Max. number of black marks per 1 coil WSFS |
|-------------------------------------|---|--|
| 100 | 70–110 | 3 |
| 150 | 105–165 | 5 |
| 300 | 210–330 | 9 |

Table 8

Coil dimensions

| Weight kg | Outside diameter OD mm | Inside diameter ID mm | Total width W mm | Arbor hole diameter AD mm |
|--------------|---------------------------------|--------------------------------|---------------------------|------------------------------------|
| 70–150*) | max. 1,130 | 600+10 | 160–320 | 130 |

*) higher weights upon agreement

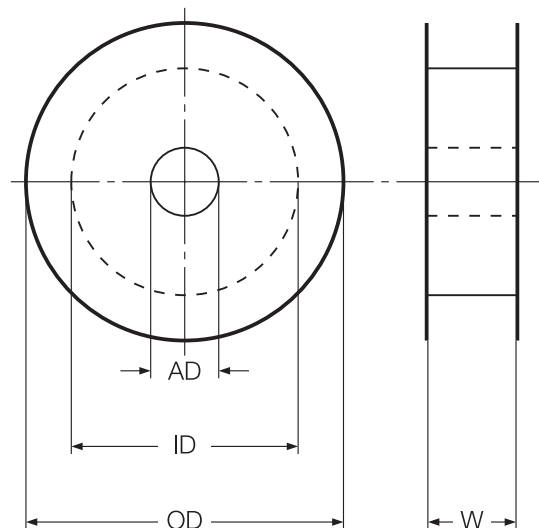


Fig. 1

Table 9

Number of tests on final product

| Type of test | Number of tests |
|---|---|
| Mandatory test <ul style="list-style-type: none"> ● Tensile ● Grain size ● Eddy current ● Dimensions **) ● Drift expansion ● Cleanliness **) | one per lot *) one per lot 100 % one per lot one per lot per lot |
| Upon agreement <ul style="list-style-type: none"> ● Analysis ***) ● Hardness | |

*) A lot is a quantity of 2500 kg of tubes in the same temper and dimensions.

***) Constantly controlled during manufacturing process, see table 1.

***) Analysis according to E 10204 2.2.

Table 10

Calibration standard for ec-testing (diameter of drilled holes)

| Tube outside diameter mm | Diameter of drilled holes mm |
|--------------------------|------------------------------|
| from 6 to 9.53 | 0.4 |
| over 9.53 to 19.00 | 0.6 |
| over 19 to 22 | 0.7 |

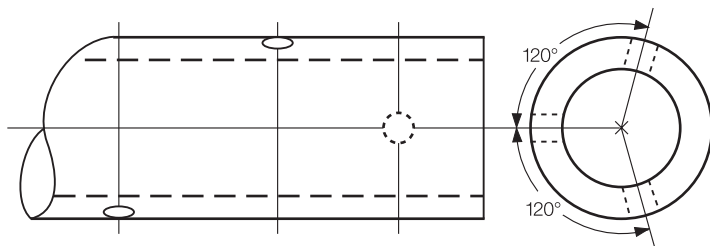


Fig. 2

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