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Copper-clad steel earthing materials • since 2009

# Copper-Clad Steel Earthing in China: Twenty Years of Practice

## From 0.25 mm electroplated to 0.6 / 0.8 mm continuous-cast, annealed – what the projects found, and how five standards wrote it down

This report traces the use of copper-clad steel in Chinese power earthing: how it began with 0.25 mm electroplated product, what engineering practice discovered, how product standards, anti-corrosion standards and the technical-supervision guide gave the same answer at three levels, and why "thick layer, continuous-cast, annealed" is now the norm for horizontal conductor. Every clause is quoted from the standard with its reference, for review by overseas designers, consultants and owners.

**Technical report ZTCJ-TR-01** • October 2026 • Rev. 1
Prepared by the ZTCJ engineering department • Reviewed by Cong Yuanxin, Chief Engineer
Based on DL/T 1312-2023, Q/GDW 10466-2021, DL/T 2094-2020, Q/GDW 12015-2020, DL/T 2650-2023

## Summary

**In one sentence:** nearly twenty years and millions of kilometres of Chinese practice moved the copper layer of copper-clad steel horizontal conductor from 0.25 mm to 0.6 / 0.8 mm and the process from electroplating to continuous casting with annealing – and this is not one company's claim but the written position of five standards at three levels: product, anti-corrosion and technical supervision.

- **Starting point (from about 2005):** ERICO brought 0.25 mm electroplated copper-clad steel to China, built the first demonstration projects and persuaded design institutes to accept copper-clad steel as an earthing material. We acknowledge that pioneering work.
- **What was found:** 0.25 mm comes from the international rod convention (0.254 mm in UL 467); transferred to horizontal conductor it cannot cover the corrosion loss of a 30-year design life in medium- and high-corrosivity soil; a plated layer cannot be annealed, hard wire is difficult to lay, and a scratch becomes a local failure.
- **The standards' answer:** DL/T 1312-2023 and Q/GDW 10466-2021 state that horizontal conductor "should be in the annealed condition", prohibit the sleeve cold-drawing process and add 0.6 / 0.8 mm sizes; DL/T 2094-2020 and Q/GDW 12015-2020 require ⩾ 0.6 mm in medium and ⩾ 0.8 mm in high corrosivity; DL/T 2650-2023 Table 4 fixes "0.25 / 0.60 / 0.80 mm for low / medium / high" as the acceptance line for technical supervision.
- **Today:** thick-layer, continuous-cast, annealed copper-clad steel is the routine replacement for solid-copper grids in Chinese grid, rail and chemical projects; 0.25 mm plated product has returned to where it belongs – vertical rods and low-corrosivity soil.

## 1 Starting point: the introduction of 0.25 mm plated copper-clad steel

Chinese power earthing was long built on hot-dip galvanised steel. In the early 2000s ERICO introduced copper-clad steel earthing products and exothermic welding to China systematically, built the first demonstration projects and persuaded design institutes that a steel core with a copper layer could serve as an earthing conductor. The product of the day was 0.25 mm electroplated copper-clad steel – the international specification for vertical rods (UL 467 requires at least 0.254 mm of copper at any point on a rod), carried over with the product onto horizontal conductor.

The historical value of that step should not be underestimated: without those demonstration projects there would have been no Chinese manufacturers following and no standards system. Our company entered the industry afterwards, and the thick-layer continuous-cast product we make today still follows the road ERICO opened.

0.25 mm plated product is still used in China, and has travelled with Chinese EPC contractors to a number of countries in Asia and Africa. The point of this report is not that it "cannot be used", but where the standards placed it after twenty years of practice.

# 2 What engineering practice found

## 2.1 Horizontal conductor and vertical rods do different jobs

A vertical rod dissipates: driven into deep soil, it works through its surface in contact with the ground; the current through any one rod is small, and deep soil is low in oxygen and usually mild. A horizontal conductor is the current-carrying trunk of the grid: fault current concentrates in the lengths near the injection point and the section must pass a thermal-stability check; it lies in the shallow layer, where oxygen is high, wet and dry alternate and corrosion is most active; and it is dragged during backfill. Applying the rod's 0.25 mm to horizontal conductor put a dissipating component's copper on a current-carrying component.

## 2.2 The corrosion allowance does not add up

Table 1 of DL/T 1312-2023 and Table 1 of Q/GDW 10466-2021 give the average corrosion rate of copper by soil corrosivity class – the design basis both product standards share:

| Soil corrosivity | Negligible | Low | Medium | High | Very high / high (special) |
|---|---|---|---|---|---|
| **Average copper corrosion rate, mm/a** | 0.001 | 0.003 | 0.007 | 0.012 | 0.017 |
| **Loss over 30 years, mm** | 0.03 | 0.09 | 0.21 | 0.36 | 0.51 |
| **Covered by 0.25 mm?** | yes | yes | barely, nothing left | no | no |
| **0.60 mm** | — | — | yes, 0.39 left | yes, 0.24 left | barely |
| **0.80 mm** | — | — | yes | yes, 0.44 left | yes, 0.29 left |

Rates from DL/T 1312-2023 Table 1 / Q/GDW 10466-2021 Table 1; "loss over 30 years" is rate × 30, without scratches, crevice corrosion or stray current. Both standards add: where pH < 4.5, design one corrosivity class higher; in very high corrosivity, use copper.

The conclusion is direct: in medium-corrosivity soil 0.25 mm is just used up at year 30 with no margin; in high corrosivity it does not reach 30 years. And China's large substations, chemical complexes and coastal projects fall largely in medium and high corrosivity.

## 2.3 Two hard limits of the plated product

- **It cannot be annealed.** A plated layer does not survive annealing, so the product is supplied hard. Hard wire springs back when bent, will not hold its shape in the trench and is awkward to align for

exothermic welding – the earliest and most common feedback from site crews.

- **It is too thin to be scratched.** A 0.25 mm layer is easily scored down to bare steel when dragged over stones or rebar; bare steel beside copper forms a corrosion cell and the core corrodes from the scratch. DL/T 2650-2023 clause 5.1.6.7 later wrote this in: where scratches, impact or abrasion break the copper and the remaining thickness no longer meets Table 4, that length shall not be used.

## 3 The standards' answer: three levels, five standards

China's answer was not given by one standard. Three levels each wrote it from their own angle, and they corroborate one another.

### 3.1 Product standards: what the product must be

DL/T 1312-2023 *Technical conditions for copper-clad steel for power engineering earthing* (National Energy Administration, replacing the 2013 edition) and Q/GDW 10466-2021 of the same title (State Grid Corporation of China, replacing Q/GDW 1466-2014) are the two copper-clad steel product standards. After revision their key clauses use the same wording:

> 4.2 The manufacturing process of copper-clad steel should be continuous casting or electroplating; the sleeve cold-drawing process shall not be used. Copper-clad steel is classified as annealed or non-annealed; horizontal earthing conductor should be in the annealed condition.
>
> — DL/T 1312-2023 clause 4.2; Q/GDW 10466-2021 clause 4.2 is identical ("the sleeve process shall not be used")

> 4.6 Copper-clad steel shall be selected for corrosion resistance according to the local soil; the copper thickness should preferably be designed from local soil corrosion data, or from the copper corrosion data of Table 1. Where the earthing environment has pH < 4.5, design one soil-corrosivity class higher; in very high corrosivity use copper.
>
> — DL/T 1312-2023 clause 4.6

The list of technical changes in the foreword of DL/T 1312-2023 is itself a record of practice: manufacturing requirements revised and sleeve-type product prohibited; copper thickness and environmental requirements added; **0.6 mm and 0.8 mm copper thicknesses and custom thicknesses added**; uniformity revised to a minimum at any measuring point; tensile strength of vertical electrodes ($\geqslant$ 550 N/mm$^2$) and bending of horizontal conductor (90° × 3) revised; a minimum conductivity added; thickness measurement revised (9 points on rod and wire, 12 on tape). The foreword of Q/GDW 10466-2021 lists the matching changes: process requirements added, thickness sizes added, uniformity revised, electrical and corrosion tests revised, corrosion rates revised and moved into the body.

The model code writes the process into the product's identity: CCS EP for electroplated, CCS CC for continuous-cast, followed by relative conductivity, minimum copper thickness (commonly 0.25 / 0.60 / 0.80 mm) and size. The thickness tables of the two standards are identical:

| Model | Minimum copper thickness, mm (at any point) | Source |
|---|---|---|
| CCS-XX-XX-0.25-XX | 0.25 | DL/T 1312-2023 Table 3; Q/GDW 10466-2021 Table 3 |
| CCS-XX-XX-0.60-XX | 0.60 | |
| CCS-XX-XX-0.80-XX | 0.80 | |
| Other thicknesses | nominal (not below 0.25) | |

## 3.2 Anti-corrosion standards: how thick the copper must be

DL/T 2094-2020 *Technical specification for corrosion protection of AC power engineering earthing* and Q/GDW 12015-2020 *Technical specification for corrosion protection of power engineering earthing materials* answer the same question from the anti-corrosion side. Both grade by soil corrosivity:

| Soil corrosivity | DL/T 2094-2020 (clause 5.2.1) | Q/GDW 12015-2020 (clause 5.2.2) |
|---|---|---|
| **Negligible** | plain carbon steel or hot-dip galvanised steel | hot-dip galvanised steel preferred |
| **Low** | hot-dip galvanised, zinc-clad or copper-clad steel; copper layer of copper-clad steel > 0.25 mm | hot-dip galvanised or copper-clad steel; minimum copper per DL/T 1312, designed from local corrosion data |
| **Medium** | hot-dip galvanised steel preferred; galvanised steel with cathodic protection, copper-clad steel or zinc-clad steel permitted; **copper layer > 0.6 mm** | hot-dip galvanised steel, copper, copper-clad steel or zinc-clad steel; **minimum copper ⩾ 0.6 mm** |
| **High** | galvanised steel with cathodic protection preferred; high-purity iron, zinc-clad steel, copper, copper-clad steel, stainless steel or stainless-clad steel permitted; **copper layer > 0.8 mm** | hot-dip galvanised steel, copper, copper-clad steel, stainless steel or stainless-clad steel; **minimum copper ⩾ 0.8 mm** |
| **Special cases** | copper and copper-clad steel not recommended where pH ⩽ 4.5 (clause 5.2.3) | copper preferred in coastal, reclaimed, chemical and saline areas with salt ⩾ 1.5 % (5.2.2.5); copper-clad steel ⩾ 1.0 mm where pH ⩽ 4.5 (5.2.2.6) |

Q/GDW 12015-2020 clause 4.8 names the important sites directly: power plants and substations of 330 kV and above, fully indoor substations, hub substations of 220 kV and above, urban substations of 66 kV and above and compact substations in medium- and high-corrosivity areas, and 110 kV plants and substations in high and special-high corrosivity areas, "after technical and economic comparison, should use copper, copper-clad steel with a copper layer of at least 0.8 mm, or other equivalent anti-corrosion measures" for the earthing installation.

### 3.3 The technical-supervision guide: what a project should choose

DL/T 2650-2023 *Technical supervision guide for grounding metallic materials in power engineering* (National Energy Administration, issued 2023-10-11, in force 2024-04-11, first edition) is the supervision-level standard: it decides what utilities check in design review, construction supervision and operation. Its selection clause gathers the two lower levels into one sentence:

> 5.1.1.5 … In areas graded "negligible" or "low" soil corrosivity, earthing metals should be hot-dip galvanised steel; in areas graded "medium", hot-dip galvanised steel with cathodic protection, or copper-clad steel; in areas graded "high", copper, copper-clad steel or other earthing materials of equivalent corrosion resistance.
>
> — DL/T 2650-2023 clause 5.1.1.5

| Soil corrosivity class | Minimum copper thickness, mm |
|---|---|
| Negligible, low | 0.25 |
| Medium | 0.60 |
| High | 0.80 |

DL/T 2650-2023 Table 4, "Copper thickness of copper-clad steel earthing materials versus soil corrosivity class"; clause 5.1.6.4 requires the minimum at any measuring point to meet Table 4.

The guide also states: copper and copper-clad steel may be used in the same earthing area (5.1.1.2); earthing materials for long-term use shall not be bare carbon steel, and aluminium shall not be used (5.1.1.4); indoor and underground substations shall use pure copper (5.1.1.7); the bond of copper-clad steel should be sampled and tested on site (5.1.6.6; Annex B, site bend / hammer method); coating quality may be assessed by a site high-current test (5.1.6.9; Annex C).

## 4 Why "continuous-cast + annealed"

Taken together the three levels point to one product: copper 0.6 / 0.8 mm, not below nominal at any point, annealed soft temper, able to pass three 90° bends and the bond test. Stacked, those four requirements give continuous casting a natural advantage:

- **Economy of the thick layer.** Depositing more than 0.6 mm by electroplating is slow and costly; in continuous casting the steel core passes through molten copper and the copper crystallises onto it, 0.6–1.0 mm in one pass. Clause 3 of DL/T 1312-2023 defines continuous casting and electroplating side by side – both are permitted, but in the thick-layer range casting is the economical one.
- **It can be annealed.** The cast product is metallurgically bonded and can be annealed coil by coil to the soft temper that clause 4.2 asks for in horizontal conductor; a plated layer loses its bond in annealing and no annealed plated product exists.
- **Bond strength.** A metallurgical bond has no interface gap and passes stranding (every wire twisted and bent repeatedly), the 45° cone hammer test and site bending – which is why DL/T 2650

Annex B can move the bond test onto the construction site.

- **The process that was retired.** Sleeve cold drawing (a copper tube drawn down over a steel core) is expressly prohibited by both product standards, because tube and core are mechanically fitted rather than bonded and blister or separate in high-current and corrosion tests.

Electroplating itself was not rejected. On vertical rods, which are driven, the hard temper is exactly what is needed; in low-corrosivity soil and for bonding, 0.25 mm plated product remains mature and economical. Both product standards keep EP as a valid model. What the standards changed is not the legitimacy of the process but its place on horizontal conductor.

# 5 Where practice stands today

## 5.1 Scale and landmark projects

By industry practice, thick-layer copper-clad steel horizontal conductor has been laid over millions of kilometres in China, under UHV substations, high-speed rail, metro, PV plants and chemical complexes, in soils from coastal saline and arid alkaline to acidic red soil below pH 4.5, permafrost and the humid tropics. Representative projects supplied by our company include Tianjin Jinbin Light Rail Line 9 (China's first running earth conductor retrofitted with copper-clad steel), Beijing Metro Line 10 (Beijing's first), the Xiong'an – Beijing Daxing Airport Express, Beijing Metro Line 22 (Pinggu Line), the Datang Keqi coal-to-SNG plant, the Xinjiang East Hope integrated coal-power project and the Ningxia Coal HDPE project.

## 5.2 Acceptance practice

As the standards took effect, Chinese projects settled on a practical acceptance routine that overseas projects can adopt directly:

- Copper thickness: magnetic gauge (GB/T 4956) or microscope (GB/T 6462); on rod and wire, three sections at least 50 mm from the end, three points at 120° each – nine points, minimum compared with nominal; on tape, three sections × four points, twelve (DL/T 1312-2023 clause 7.3). Routine inspection checks thickness and surface on every rod or reel (clause 8.6.2).
- Bond: cut a 45° cone on site and hammer the copper off, inspecting the interface for separation; or site bending (DL/T 2650-2023 Annex B).
- Coating quality: site high-current test (DL/T 2650-2023 Annex C).
- Transport and installation: avoid scratches; bending radius not less than ten times the diameter (Q/GDW 12015-2020 clause 6.1); scratched lengths not to be used (DL/T 2650-2023 clause 5.1.6.7).

# 6 What this means for a project abroad

Overseas projects usually work to UL 467, IEC 62561-2 or IEEE 80. These complement rather than contradict the Chinese system. UL 467 is an equipment safety-listing standard, mainly for rods,

requiring ⩾ 0.254 mm of copper on a rod and silent on the corrosion life of horizontal conductor; IEC 62561-2 covers lightning-protection components, is concerned with lightning impulse and requires ⩾ 70 µm of copper on conductors; IEEE 80 gives thermal constants for copper-clad steel wire (40 % and 30 % IACS) and calculates any construction from its geometry, but sets no copper thickness. The gap the five Chinese standards fill is exactly "how much copper a horizontal conductor needs under power-frequency fault current and thirty years in the soil".

Our advice to overseas designers:

- Check the section for thermal stability to IEEE 80, and set the copper thickness from local soil corrosivity and design life; without local data, the corrosion rates of DL/T 1312 Table 1 and the classes of DL/T 2650 Table 4 can be used directly.
- Specify "minimum copper thickness at any measuring point", not an average, and state the annealed temper and three 90° bends.
- On delivery, gauge the copper by the nine-point method and hammer-test the bond on site; neither needs a laboratory – a thickness gauge and a hammer are enough.

## 7 Our position

Our company has made nothing but copper-clad steel earthing materials since 2009; the Mingguang plant in Anhui runs both a continuous-casting line and an electroplating line, and products are type-tested to the full DL/T 1312-2023 programme in a CMA / CNAS dual-accredited laboratory. We supply 0.25 mm plated product for vertical rods, low-corrosivity soil and specifications that call for it; for horizontal conductor in medium- and high-corrosivity soil we recommend 0.6 / 0.8 mm continuous-cast, annealed product – for the reasons set out in this report, every one of which can be found in the text of the five standards. For any specific project we provide, free and within 24–48 hours, a sizing report with both options side by side: cost and life at 0.25 mm, cost and life at 0.6 / 0.8 mm. The choice belongs to the designer and the owner.

## References

1. DL/T 1312-2023, Technical conditions for copper-clad steel for power engineering earthing, National Energy Administration; replaces DL/T 1312-2013.
2. Q/GDW 10466-2021, Specifications for copper-clad steel in power engineering grounding, State Grid Corporation of China, issued and in force 2022-01-24; replaces Q/GDW 1466-2014.
3. DL/T 2094-2020, Technical specification for corrosion protection of AC power engineering earthing, National Energy Administration.
4. Q/GDW 12015-2020, Technical specification for corrosion protection of power engineering earthing materials, State Grid Corporation of China, issued and in force 2020-11-27.
5. DL/T 2650-2023, Technical supervision guide for grounding metallic materials in power engineering, National Energy Administration, issued 2023-10-11, in force 2024-04-11.
6. IEEE Std 80-2013, IEEE Guide for Safety in AC Substation Grounding; UL 467, Grounding and Bonding Equipment; IEC 62561-2, Lightning protection system components – Part 2.

This report is technical information; quoted clauses are our translations and the official Chinese editions govern. Project references are the company's supply record; the full list is available on request. Beijing Zhutiechengjin Electromechanical Equipment Co., Ltd. · www.ztcjbj.com · WhatsApp +86 186 1002 3872