**DOA 1916 T, 20 heller part I, German East Africa 20 Heller 1916, Tabora-brass, prefab brass & copper**

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## Synopsis

We are examing German East African 20 Heller coins and quantifying their electrical conductivity, alloying metals, and density. The First question we wish to answer is if the three materials, mentioned by *Schumacher* in his article in *Metall und Erz* photo=110484, a) locally smelted *Tabora-brass*, b) prefabricated brass (*prefab-brass*) from external sources, and c) prefabricated copper, could be separated by testing their properties. The term prefabricated *(prefab*) is used here to indicate any material that didn't pass through the melting pots of the Tabora mint.

As the majority of copper coins show lower electrical conductivity than might be expected from pure copper, a second question to be answered is if bronze was perhaps also used as material for the coins..

Testing methods and properties of different coppers and copper alloys will be described in this paper.

Description of the different types of coins is based on the system used in Kees Uitenbroek's *German East Africa emergency coinage struck at Tabora in 1916 – a die catalogue* (free e-copies available at info@ptbvhrokerspartij.nl ). In this system each separate die is classified by a series of letters and numbers indicating a side of the coin, main-type, sub-type and individual die.




Figure 1, possible main type die combinations

The first letter indicates the side of the coin struck by a die, H for Heller-side, D for DOA-side.

The next letters indicates the main type according to the system used by Krause-Mishler. Thus HA = KM reverse A, HB reverse B, HA(C) reverse C, DA obverse A and DB obverse B.

Sub-types are indicated by a number. These sub-types are based on changes in the positive dies (hubs) used to strike the negative production dies. Thus a die with a lower subtype number was produced before a die with a higher number. This does not necessarily mean these dies were also used in a first in - first out order.

The lower case letters at the end of a die's title mark the individual dies. They do not indicate any sequence.
Conversion to the German Jaeger catalogue is as follows:
HA-DA & HA(C)-DA = N 724
HB-DA = N 725
HA-DB & HA(C)-DAB = N 726
HB-DB = N 727

It is shown that locally smelted *Tabora-brass* changed properties during time and from this separate groups can be recognized.
Another group is thought to be composed of *prefab-brass*.
As properties of the different brass groups overlap, coins can't be distinguished piece by piece, but for certain die combinations it may be presumed that they did not strike Tabora-brass coins.

Two small separate groups of *prefab-brass* coins with high electrical conductivity are described. Possible dates for first appearance of HA-DA, *prefab-brass* and copper coins are proposed. An estimate of the mintage of the main types is given.

Also it is shown that the transition between the striking of *only brass* to *only copper* coins may have been as little month, if the striking of only copper coins took place towards the end of the production period of the 20 Heller coins.

Results of X-ray fluorescence analyses show different kinds of copper were used for the copper coins, some of which might be designated as modified or enhanced copper. Use of such additional specifications is discouraged by the American Society for Metals, which in their definition of copper include all materials with a designated minimum copper content of 99.3% or more (ASM Speciality Handbook: Copper and Copper Alloys books.google page 6). According to this definition, *all non-brass 20 Heller struck in Tabora must be regarded as copper.*

The influence of the trace amounts of additional elements, found in the copper coins, could explain the low electrical conductivity of some of the coins. The low electrical conductivity of some other copper coins can't be fully explained by the X-ray fluorescence test results, as the equipment available could not test for deoxidizing agents like phosphor and silicon.

No bronze was found.

20 Heller coins made of copper can be distinguished from those made of brass by different testing methods, which are described. Suggestions for adequate testing methods and the interpretation of their results are given.

**Question**

*Schumacher* mentions in his article in *Metall und Erz* photo=110484 that at first the 20 Heller coins were struck on locally fabricated brass, produced by smelting scrap metal, which we will call *Tabora-brass*. He mentions that about 1,000,000 coins, equal to 60% of the total amount of 1.634.700, were struck on this material.

As melting pots ran out, coins were struck on *prefab-brass* and, when this became scarce, also on *prefab-copper*. *Schumacher* states that about 600,000 coins were struck on these prefab materials, equal to 40% of the total. Of this total, little more than half (about 330,000) were struck on *prefab-copper*.

Main question to be answered is which exact materials were used, and if it is possible to distinguish between them. To answer these questions, the authors assembled data on electrical conductivity wiki/Electrical_resistivity_and_conductivity density and material composition of the coins.

Also the question whether the *Schumacher* data can be trusted will be addressed.

Due to restrictions in the capacity to see certain materials with low atomic numbers, of some of the *X-ray fluorescence analyses* (*XRF* wiki/X-ray_fluorescence ) machines used to analyse material composition, and lack of knowledge of the way some of the programs used on these machines interpret the actual measurements, some care had to be taken in interpreting the results.

As most of the coins tested are not in pristine condition, it must be kept in mind that the *XRF* results not only reflect the original material, but also a hundred years of often harsh survival conditions, which have left their mark upon the surface of the coins.

*XRF* results from different spots on the coin may vary considerably.

The problem that *XRF* only analyses the surface of a coin (and not its internal make up) has been overcome by filing several coins, to allow analysis of an uncontaminated sample.

Measuring the *electrical conductivity* (*EC*) it should be kept in mind that you are measuring *EC* of a coin on a specific spot, and that this is not necessarily the *EC* of the original material of the coin. As yet inexplicable, in some cases, significant differences in measured *EC* exist between the two sides of a single coin. Although penetration depth of *EC* measuring is much deeper than that of *XRF*, the result is still greatly dependent on *EC* of the outer layers.

Data collected on *EC* stems from different sources, using different measuring equipment. One series of tests performed on nearly all coins then available, was conducted June 2015, using a *Hocking Autosigma 2000 B/DL* with a 6.5 mm 250 kHz probe. Both sides were measured separately. Another series of measurements was permormed on both sides of 86 other coins in August 2015, using a *Helmut Fischer Sigmascope* at 60 kHz with a larger measuring area.

Results for *EC* for the same coin differ considerably in a few cases. Some of these variations may be explained by mistakes in reading and transcribing the results;  Still the combined results of all tests are considered reliable enough to present an overall impression.

A glossary of metallurgical technical terms glossary-terms

**Tabora-brass**

**Metal composition**

Composition for Tabora-brass are given by both *Krenkel* 110480 and *Schumacher* 110484

*Krenkel* gives 70.5% copper, 27.5% zinc, 0.5% lead & 1.5% aluminium.
In XRF results, when no aluminium could be measured, this would give +/- 71,5% copper and 28% zinc.

*Schumacher* gives 24 kg scrap brass, 6 kg copper, 0.51 kg lead & 0.17 kg aluminium, on a total of 30.68 kilogram. With scrap brass containing 70% copper and 30% zinc, the result would be an alloy of 74,3% copper, 23,5% zinc, 1,65% lead & 0,55% aluminium.
Scrap brass containing 63% copper and 37% zinc would give: 68.9% copper and 28.9% zinc.

All percentages used in this article are by weight.

As used cartridges cases (both small arms and artillery) were a main component of the scrap brass available and cartridge brass is one of the names used for brass containing 70% copper, a high copper content may be expected for Tabora-brass.
Lead content above 1% was only found on the surface of one coin (1.35%), but on the filed part of it only 0.8% showed.

| | |
|---|---|
|  HB1w-DB1b EC 13.3-13.6 MS/m | Unfiled part: copper 74.23%, zinc 17.77, tin 0.14, lead 1.35, aluminium 3.71, silicon 2.66, sulphur -, nickel 0.09, iron 0.07%<br>Copper-zinc ratio: 80.7-19.3<br><br>Filed part: copper 74.85%, zinc 21.92, tin 0.12, lead 0.81, aluminium 1.11, silicon -, sulphur 0.99, nickel 0.10, iron -<br>Copper-zinc ratio: 77.3-22.7 |

Figure 2, high lead content

Whether or not the sulphur found in the composition of the filed part, stems from remnants of gunpowder in spent cartridge cases, has not yet been answered.

Before WW I copper and brass were not always up to standards we take for granted today; in 1925 the German *DIN* norms were composed, where 5 classes of copper were defined.

| Copper DIN 1708, April 1925, page 1 | | | |
|---|---|---|---|
| Name | Short | Cu minimum % | Usage examples |
| Hüttenkupfer A (containing arsenic & nickel) | Cu A | 99.0 | Fireboxes, “Stehbolzen” |
| Hüttenkupfer B (low arsenic) | Cu B | 99.0 | Casting alloys as well as alloys with less than 60% copper |
| Hüttenkupfer C | Cu C | 99.4 | Copper plates & tubes |
| Hüttenkupfer D | Cu D | 99,6 | Alloys with more than 60% copper for other purposes then casting |
| Electrolytic copper E | Cu E | – *) | Electrical lines, high grade alloys |
| – *) Only electrical conductivity is specified.<br>Stehbolzen would be the stays between firebox and boiler. | | | |

Figure 3, extract from *DIN 1708, 1925*

The American *Standard specifications for spelter* (zinc), serial designation B6-18, 1918 books.google page 1310, gives 5 grades, the middle grade is named Brass Special, which may contain a maximum of 0.6% lead, 0.03% iron, 0.5% cadmium and no aluminium, maximum for all together 1%.

Brass mixed from 70% copper 99.6% fine and 30% zinc 99% fine might thus contain 0.7 x 0.4 + 0.3 x 1 = 0.58% of other metals, of which more than 0.3 X 0.6 = 0.18% might be lead.



Figure 4, Swakopmund Pass

*XRF* tests of a German Southwest African Swakopmund native pass, produced in 1907 in Germany showed 69.4-68.9% copper, 30.7-30.3% zinc and 0.28-0.25% lead.

Where in this article more than one figure is given for certain properties, these figures represent the highest and lowest values of more then one measurement, mostly performed on different sides.

*Meyer's Großes Konversations-Lexikon – 1905* Meyers-1905 gives lead content of zinc from different sites. Many of them contain more lead than the American standard for Brass Special would allow.

| Bezeichnung | Zink | Blei | Eisen | Kadmium |
|---|---|---|---|---|
| Schlesisches Zink (1871) . . . . . | 97,471 | 2,393 | 0,136 | Spur |
| Zink aus Bleiberg (1871) . . . . . | 98,054 | 1,563 | 0,101 | 0,282 |
| Zink aus La Salle (1871) . . . . . | 99,378 | 0,503 | 0,041 | 0,078 |
| Pennsylvanisches Zink . . . . . | 99,982 | — | 0,018 | — |
| Zink von Georgshütte, Schlesien (1885) | — | 1,4483 | 0,0280 | 0,0245 |
| Zink von der Neckehütte (1885) . . . | — | 1,1921 | 0,0238 | — |
| Zink von Sagor (1885) . . . . . | — | 0,633 | 0,032 | 0,054 |

Figure 5, extract from *Meyer's Großes Konversations-Lexikon, 1905*

In the pre-WW I *British Standard Specifications for Railway Rolling Stock Material* reportbritish2405 it is prescribed that brass alloys for tubes for locomotive boilers should contain no more than 0.75% materials other than copper and zinc.

Thus the copper and scrap brass used in *Tabora-brass* would themselves contain impurities, which will show up in *XRF*. Contaminants (such as dirt and paint) on the scrap

metal entering the melting pot will also potentialy present themselves.

*XRF* of the coins show the layer of dirt adhering coins to contain aluminium and silicon. This layer can hardly be removed without damaging the coins.

The smelting process itself has effects on the zinc content of the alloy. *A. Ledebur* states in his book *Die Legierungen in ihrer Anwendung für gewerbliche Zwecke* dielegierungen on page 153 that during the smelting process 5 to 8% of the zinc content will disappear. A mixture containing 30% zinc before smelting would thus leave the oven containing 28.5 to 27.6%.

Inspecting the *XRF* test results of the brass 20 Heller coins, it might be expected Tabora-brass coins could be distinguished from prefab brass coins by their higher copper and lead content as well as the appearance of aluminium. That is, if the smelters would have stuck to the original alloy *'recipe'*.

As it is, only a limited amount of coins, mostly of the HB1-DB series, show a low zinc content of about 25%. These coins also contain more lead then the rest. Thus the original recipe may have been adhered to only for a short time.

The addition of copper, lead and aluminium seems to have stopped and addition of zinc may have started at a certain moment to counter loss of zinc content.

The molten brass was cast into bars 32 mm wide and 3 to 5 mm thick. Rolling to the required thickness of about 2mm would increase the length of the material with little effect on its width. A low estimate would require 30 x 33 mm of bar to produce a 29 mm flan. Thus 66.7% of the molten material would end up as coin and 33.3% would return to the melting pot, having 1.5 to 2.4% less zinc content then before.

As mentioned before scrap brass turned into *Tabora-brass*, without added material, would have about 2% less zinc content then before. *Cartridge-brass* containing about 30% zinc would thus produce *Tabora-brass* which would contain about 28% zinc. Coins with 28% zinc we find in all die-series. But more important, this material could also have been available as *prefab-brass*.
The German 1925 *DIN* norm for brass specify amongst others:

| Brass DIN 1709, April 1925, page 1 | | | | |
|---|---|---|---|---|
| Name | Short | Cu % | Zn % | Usage examples |
| Druckmessing | Ms 63 | 63 | 37 | Amongst others: tubes in shipbuilding |
| Halbtombak (Lötmessing) | Ms 67 | 67 | 33 | Amongst others: **cartridges** |
| Gelbtombak (Schaufelmessing) | Ms 72 | **72** | **28** | Amongst others: striking |
| Hellrottombak | Ms 80 | 80 | 20 | |
| Mittelrottombak (Goldtombak) | Ms 85 | 85 | 15 | |
| Rottombak | Ms 90 | 90 | 10 | |

Figure 6, extract from *DIN 1709, 1925*

The 1927 *International Critical Tables of Numerical Data, Physics, Chemistry and Technology, Volume II* books.google page 386 bottom right, describes *cartridge-brass* sheet and strip as copper 68-74%, nickel < 0.1, lead < 0.07, iron < 0.05, bismuth < 0.006, no tin, no antimony, other metals < 0.005%, rest zinc (32-26%). The range of zinc content

of brasses used for making cartridges thus seems to have been rather wide. Copperalliance.eu gives data for CuZn28 and CuZn30 on one sheet copperalliance.eu It shows that also in more modern times zinc content of brasses of the same type can vary considerably. CuZn30: copper 68.5-71.5% (zinc 31.5-28.5%)

Stock of used cartridges would not only contain German cartridges but also British, collected after the failed attack on Tanga November 1914. Besides scrap brass from other source would contain brasses with higher zinc content than cartridge brass.

Therefore it becomes clear zinc content alone can't be used to differentiate between *Tabora-brass* and *prefab-brass*.

**Prefab brass**

**Flan defects**

*Prefab-brass* will have been free of casting and rolling errors. Thus coins struck on flans made of *prefab-brass* that had not to be rolled to the right thickness will be free of defects. *Prefab-brass* rolled to the required thickness might show defects caused by rolling, but no casting errors. Cold working of brass, like rolling, punching and striking, will *work-harden* the material and lessen its ductility. Lack of proper annaeling as the material becomes to hard, may explain both cracking along the rim caused by the punching of the flans and cracks extending from the rim caused by the striking of the coins.

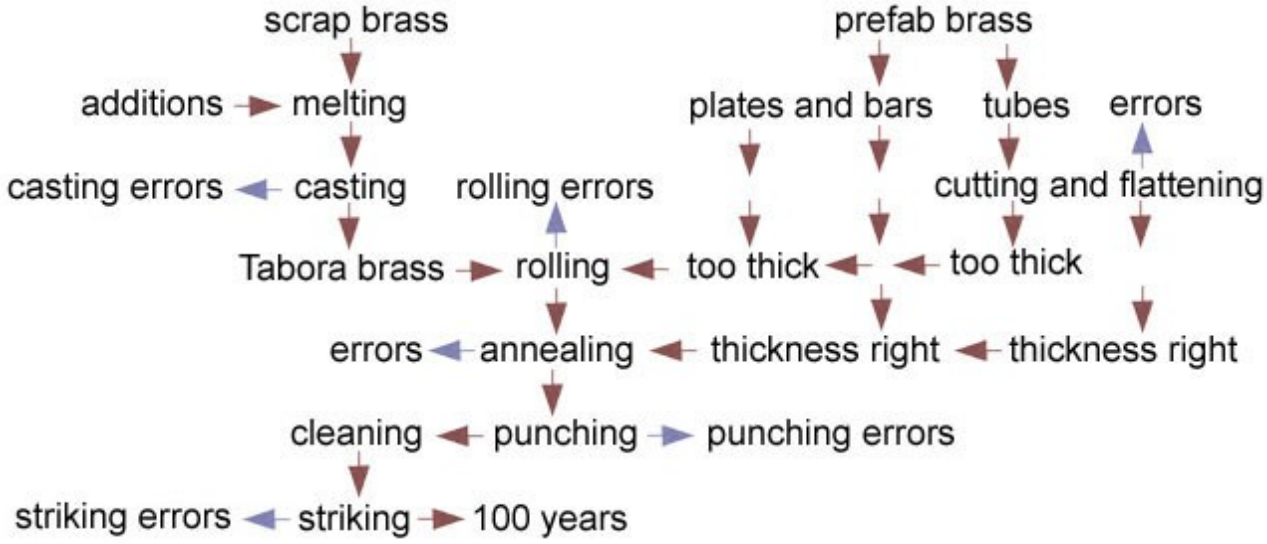



Figure 7, production process

Because there exist of course also faultless *Tabora-brass* coins, and it is difficult to differentiate between casting and rolling defects, only the frequency of occurrence can give an indication which material was probably struck by certain die combinations. If 50% of the flans show defects no doubt it is practically all *Tabora-brass*. If hardly any flan defects occur most probably only *prefab-brass* is involved. In between there might be a grey zone where both materials were struck.

In 2013 an inventory was made of possible casting errors on the coins of which pictures were available. (Bad pictures and bad coins which didn't show clear errors were counted as being without error.) In figure 8 adjacent die-combinations that are die-related (due to the fact they share dies used in other die-combinations), are highlighted by yellow or green. Pink is used for die-combinations that share HA(C)1c.

| H-D<br><br>H-D<br><br>H-D H-D<br>H-D H-D | x-y<br><br>x-y (z) | No tested copper coins known – x = number of brassy* coins with what looks like casting errors - y = number of brassy* coins without what looks like a casting error<br>Tested copper coins known – x-y numbers of brassy* coins as above - (z) = number of coppery* coins with what might be a casting error.<br>Die connected die-combinations | | | | | |
|---|---|---|---|---|---|---|---|
| HB0 | 2-2 | HB2i-DB2o | 2-1 | HA3i-DA9f | 4-21** | HB5d-DB3g | ??* |
| HB1a-DB1a | 9-3 | HB2j-DB2p | 4-4 | HA3j-DA9e | 2-13 | HB5e-DB3g | ??* |
| HB1b-DB1b | 28-9 | | | HB4c-DA11b | 0-15** | HB5f-DB3h | ??* |
| HB1w-DB1b | 9-14 | HA(C)1a-DA1a | 31-22 | HB4c-DA11c | 2-10 | | |
| HB1c-DB1c | 3-4 | HA(C)1b-DA3b | 11-12 | HB4c-DB3b | 6-24 | HB5g-DB3i | 0-8 |
| HB1c-DB1v | 4-4 | HA(C)1c-DB3u | 8-5 | HA3x-DB3b | 0-4 | HB5h-DB3l | ??* ** (1)*** |
| HB1c-DB1y | 20-17 | HA3h-DA6a | 4-0 | **HA4d-DB3b** | 6-39 | HB5i-DB3j | 2(?)-14 |
| HB1d-DB1d | 3-3 | HB4d-DA6a | 3-7 | HA4a-DA8a | 7-18 | HB5j-DB3j | 2 (?**)-9 |
| HB1z-DB1z | 11-2 | HB3d-DA6a | 5-22 | **HA4b-DA10a** | ??* (1) | HB5k-DB3k | 0-9 |
| HB1e-DB1x | 8-7 | HA(C)1c-DA6a | 6-22 | HA4c-DA11a | 0-38 | HB5l-DB3l | ??* |
| HB1e-DB2a | 23-14 | HA(C)1c-DA3v | 2-22 | | | HB5m-DB3m | 1-0 (?****) |
| HB1t-DB2t | 1-1 | HA3w-DB3v | 5-27 | HB3c-DA3a | 2-15 | HB5n-DB3n | ??* |
| HB1s-DB2t | 1-0 | HA(C)1d-DA2a | 2-2 | HB5y-DA8b | 5-46 | | |
| HB1f-DB2b | 2-2 | HA2b-DA2a | 10-11 | **HB5z-DA9c** | 1-28 **(1)**** | HB5o-DB3o | 0-16 |
| HB1f-DB2c | 2-1 | HA2a-DA1b | 8-16 | | | HB5p-DB3o | 0-35 |
| HB1g-DB2c | 18-16 | HA2d-DB3w | 16-16 | HB3a-DB2n | 0-4 | HB5q-DB3p | 0-25 (1)***** |
| HB2a-DB2c | 12-5 | HA2d-DA4c | 4-12 | HB3a-DB2l | 4-20 | HB5r-DB3q | 1 (?)-6** |
| HB2b-DB2d | 21-23 | HA3a-DA4c | 9-9 | HB3b-DB2m | 5-27 | HB5s-DB3q | 0-5 |
| HB2c-DB2e | 19-16 | HA3b-DA5a | 17-16 | HB3y-DB2x | 5-19 | | |
| HB2d-DB2f | 4-7 | HA3c-DA6b | 5-10 | HB3z-DB2z | 2-10 | | |
| HB2d-DB2g | 6-20 | HA3d-DA6c | 7-8 | | | | |
| HB2e-DB2h | 7-17 | HA3m-DA6e | 4-11 | HB4a-DB3a | 4-11 | | |
| HB2f-DB2i | 12-9 | HA3e-DA7a | 6-19 | | | | |
| HB2g-DB2i | 7-11 | HA3e-DA5b | 4-22 | HB5a-DB3c | 2+2?-22 | | |
| HB2g-DB2j | 7-9 | HA3k-DA5b | 0-4 | HB5a-DB3d | 1-9 | | |
| HB2h-DB2j | 7-5 | HA3f-DA8c | 4-9 | HB5b-DB3d | 3-10 | | |
| HB2h-DB2k | 3-7 | HA3f-DA8d | 0-2 | HB5b-DB3e | 4-31 | | |
| | | HA3g-DA9b | 2-29 | HB5c-DB3f | 0-35 | | |

* Brass & copper looking on picture.
** doubling occurs
??" Most if not all coins of this combination copper, no tested brass known
** Rolling error? 69131 bottom 2nd left. Coin not tested so might still be brass.
*** A rather brutish error 61275 Might be post-striking, but a similar error occurs on a non-struck brass flan.
**** 69925 Impossible to tell from pictures how many of the other HB5m-DB3m are brass. At least this one looks brassy.
***** Rolling error? 84654 Creases coin top right don't look like scratches. Coin at bottom left corrosion?

Figure 8, flan errors

This survey shows that there is a clear difference between series of die-combinations which struck coins with hardly any flan errors and those of which a majority show such errors.

**Copper as indication for prefab brass**

Copper was introduced in the mint as *prefab-brass* became scarce. A most likely place to look for *prefab-brass* coins would be the brass coins struck by die combinations that also struck copper coins and the combinations die-related to them. This is confirmed by the low numbers of brass coins with flan defects, struck by die combinations that struck also copper coins.

These combinations encompass **5**, **Z** & part of **B** in figure 9 below.

As most of the brass coins struck by these dies must be *prefab-brass* coins those *prefab-brass* coins struck by other die combinations would be conform in their specifications regarding EC and zinc content.

**Electrical conductivity (EC)**

*Electrical conductivity* (*EC*) wiki/Electrical_resistivity_and_conductivity measurement of 20-Heller brass coins gives results ranging from 9 to 18 MS/m.

The lowest values are found for the HB0-DB0 coins, the highest values for the HB5-DB3 series. Increase is gradual and series overlap. *EC* measurement itself may be influenced by factors we are not aware of. In some cases one side of a coin may give a different result than the other, while measurements of the same coin with different machines may differ slightly.

Higher zinc content lowers *EC* of brass. Where *XRF* gives a low zinc content of the surface, *EC* might indicate a higher content in the interior.

On the other hand cold working of brass might lower *EC* by 3 MS/m compared with the same material after annealing. CuZn30.pdf

All these factors and variables make it difficult to use *EC* alone to differentiate between *Tabora-brass* and *prefab-brass*.

Other data sheets from Kupferinstitut: werkstoff-datenblaetter.html

**Combination of metal composition and electrical conductivity**

Combining data for metal composition and electrical conductivity in a graph shows clustering of certain series of coins. The green lines connect values given in literature for *EC* of different brasses. The value for *EC*, used in figures 9 and 12, is the higher of the two values measured on opposite side of coins, if available. Otherwise *EC* from other sources is taken. Zinc content is the highest value measured if more than one spot was tested.

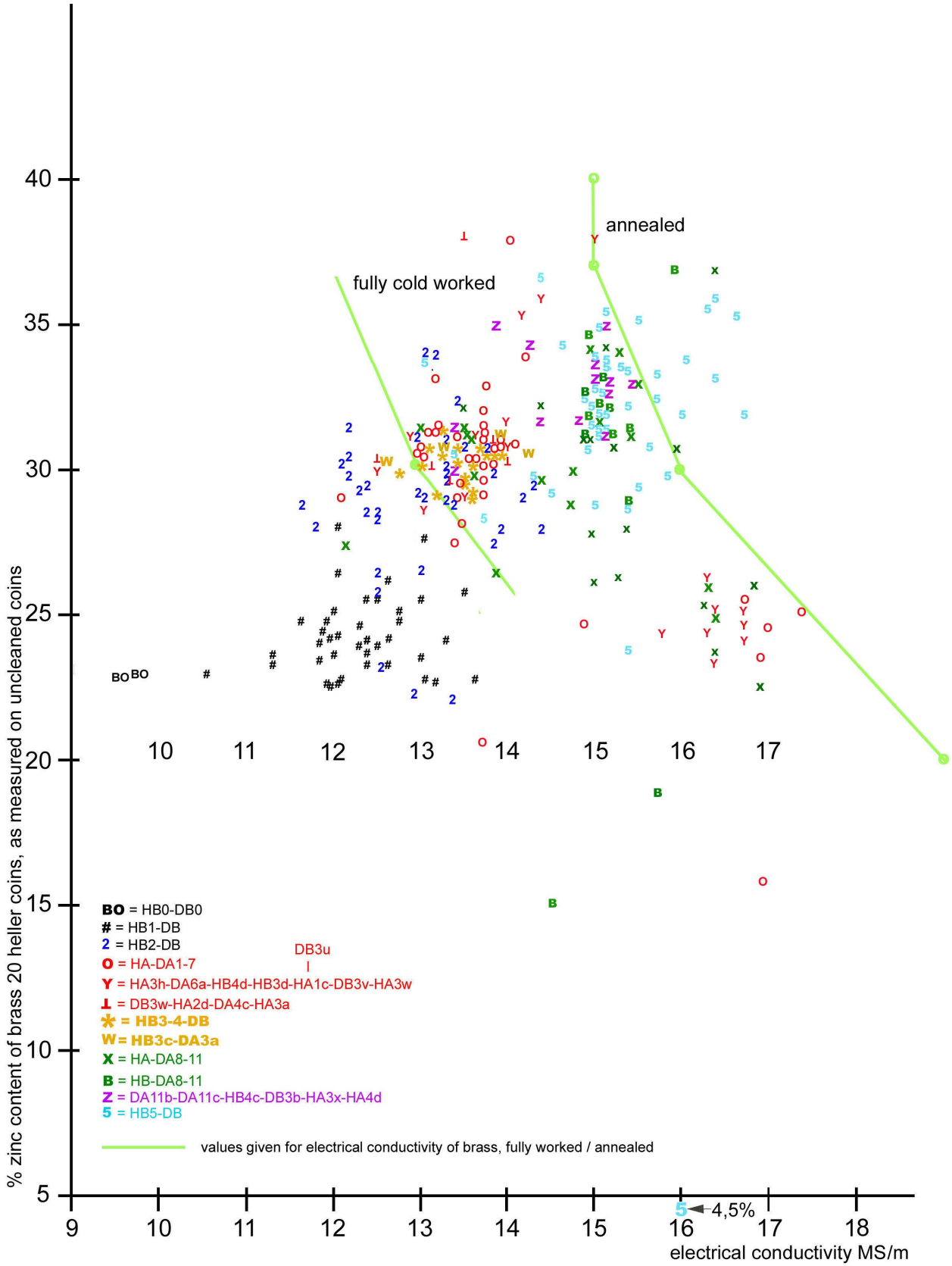



Figure 9, combination of metal composition and electrical conductivity

The series have been chosen based on die-combinations and die-relationships.

**Overlapping in the striking of Tabora-brass and prefab brass**

The production of *Tabora-brass* ended because the mint ran out of melting pots. This will not have been a sudden death, as the last pots will have ended their life span one by one. As production of *Tabora-brass* became lower than the demand for blanks, *prefab-brass* will have been started to be used in parallel with *Tabora-brass*. *Prefab-brass* being easier to work with, it even can be imagined that a small stock of *Tabora-brass* was formed, and used later as supplies of *prefab-brass* were exhausted.

Thus we may expect that some die combinations struck both *Tabora-brass* and *prefab-brass* coins, and possibly these two and copper coins, simultaneously .

**The outskirts**

In the graph above, showing the zinc content and EC of the tested coins, three minor groups of coins with high zinc content or high EC stand out from the rest. If the flans for the coins of one of these groups were produced from a single batch of material, it could well be these coins were struck nearly simultaneously.

The first group shows high zinc content of +/- 37%.
It contains 6 coins from 6 different die combinations: HB3d-DA6a, HA2d-DB3w, HA3e-A5b, HA3g-DA9b, HB5y-DA8b and HB5q-DB3p.



Figure 10, coins with high zinc content

The HB3d-DA6a (Zn 36.5-37.9%, EC 14.7-15.0) and HA3e-DA5b (Zn 37.9%, EC 14.1 MS/m) did also strike, or are die connected to die combinations that did strike "*LHH*" coins, which are described below.

The HA2d-DB3w (Zn 31.5-37.9%, EC 12.7-13.5 MS/m) did also render 0.4-0.5% tin and

0.4-1.2% lead, which very much resembles pollution of the H-side of a copper HA4d-DB3b coin (figure 23, right side)
Seven other coins from HA2d-DB3w and die-related die-combinations show zinc content between 27 and 33.4%, EC between 12.8 and 14.0 MS/m.

The HB5q-DB3p die combination also struck copper coins, which none of the five other combinations did. Five other HB5q-DB3p tested 27.4-33.8% zinc.

The HA3g-DA9b (Zn 36.9%, EC 16.3-16.4) is an exception amongst nine other tested HA3g-DA9b with Zn 26.1-32.3% and EC 13.3-15.9 MS/m.

The HB5y-DA8b shows a linear colour pattern. On both H and D side a dark and a light spot were analysed, resulting in Zn 29.7, 36.1, 36.8, 26.2%. A mistake in placement of the coin in the machine, or in notation of sequence can't be excluded. Five other HB5y-DA8b rendered EC 14.8-16.6. Three of them show Zn 29.1-32.1%, EC14.8-15.4 MS/m. One, probably chemically cleaned, shows Zn 18.9%, EC 15.1-15.6 MS/m and one not XRF tested EC 16.5-16.6 MS/m. As density of the last was measured as 8.34 g/cm3, this is probably a “NHN” coin as mentioned below, which might indicate a connection to die combinations that struck such coins.

Besides their high zinc content the coins seem to have little in common and, being singletons, their appearance seems to be unrelated to each other.

The second group has low zinc content in combination with high EC and high density.

**Coins with Low zinc content in combination with High EC and High density (LHH)**

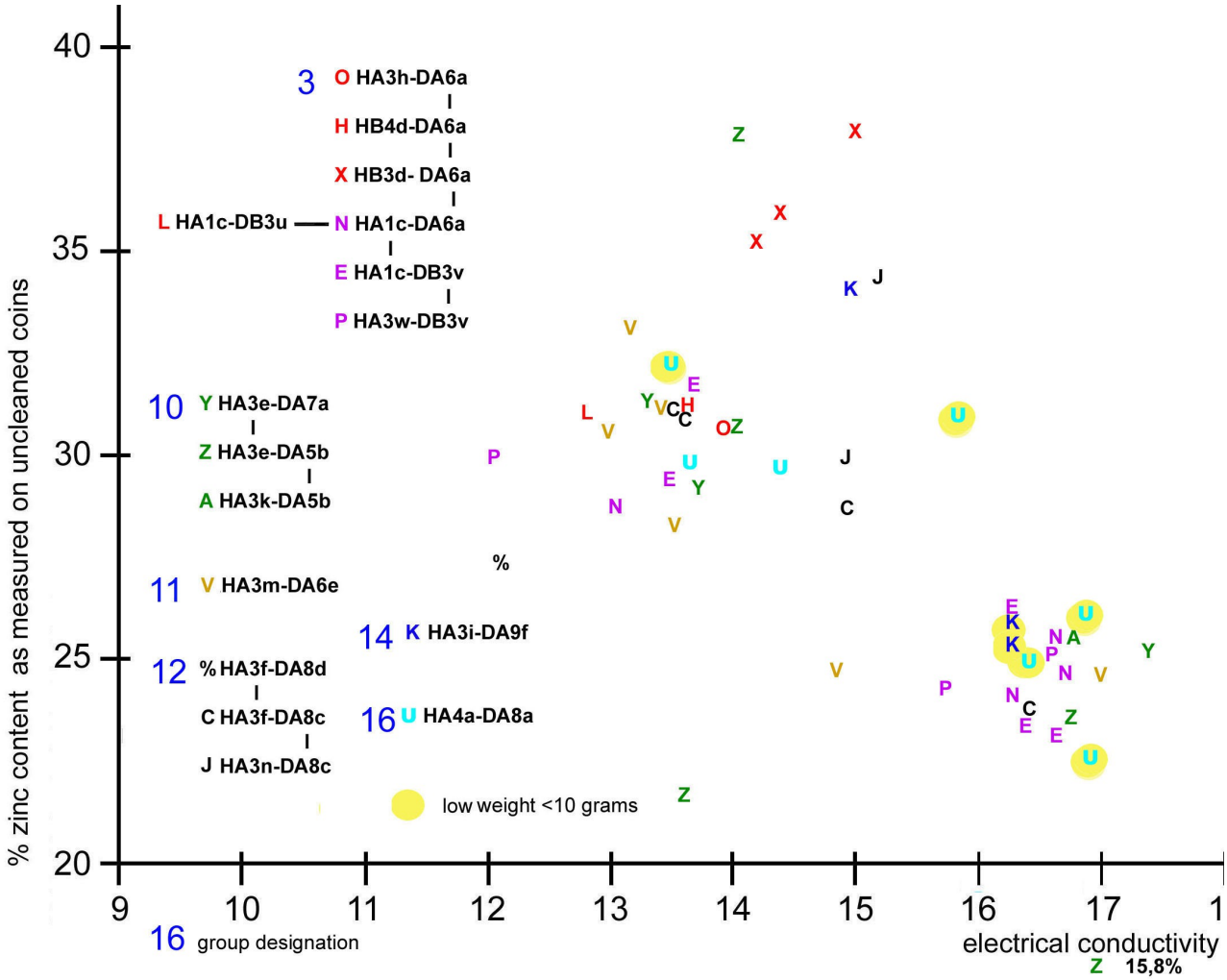



Figure 11, combination of metal composition and electrical conductivity for selected groups

The concentration of LHH coins at the southeast outskirt consist of coins from only a few groups of die-combinations, which did also strike coins with “normal” characteristics. Typically the LHH coins have a low zinc content of around 25% and a very low lead content, a high EC around 16 MS/m and a high density of around 8.50 g/cm3. More on density and the way it was measured is said below.
The very low lead content, which implies a very low lead content of the zinc used to produce the brass, might be helpfull in tracing the origin of this brass. Figure 5 above mentions zinc from Pennsylvania as containing no lead, but there might have been other regions too.

Group numbers are being introduced as easy reference to groups of coins struck by one or more die combinations. For a complete list of group numbers see figure 12.

As yet no LHH coins have been found struck by HB5-DB3 die combinations. Although LHH coins almost surely don't stem from brass cast in Tabora, as this hardly ever reached EC above 14 MS/m, it can't be excluded they were struck on scrap brass that escaped the melting pot. The relatively large amount of LHH coins would suggest a considerable batch of LHH material.

Group 3 poses a sequencing problem: either the HA(C)1c-DB3u die combination was used before HA3h-DA6a and HA(C)1a was later used again to replace HB3b, or HA3h-DA6a through HB3b-DA6a die combinations came first and DA6a was later reused to replace DB3u.

Just one tested **L** HA(C)1c-DB3u coin with low EC and normal zinc content (Tabora-brass) is not enough to more than suggest that this die combination precedes the **O-H-X** series. This suggestion is strongly supported though by the misfit of HA1c-DA6a combination in the probable die production order. The third inner leaf above H broke of the positive die after only 4 HA(C)1 dies had been produced, three of them being used in combination with early DA dies. At least eight DA dies had been produced before the first DA6 die could make its appearance.
In the figures HA1 is used as short for HA(C)1

The third group consists of coins with a normal zinc content, high electrical conductivity and normal density.

### Normal zinc content in combination with High EC and Normal density (NHN)

Besides the LHH coins, where low zinc content could explain high EC and high density, another group of fourteen coins, with normal zinc content of 31.8-35.9%, high EC over 16 MS/m and normal density between 8.26 and 8.40 has been found (NHN). These NHN coins are struck by only three groups of die combinations, These groups are also related by other characteristics of the coins they struck. The coin with zinc 36.9%, EC 16.3-16.4, described before, may also belong to this group of NHN coins. For groups of die combinations that struck NHN coins see figure 12

### Standard prefab brass

Standard prefab brass would designate the run of the mill brass you would get if you would go to a shop and ask for a piece of brass, without further special requirements. Looking at the brass coins, struck in Tabora by the vast majority of die combinations that did also strike copper coins, you would have got a piece of brass with a zinc content somewhere between 28 and 35% (or maybe even 37%), EC somewhere between 14 and 16 MS/m and a density ranging from 8.30 to 8.45 gr/cm3.
The prefab brass Swakopmund native pass shown above in figure 2 contains about 30% zinc, 0,3% lead, EC is 14.5 MS/m, density 8.38 g/cm3.

Data sheets for brass with 28 to 33% zinc content copperalliance.eu , kupferinstitut.de , copperalliance.eu and wieland.de give a density of 8.55 to 8.5 gr/cm3 for these materials. Density measurements conducted by Balke, and by Hammer & Franquinet, as presented in figure 37 in the density testing paragraph below, confirm that density values of 8,5 gr/cm3 and above are seldom reached in coins tested.

### Low weight coins

On page 189, The Handbook of Tanganyika 1930 mentions that the first batch of coins from (prefab) brass sheets, to a value of 4,000 rupees (20.000 coins), came out light in weight, viz. eight grams.
HA3i-DA9f and HA4a-DA8a die combinations produced such low weight coins, but no copper coins. They would thus be a marker of the striking of the first prefab brass coins.

Low weight coins below 10 grams are also found for the die combinations HB5g-B3i > HB5h-DB3i and B5o-B3o > B5p-B3o, but in contrast these combinations did also strike copper coins.

As can be seen above (figure 11, yellow dots) three low weight HA3i-DA9f and two low weight HA4a-DA8a are LHH coins (9.6, 7.5, 7.7, 8.7 and 9.7 g).
Regarding to the values of the two other HA4a-DA8a, it could be suggested that beside LHH brass also rods made of Tabora-brass (1 coin: 7.4 g, EC 13.5-13.2 MS/m, Zn 29.6-

31.3%, Pb 0.37-0.52%) and of non-LHH prefab brass (1 coin: 8.8 g, EC 15.9-15.7 MS/m, Zn 24.1-30.7%, Fe 0.04-0.12%) were rolled to a lesser thickness, possibly to compensate for diminishing output of Tabora-brass.

There are not enough data available on weight distribution of HA3i-DA9f & HA4a-DA8a coins to report if 20.000 is a reliable number for the amount of low weight coins from these die combinations. So far, available figures suggest a lower number.

Nor can it be ascertained whether striking of the first LHH prefab brass coins and of the first low weight coins indeed happened at the same moment, or that the striking on material from prefab brass sheets and of light weight coins were just reported in the same document. Nevertheless it may be assumed both happened near simultaneously.

The suggestion that LHH-brass and low weight coins are amongst the first prefab coins struck is strongly supported by the concurrance of a high percentage of LHH and Tabora-brass coins from the die combinations in groups 3, 10 and 16 (see figure 12 below), while only very little or no standard brass coins are known for these combinations. Data for group 14 are insufficient.

**Distribution of electrical conductivity of coins from different die-combinations**

From a considerable amount of coins EC has been measured on both sides. For figure 12 below the highest of both values has been used.

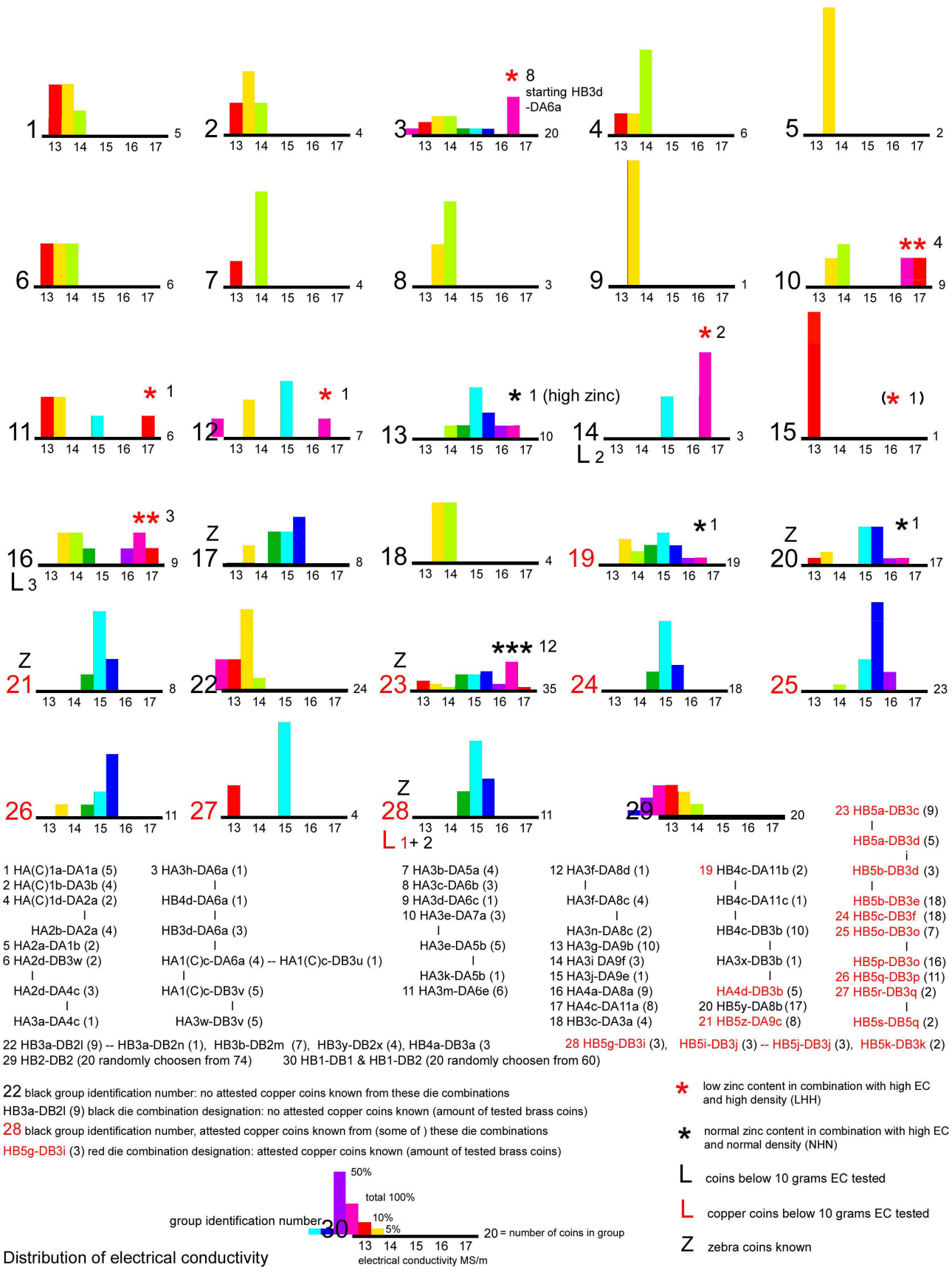



Figure 12, distribution of electrical conductivity within groups of coins

For each group (which may be a single die combination, a series of die connected die combinations or an otherwise related group of die combinations) the total amount of EC tested brass coins has been recorded as 100% and distributed in a small graph with

intervals of 0.5 MS/m. Thus 13.8 to 14.2 = 14, 14.3 to 14.7 = 14.5 etc. Intervals are coloured for better readability.
Some groups are very small and those results are thus statistically not very reliable.

Of the earliest coins, summarised in group 30, HB1-DB1 & HB1-DB2 die combinations, only two coins, out of sixty, score EC over 13.2 MS/m, highest value being 13.6.
Group 29, HB2-DB2 die combinations, scores slightly higher: ten coins 13.3-13-7, eight 13.8-14.2, two over 14.2, highest 14.4 MS/m (in total 20 out of 74).
Only the die combination HB2b-DB2d, with three coins reaching 13.9-14.2 MS/m, one 13.1 and three 12.3-12.5 would be compatible to any of the later groups. Also, it would be hard to distinguish HB2i(?)-DB2o and HB2j-DB2p from, for example, group 1 and group 22. Tentatively it could be stated that group 1 (HA(C)1a-DA1a) was struck after most of the coins of group 29 were produced. This could render a terminus post quem for these coins.

On the other side we have group 24 with coins from die combinations that did strike mainly copper coins. Their EC is completely different and they may be regarded as standard prefab brass. Groups 1, 2, 4 to 9 and 18 show no signs of standard prefab brass, nor any LHH coins.
RFA tests are available for two coins of group 15, but only one of them has yet been EC tested. The RFA of the other indicates it must be a LHH brass coin.

LHH coins are attested for groups 3, 10, 11, 12, 14 and 16. Only group 10 shows as yet no sign of standard brass coins. Above it has been argued these LHH coins are the first prefab brass coins struck.

The high zinc high EC coin from group 13 is possibly an exception, not connected to the NHN coins of group 19, 20 and 23.
Only the last of the five die related die combinations of group 19 is attested to have struck copper coins. All four die related die combinations of group 23 have struck copper coins, although they are not common.
Both group 19 and 23 did strike Tabora-brass coins
Group 19 and 21 are connected by the fact that in both groups most copper coins are containing around 0.3% tin, a rare copper composition hardly found in any other groups.

Wherever placed, groups 13 (HA3g-DA9b, J724), 15 (HA3j-DA9e, J724), 17 (HA4c-DA11a, J724) and 20 (HB5y-DA8b, J725) should be taken as possible candidates for copper coins, as well as the first four combinations of group 19.

In trying to sequence the 20 Heller coins it should not be forgotten that in between limited amounts of 5 Heller coins were struck on the same machines, putting small gaps in time between successive 20 Heller combinations.

**Mintage and dating of Tabora-brass, prefab brass & copper**

Schumacher gives the following data: prefab brass +/- 270,000, prefab copper +/- 330,000. Leaves +/- 1,030,000 Tabora-brass ( emuenzen.de/forum/attachments/praegezahlen ).
Putting these numbers in a graphical representation of coin production gives an indication of the date before which production in a certain metal must have started. That is 24th of June for prefab brass and 14th of July for copper.

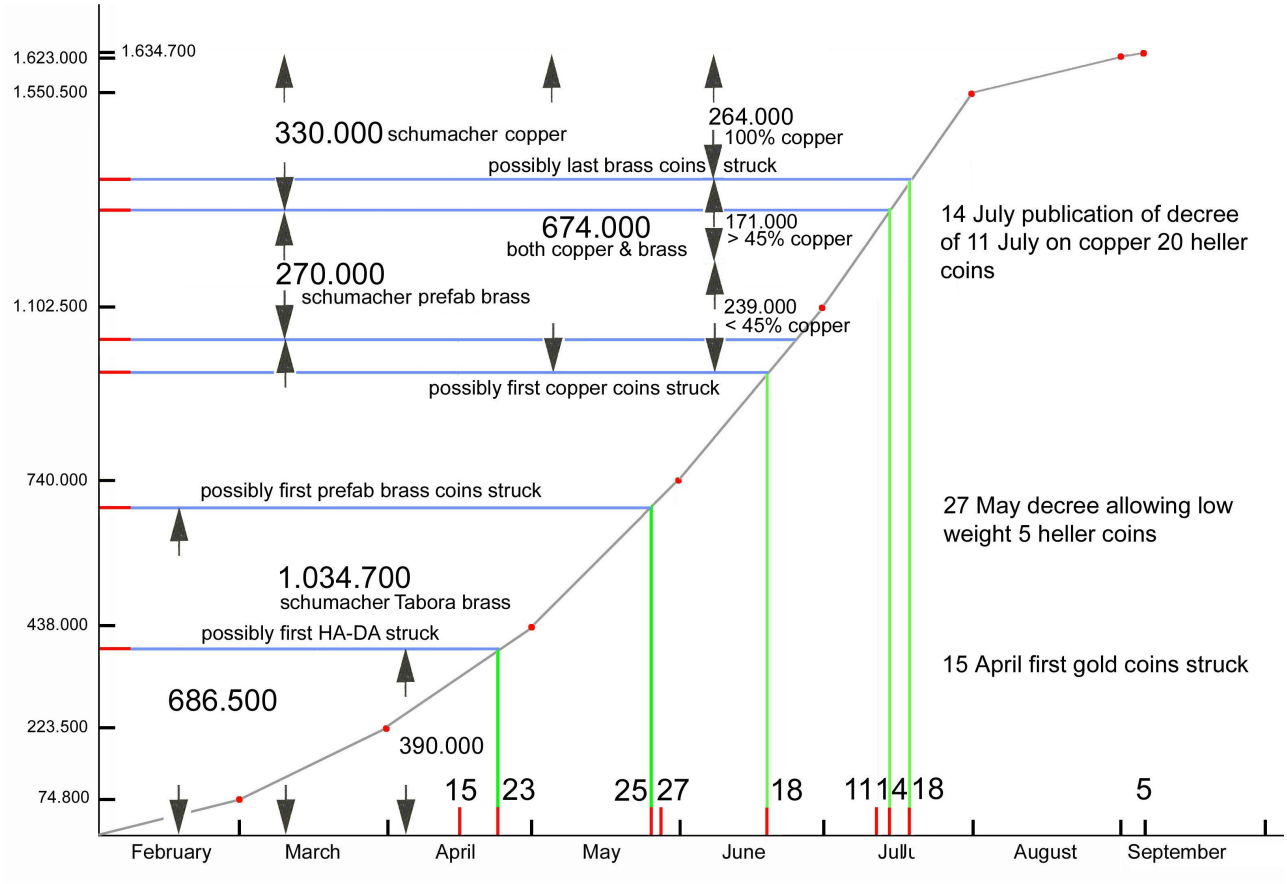



Figure 13, 20 Heller coin production time line

For copper coins there is an edict of 11th of July http://www.zeno.ru/showphoto.php?photo=112676 announcing them. The 3 days between 11th and 14th of July don't allow for more than 2 die-combinations producing brass as well as copper coins. As there are at least 16 die-combinations that produced coins in both kinds of material, the decree most likely must have been issued in order to legalize already produced coins.
Taking my own collection of 20 Heller coins, I would say that possibly 8 die-combinations produced copper coins only.

14th of July the edict was published in the Amtlicher Anzeiger and was mentioned in the Deutsch-Ostafrakanische Zeitung as well. http://www.zeno.ru/showphoto.php?photo=145222
There, it is also mentioned that the brass coins would be produced further.

The coincidence of the publication date of the decree with a number of 330,000 coins still to be produced makes one wonder if Schumacher's number of 330,000 copper coins is not based on this same kind of calculations. There seems to have been little reason to keep separate count of copper and brass coins produced.
Schumacher was head of the gold mint. The railway company managed the Heller mint so all Schumacher knew about the production of Heller coins would be from second or third hand.

The calculations below, of which the results have been presented in figure 14 above, are based on the blue figures for die production in the spread sheet “2015a incl MPO” which may be downloaded from the first entry in praegezahlen-deutsch-ost-afrika-doa-1916
As there may be a difference in survival rate of coins from different die combinations, all figures calculated based on these data, of coins offered for sale today, are to be

considered tentative.

Taking 14.7 MS/m as upper limit for Tabora-brass and using percentages based on the distribution shown in figure 14, about 1400 out of the 2710 coins would be Tabora brass, which corresponds to a mintage of about 845,000 coins. If the percentages were correct the 95% confidence interval would be 845,000 plus or minus 31,000. In conclusion, prefab brass and copper coins would account for a total of about 790,000 (+/- 31,000).
Referring to the section “copper coins” below, a total of at least 425,000 is suggested for the mintage of copper coins. This would leave 365,000 as mintage for prefab brass coins. As part of the coins with an EC from 14.3 – 14.7 MS/m almost surely will be prefab brass, the figures for Tabora-brass above must be regarded as a high estimate and those for prefab brass as a low one. The mintage of this group of coins (EC 14.3- 14.7 MS/m) might be estimated at about 70,000 coins, giving a low number of 775,000 for Tabora-brass and a high number of 435,000 for prefab brass.
Combining these figures with a 95% confidence interval of about plus or minus 30.000 coins it can be stated that mintage of Tabora-brass amounted to between 745.000 and 875.000 coins, while between 335.000 and 465.000 prefab brass might have been struck.

1138 out of the 2710 coins were struck by die combinations that didn't strike coins with EC above 14.7 MS/m, which corresponds with a mintage of about 686,500 coins. This amount of 20 Heller coins would have been produced by the mint around 25th of May. If indeed no Tabora-brass was produced with EC above 14.7 MS/m, this would give a terminus ante quem [before which] for the stricking of the first prefab brass coins. The 95% confidence interval of plus or minus 30,500 corresponds to the mintage of 3 days.

Only two days later, on the 27th of May, a decree http://www.zeno.ru/showphoto.php?photo=112825 announces that the weight of 5 Hellers, which before had been ordained to be about 5 grams, was now allowed to be between about 3 and 5 grams. A 5 grams brass 5 Heller flan with a diameter of 22.5 mm and a density of 8.5 gram/cm3 would have had a thickness of 1,16 mm. This is exactly the same thickness as the thickness of a 8 grams 20 Heller flan with a diameter of 28.5 mm.
As the transition from thick-flan 5 Heller to thin-flan ones is abrupt, it seems probable that the decision to strike these coins on low weight flans, obtained directly from the side walls of shell cases, may also have had something to do with a shortage of material for 20 Heller coins. So, some of the low weight 20 Heller coins may have been struck on material originally intended for striking of 5 Heller coins.

A terminus ante quem for the striking of the first copper coins could be deduced from the amount of 1117 coins struck by die combinations that are known to have struck copper coins. This corresponds to about 674,000 coins. To produce them the mint would have to have struck the first copper coins before or around 18th of June.
For some die combinations there are only copper coins found so far. 438 out of 2710 coins were struck by these combinations, corresponding to a mintage of about 264,000 coins. Derived from this calculation, 18th of July would be the terminus ante quem for a coin struck by one of these combination. However, it can't be excluded that some brass coins were still struck after that date.
In the section on copper coins it is suggested that die combinations striking between 45 and 90% copper coins struck a total of about 171,000 coins (i.e. brass and copper), and those which did strike between 1 and 45% copper coins did strike about 239,000 brass and copper coins.
Some Tabora-brass coins were struck by die combinations that struck low percentages of copper coins. It might be that Schumacher based his total of 600,000 prefab brass and

copper coins on a date for the last casting of Tabora-brass.

As stated above a terminus post quem for introduction of the HA-DA die combinations would be after striking of the coins of groups 29 and 30 (without those of HB2j-DB2p and HB2i?-DB2o). This corresponds to a total of 390,000 coins, calculated from the 646 out of 2710 coins in our database, which amount would have been reached by the 23th of April. If HA(C)1a-DA1a would also proceed HB2b-DB2d (63 counts = 38,000 coins) this date would move another 5 days forward to 18th of April.
It might be a coincidence that this date is only some days away from the date of striking the first 15 Rupee gold coins, that is on 15th of April. On the other hand, after the 15 Rupien dies had been finished, a well trained engraver was at the disposal of people who might have disliked the original design of the 20 Heller coins.

Also a rough estimate of the mintage of the main types can be derived from the interpolation of the figures for 2014 and 2015 based on our data:
HA-DA: 335,000 +/-25,000, including 39,000 +/-10,000 HA(C)-DA, and 49,000 +/-11,000 copper HA4b-DA10a
HA-DB: 106,000 +/-15,000, including 12,000 +/-5,000 HA(C)-DB
HB-DA: 127,000 +/-15,000
HB-DB: 1,067,000 +/-29,000

**Conclusion**

Typical Tabora-brass coins shows casting errors and an EC below 14.2 MS/m. Probably all die combinations with HB1 and HB2, as well as those in groups 1, 2, 4 to 9 and 18 in figure 12 above, did produce Tabora-brass coins only.

Tabora-brass is not restricted to combinations mentioned above, but lingers on as first LHH brass and then standard prefab brass start to be used nearly simultaneously.
If the supposition is correct that HA(C)1c-DB3u was struck some time before the rest of group 3, all HA(C)1c-DB3u might be Tabora-brass. More data on EC of HA(C)1c-DB3u coins are necessary for confirmation.

Possibly for a small period of time only standard prefab brass coins were produced by the die combinations of group 13 and 17 before nearly simultaneously copper and NHN-brass coins appear.

Groups 24 and 28 seem to be a safe bet for a prefab brass coin, if the colour of the coin is right. Groups 17, 20 and 21 seem to be pretty reliable for the other main types. Probably standard prefab brass HA(C)1c exist, but none have been found yet, most seem to be Tabora-brass or LHH brass.

Figures given by Schumacher of mintage of prefab brass and copper coins are not supported by figures derived from surviving coins. The latter are about 30% higher. Mintage figures of the main types could be calculated but must be regarded as tentative. Mintage figures of Tabora-brass and prefab brass could only be calculated with broad margins. It seems that mintage of coins made of Tabora-brass has been about twice as high as that of prefab brass coins.
Possibly the first HA-DA coins were struck around 23rd of April, the first prefab brass ones around 27th of May and the first copper coins around 18th of June.

**Copper**

ASM Speciality Handbook: Copper and Copper Alloys books.google page 6 gives as definition of copper: “Coppers are metals that have a designated minimum copper content of 99.3% or higher. … … The term “modified copper” has also been used to describe metal for which the specified minimum copper content is less than 99.88% but not less than 99.3%, silver being counted as copper. This term is no longer recommended for usage.”

As the 1925 German DIN norm 1708 for copper (figure 3) shows, contemporary copper used for specific purposes could be of a lesser quality than the copper of modern specifications.

A correspondent wrote: “For primary copper it would be sold on the reputation of the refiner. No much notice was taken of standards then and not much more later. …. For secondary (recycled) copper, frequently fire refined, the impurities would be many, varied and wondrous at that time. Tin would be frequent, coming from solder. 'Floor sweepings copper'.”
Bronze might not always have been recognized as such, ending as copper in the melting pot.

In 1926, E. Sauerbrey mentions in “Die deutschen Werkstoffnormen der Nichteisenmetalle” (Dinglers Polytechnisches Journal 341, p. 192-194) that copper sheets are rolled from C-Cu (copper more than 99.4%) if they are to be deep-drawn or pressed, otherwise from D-Cu (copper more than 99.6%). If electrical conductivity has relevance E-Cu is chosen. Copper pipes are drawn seamless from C-Cu.



Figure 14, tested 22 mm deoxidized copper tube produced by KME

Modern copper tubes for domestic gas and water installations are produced from Cu-DHP Kupfer/Cu-DHP which is supposed to contain at least 99.9% copper and 0.015-0.04% phosphor. EC given on the data sheet is 43 MS/m with a possible margin from 41 up to 52 MS/m depending on alloyed elements. A piece of tube tested in July 2015, produced by KME kme.com/en/sanco , rendered in its original form EC 47.2 MS/m, hardness HV5 92.9 kp/mm2. After severe hammering the tube tested EC 47.8 MS/m, HV5 107 kp/mm$^2$, and after annealing EC 47.2-48.2 MS/m, HV5 40-45 kp/mm$^2$.
In August 2015 a piece hammered flat rendered EC 47.9-48.2 MS/m. XRF analysis gave the following results: Cu 99.95%, Zn 0.018%, Sn –, Ni –, Fe 0.009, Pb 0.014, Ag 0.005, As –, Co –, Sb –, Bi 0.020, Cd 0.005, other elements were not tested.
Also the calibration element of the EC-meter, stating EC = 58.36 MS/m, was XRF tested: Cu 99.97%, Zn 0.024%, Sn –, Ni –, Fe –, Pb 0.011, Ag 0.008, As 0.003, Co –, Sb –, Bi 0.018, Cd 0.001.
As zinc is probably no part of either alloy, these tests show that care should be taken in interpreting readings of such very small amounts of elements in XRF results. They may be the result of misinterpretation of signals from elements not included in the program, lack of calibration of the program, pollution of the testing area or just results below accuracy level of the machine.

One piece of the copper tube was hammered flat on a dirty concrete floor in order to imitate the roughness caused by rolling dirty sheets of copper between damaged rolls used in Tabora. Afterwards the EC was 46.9-47.2 MS/m, density 8.83 gr/cm$^3$.

The difference of more than 10 MS/m, between the EC of the copper tube and that of the calibration element, is caused by the minimal amount of phosphor that got alloyed in the copper of the tube as a residue of the phosphor used to deoxidize this copper. This information does not shown in the XRF results since the XRF machine was not equipped to detect phosphor.

Some specifications for copper are given in the American book: Standards and Specifications for Metals and Metal Products 1933 books.google page 1170ff (pages scroll upwards)
Starting page 1174 bottom right, Serial Designation B72-28T, 1928, Fire refined copper, other than lake, is intended for use in rolling into sheet and shapes for mechanical purposes, and for certain grades of wrought-copper alloys, and is not intended for electrical purposes: copper + silver > 99.75%, arsenic < 0.1, nickel < 0,1, oxygen < 0.75, tin < 0.05, all others < 0.01%
Starting page 1175, top right, QQ-C521, 1932: Grade B, refined from ore or reclaimed from scrap: copper + silver > 99.5%, bismuth < 0.01, antimony < 0.05, arsenic < 0,03, iron < 0,1, lead < 0.05, nickel < 0.2 and tin < 0.2%.

Meyers Großes Konversations-Lexikon Meyers-1905/A/Kupfer gives some analyses of copper from different sources.

| Erzeugungsort | Gehalt in Prozenten: Kupfer | Silber | Blei | Arsen | Antimon | Nickel | Eisen | Wismut | Sauerstoff | Schwefel | Bemerkungen |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Garkupfer, rohgares Kupfer, Rosettenkupfer.** | | | | | | | | | | | |
| Mansfeld | 98,370 | 0,020 | 0,600 | — | — | 0,360 | 0,050 | — | 0,580 | 0,070 | — |
| Schweden | 99,170 | — | 0,470 | — | — | — | 0,050 | — | — | 0,110 | 0,5 Proz. Mangan |
| Südaustralien | 99,480 | — | 0,360 | — | — | — | — | 0,048 | — | — | — |
| **Hammergares, raffiniertes Kupfer.** | | | | | | | | | | | |
| Oker (Hampe) | 99,325 | 0,072 | 0,061 | 0,130 | 0,095 | 0,064 | 0,063 | 0,052 | 0,117 | 0,001 | 0,012 Proz. Kobalt |
| | 99,357 | 0,072 | — | 0,104 | 0,067 | 0,079 | 0,065 | 0,051 | 0,157 | 0,001 | 0,010 " " |
| Mansfeld (Hampe, Seigerhütte bei Hettstedt) | 99,612 | 0,029 | 0,020 | 0,017 | 0,002 | 0,211 | 0,004 | — | 0,075 | 0,002 | — |
| Riechelsdorf | 99,311 | — | 0,210 | — | — | 0,280 | 0,020 | — | — | — | 0,08 Proz. Alkalimetalle |
| Mansfeld, diverse Sorten | 99,400 bis 99,550 | 0,028 bis 0,030 | 0,043 bis 0,103 | — | — | 0,239 bis 0,275 | 0,025 bis 0,132 | — | nicht angegeben | — | — |
| Chile | 99,721 | 0,030 | 0,204 | — | — | — | 0,045 | — | — | — | — |
| | 99,742 | 0,016 | 0,132 | — | — | — | 0,110 | — | — | — | — |
| Oberer See (Nordamerika) | 99,920 | 0,030 | — | — | — | — | — | — | 0,280 | — | Kein Arsen, Antimon und Wismut enthaltend |
| | 99,890 | 0,030 | — | — | — | 0,003 | 0,005 | — | 0,190 | — | |
| | 99,830 | 0,030 | — | — | — | 0,030 | — | — | 0,220 | — | |
| Arizona (Nordamerika) | 99,990 | 0,008 | — | — | — | — | 0,021 | — | — | — | desgl. |
| | 99,990 | 0,008 | — | — | — | — | 0,014 | — | — | — | |
| **Übergares und überpoltes Kupfer.** | | | | | | | | | | | |
| Oker (Hampe) | 98,806 | 0,069 | 0,035 | 0,102 | 0,064 | 0,064 | 0,056 | 0,048 | 0,806 | 0,002 | 0,007 Proz. Kobalt (übergar) |
| Mansfeld (Hampe) | 98,905 | 0,029 | 0,021 | 0,022 | 0,006 | 0,220 | 0,003 | — | 0,746 | 0,004 | desgl. |
| | 99,658 | 0,031 | 0,020 | 0,018 | 0,004 | 0,210 | 0,003 | — | 0,046 | 0,002 | überpolt |

Figure 15, extract from Meyers Großes Konversations-Lexikon, 1905, copper

The same lemma mentions that in 1903 Germany produced 31,446 tons of copper, imported 106,787 tons and exported 14,618 tons. This indicates the copper used to strike 20 Heller might have originated anywhere in the world.

Data for 1913 can be found in Statistisches Jahrbuch für das Deutsche Reich 1913 1913 which contains also a special chapter on its colonies.

**Arsenical copper**
wiki/Arsenical_copper

The 1925 German DIN norm 1708 has a special category for copper containing arsenic and nickel, Hüttenkupfer A.
In the pre-WW I British standard Specifications for Railway Rolling Stock reportbritish2405 and for Copper Tubes and their Screw Threads reportbritish61 arsenic coppers are prescribed, which may contain up to 0.55% arsenic.

C14100 C14100 copper (Cu) 99.4%, arsenic (As) 0.15-0.5%. Class: coppers. Inactive date 1974-07-01

Modern designations for de-oxidised arsenical copper:
CU-DPA (C14200) cu_dpa.pdf Cu (+ silver (Ag)) + As > 99.7%, As 0.15-0.50, phosphor (P) 0.015-0.50. EC 20-26 MS/m
CuAsP, DIN 17666 – 2.1491 CuAsP % idem. EC 17-35 MS/m
or C107 copper/c107 Arsenic 0.35%, Phosphor 0.03.

"C107 is a copper alloy with a small addition of arsenic which provides the alloy with enhanced tensile strength properties at elevated operating temperatures up to 300°C. As well as increasing the softening resistance, the arsenic addition also enhances corrosion resistance in specific environments.
This grade is de-oxidised, which gives it freedom from hydrogen embrittlement, making it ideal for applications requiring welding and brazing. C107 has excellent fabrication characteristics and is typically specified in boiler work, especially locomotive fireboxes."

Thick sheets are available southdevonrailwayassociation.Copper_Supply.html

Disadvantage of arsenical copper is of course that most arsenical compounds are poisonous.

| Arsenic. Per cent. | Density. Grms. per c.c. Atm. Temp. | | | Mass Conductivity. Per cent. MS/m | | | | Resistivity. Microhms per cm. Cube. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | At 20° C. | | At 65° C. | | At 20° C. | | At 65° C. | |
| | As Cast. ½ in. diam. Ingot. | As Rolled. ½ in. diam. Rod. | Annealed. ½ in. dia. Rod. 700° C. ½ hr. | As Rolled. | Annealed. | As Rolled. | Annealed. | As Rolled. | Annealed. | As Rolled. | Annealed. |
| 0·053 | 8·41 | 8·92 | 8·91 | 85·5 | 85·5 | 74·4 | 74·5 | 49.6 | 49.6 | 2·009 | 2·011 | 2·309 | 2·311 |
| 0·093 | 8·23 | 8·93 | 8·89 | 76·9 | 76·7 | 67·8 | 67·7 | 44.6 | 44.5 | 2·232 | 2·250 | 2·534 | 2·549 |
| 0·36 | 8·37 | 8·92 | 8·92 | 45·3 | 44·9 | 42·0 | 41·7 | 26.3 | 26.0 | 3·79 | 3·83 | 4·10 | 4·13 |
| 0·60 | 8·44 | 8·92 | 8·85 | 33·7 | 33·4 | 31·8 | 31·6 | 19.5 | 19,4 | 5·09 | 5·19 | 5·41 | 5·49 |
| 0·86 | 8·26 | 8·91 | 8·86 | 25·6 | 25·7 | 24·5 | 24·6 | 14.8 | 14.9 | 6·71 | 6·73 | 7·03 | 7·04 |
| 1·04 | 8·52 | 8·91 | 8·91 | 22·5 | 22·1 | 21·6 | 21·3 | 13.1 | 12.8 | 7·66 | 7·78 | 7·98 | 8·09 |

Table 2 (adapted), D. Hanson & C.B. Marryat, Investigation of the Effects of Impurities on Copper, Part III - The Effect of Arsenic on Copper. Journal of the Institute of Metals 37m 1927, 121-143 virtually oxygen free copper

Figure 16, influence of arsenic on electrical conductivity of copper

**Influence of small quantities of other metals on electrical conductivity (EC) of copper**

The International Annealed Copper Standard (IACS) IACS.htm establishes a standard for the conductivity of commercially pure copper: electrical conductivity at 20 degrees Celsius = 58 MS/m. Conductivity is often expressed in % IACS: 100 % IACS = 58 MS/m (50% IACS = 29 MS/m etc.). Wire of 103% IACS (59,74 MS/m) has been produced, which is very near the value expected for copper without any impurity.

A graphical representation of the Influence of small quantities of other metals on EC of oxygen-free copper is given in copperalliance.pub-122-hicon-coppers page 47. Different ones can be found one page 4 of ASM publication Copper and Copper Alloys books.google (below figure 16 bottom right) and books.google page 188 (below figure 16 top right). On this page 188 a table regarding the influence of arsenic on EC (Zahlentafel 22) is mentioned, composed by D. Hanson and Marryat, which should be on one of the missing pages 189-190. This table might table 2 from: Hanson D. – Marryat C. B., Investigation of the Effects of Impurities on Copper, Part III the Effect of Arsenic on Copper, Journal of the Institute of Metals 37m 1927, 121-143, which is shown in adapted form in figure 16 above.
See also www.conductivity-app paragraph 4.1 and 1.1.2

Shorthand for chemical elements see elementsymbols

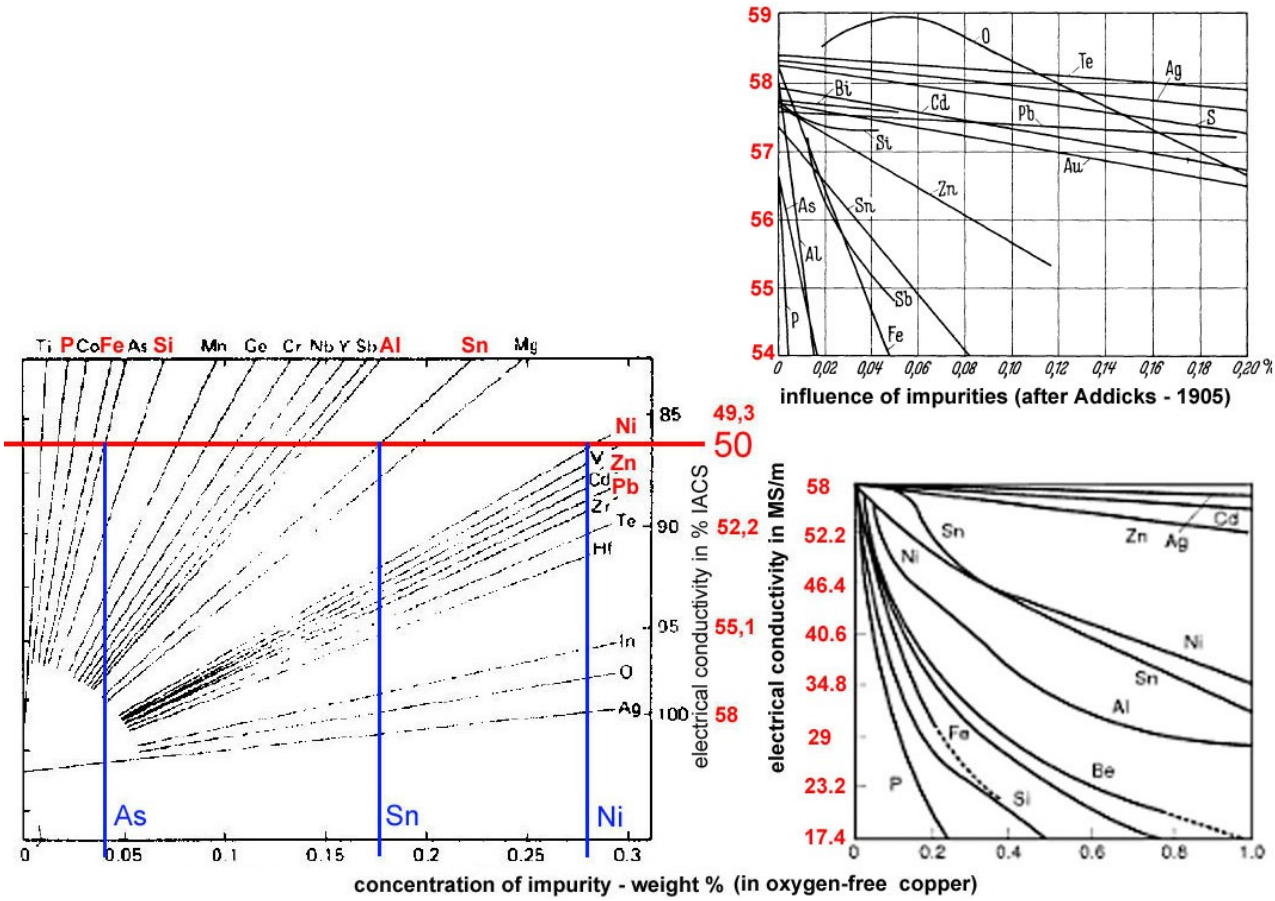



Figure 17, influence of impurities on electrical conductivity of copper

Figure 17 shows that some elements like phosphor (P), cobalt (Co), iron (Fe) and arsenic (As) are, even in very small quantities, real EC killers in deoxidized copper. If more than one element is present, the effects add up.

The book “Copper” from 1954 krishikosh pages 410-412 gives some information on effects of impurities on EC in oxygen bearing copper.

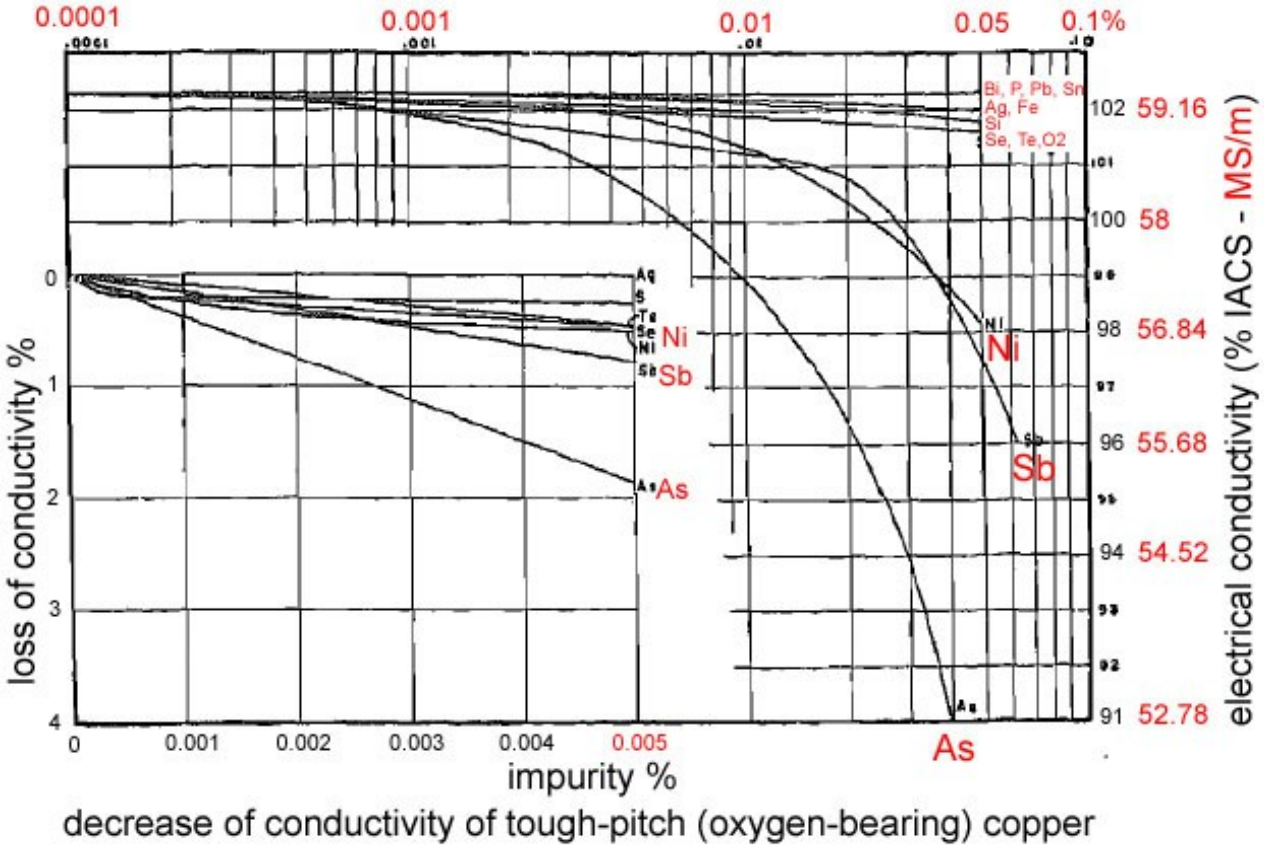



Figure 18, influence of impurities on electrical conductivity of tough-pitch copper

As and Ni are as disadvantageous to EC as in deoxidized copper, antimony (Sb) a little less. Oxides of Fe, Sn and Pb are said to be precipitated in inert form and thereby lose their effectiveness. Oxides of such elements as Zn, P, Co, Cr. Si and Al are said to be similarly formed, but to be usually eliminated during refining. Ti and Mn are not mentioned. Two questions are not answered: 1 – what if the copper doesn't contain enough oxygen to oxidize all impurities, and 2 – what is the effect of Zn, P, Co, Cr. Si, Al and their oxides if they are not fully eliminated during refining.

Some modern (deoxidized) low alloyed coppers:
CuSn0.15 aurubis-stolberg.CuSn0_15.pdf contains 0.10-0.15% tin (Sn). EC in annealed condition around 49 MS/m. kupferinstitut/CuSn0_15.pdf EC 44-55 MS/m
CuSn0.2 conductivity-app.org/alloy-sheet/15 contains 0.10-0.20% tin. EC 40-52 MS/m
CuSn0,5 conductivity-app.org/alloy-sheet/16 contains 0.20-0.55% tin. EC 33-49 MS/m
CuSn0,6 bedra.tin_bronze_alloys/bl06 contains 0,6% tin, EC +/- 25 MS/m
CuZn0.5.kupferinstitut.CuZn0_5.pdf contains 0.1-1.0% zinc (Zn). EC 46-51 MS/m
Cu-DHP kupferinstitut Cu-DHP.pdf 99.9% copper, 0.015-0.04 phosphor, EC 43 (41-52 MS/m depending on other elements)
Above alloys contain also small quantities of other elements.

The German Copper institute provides information on some low alloyed coppers
kupferinstitut.niedriglegierte-kupferwerkstoffe.html
kupferinstitut.Werkstoffe/i008.pdf
At first glance content of both webpages seems the same, but there are considerable differences.

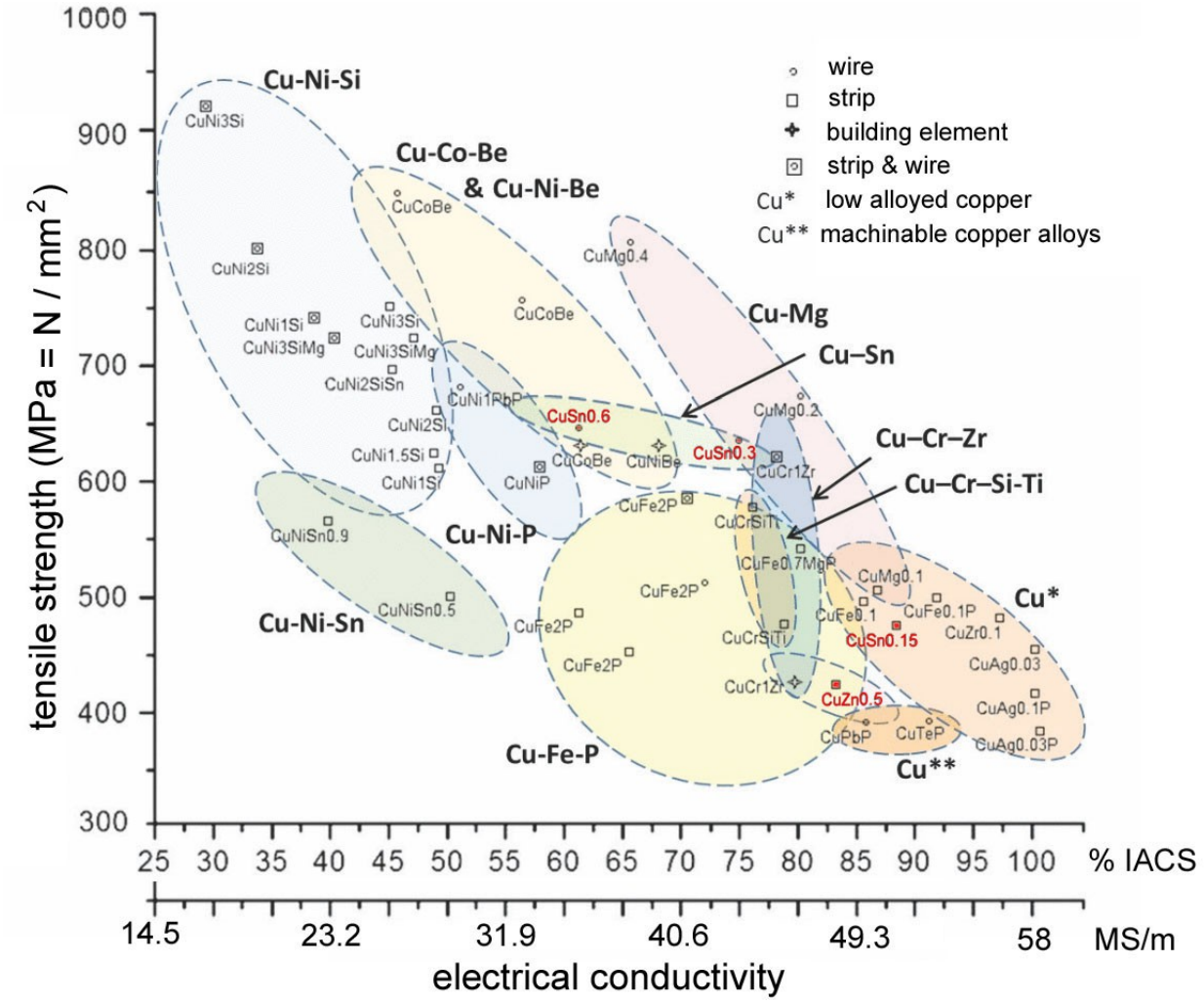



Figure 19, electrical conductivity of low-alloyed coppers

Tensile strength Ultimate_tensile_strength
For practical purposes yield stress is more important Yield_%28engineering%29 .
Especially since forces above yield stress are necessary during rolling to obtain permanent form change.

Comparing tensile strength, given for CuSn0.15 in figure 19, with the datasheet above, shows that the diagram gives the maximum value for cold worked material, which is well above that for annealed stuff (420-490 / 250-320 MPa)
Compared to Cu-ETP aurubis-stolberg tensile strength of CuSn0,15, for annealed material, is not much higher, but yield stress is at least nearly 50% higher (< 140 / > 200 MPA)

The German Copper Institute eigenschaften/kupfer shows as Tensile strength for soft copper 200 MPa and as yielding stress 40-80 MPa.

**Effects of cold working and annealing**

Effects of cold working and annealing see High Conductivity Coppers for Electrical

Engineering, CDA publication 122 coppers-for-electrical-engineering page 28 and seqq.

On page 48 you may read that selenium, arsenic, lead and antomony have marked influences on annealability at levels around 1.5 to 3 ppm, bismuth even at 0.1 ppm.

On page 32 the forming of copperoxides on the surface is mentioned. In contrast to the proces described, in Tabora these oxides were not removed when annealing was necessary between rolling operations. As a result, these oxides were rolled into the surface.

On page 73 it is mentioned that the effect of retained stresses on EC is noticeable but not too great and that hard temper high conductivity coppers show a 3% decrease in EC compared with annealed copper. This translates into a difference of about 1,8 MS/m.

**Influence of small quantities of other metals on softening temperature of copper**

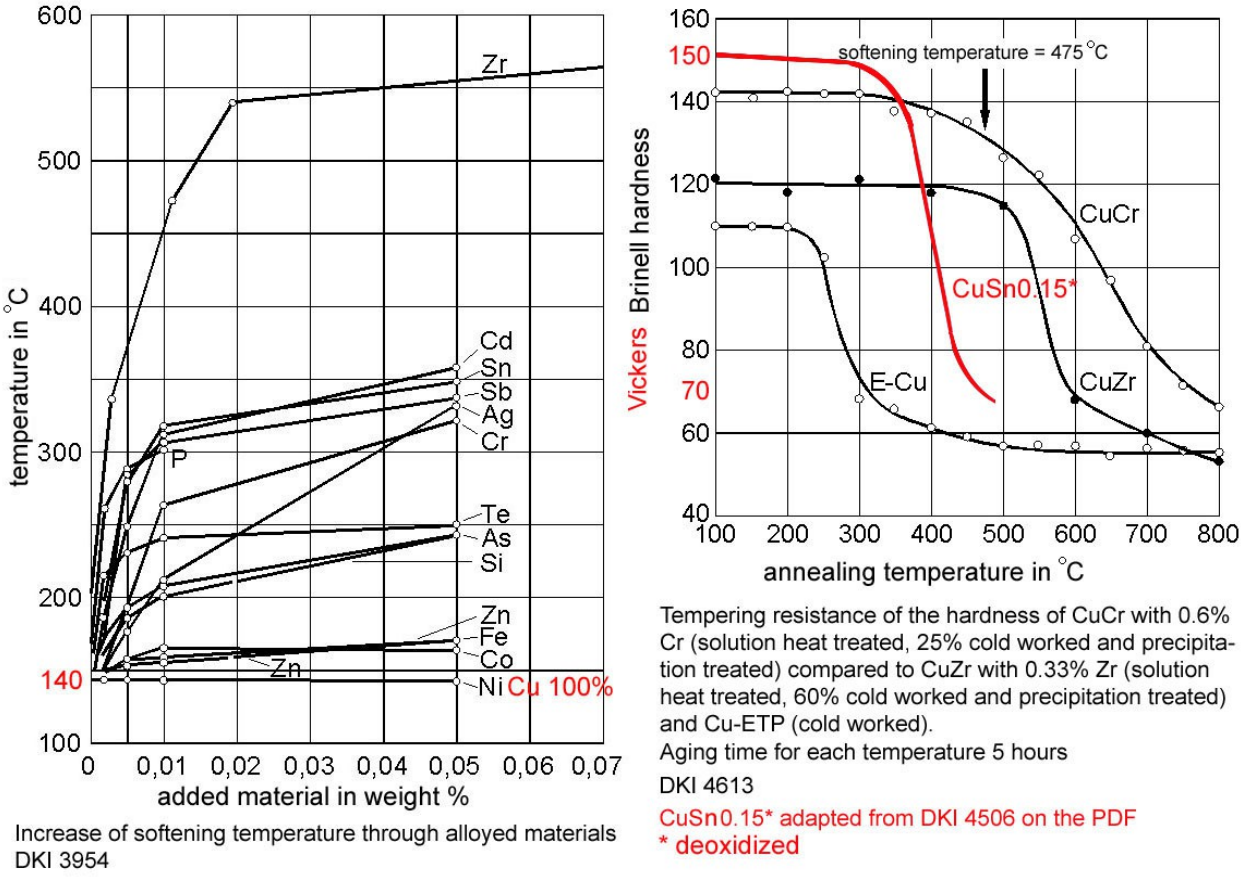



Figure 20, softening temperatures of low-alloyed coppers

The German Copper Institute's webpage on low alloyed coppers presents the graphs in figure 20 showing the effect of alloyed materials on softening temperature.
The book “Copper” from 1954 krishikosh page 413 clarifies that the values in the left graph are for oxygen free copper only. In tough pitch copper containing oxygen, low quantaties of tin (Sn), lead (Pb), silicon (Si) and chrome (Cr) have no marked effect (as long as there is enough oxygen to bind them we suppose)
Softening temperature is often defined as the temperature at which a material has lost 10% of its original strength (see Entfestigungstemperatur page 325)
Copper in the Automotive Industry softening%20temperature page 72 gives a somewhat different definition.

**Hydrogen embrittlement** (Wasserstoffkrankheit)
http://products.asminternational.org/fach/data/fullDisplay.do?database=faco&record=1673&trim=false
Welding or annealing of oxygen bearing copper may cause hydrogen embrittlement. This problem does not arise if deoxidized copper is used.
see also 2016 DKI - Copper as electrical conductive material with above-standard performance properties www.conductivity-app.org/download-single-text-pdf/cu_overview page 32-36

**Choice of copper quality**

As seen above, less pure coppers are, for many purposes, a better choice than the more pure high electrical conductive coppers types.
After cold working less pure coppers are stronger and they better resist high temperatures, such as are to be expected in steam engines, palm oil and sugar refineries.
Besides they probably would have been cheaper as a nickname like “floor sweeping copper” doesn't indicate A level prices.
Maintenance and small scale building of machinery in German East Africa would require sheets and tubes.
Still, plates and tubes available could have been high conductive coppers, as American tough pitch copper sheets and tubes were high conductive, because of the quality of the ores they were produced from.

Prime use of high electrical conductive coppers is transport of electricity. Electricity as a rule isn't transported by plates and pipes, but by wires. To produce a bar 30 mm wide and 2 mm thick a wire with a diameter of 9 mm would be required. This wire would have to be rolled sidewise, as rolling lengthwise lengthens the wire and hardly broadens it. This work would have been a very time consuming (as the rolling machine would not have been strong enough to take large pieces) and dangerous (as the rolling machine wouldn't discriminate between as a piece of wire and a finger) thing to do.

**X-ray fluorescence analysis (XRF) of 20-Heller copper coins**

XRF of 20-Heller copper coins never show impurities of more than 0.4% of tin, nickel, lead or iron and 1.1% of arsenic, other than could be explained by external causes.
Whenever phosphor could be tested the results could not be interpreted because it could also be pollution attached on the surface of the coin. Oxygen never could be tested.

The table below shows reliable XRF results for two copper coins, before (original) and after filing (geschliffen)

**Analyse von Münzen** — *Verfahren : Röntgenfluoreszenzanalyse ( RFA )*

Fa.:WAG MPA-Nr.: 310002615

| Probebezeichnung | Oberfläche | Bemerkungen | Cu % | Ag % | Pb % | As % | Fe % | Ni % | Co % | Sn% | Oberflächen-Verunreinigungen Si % | S % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J724 a / 20 He 1916 | orginal | *kleinere* | 97,7 | 0,028 | 0,058 | 0,003 | 0,06 | 0,16 | 0,032 | <0,001 | 0,7 | 0,02 |
| J724 a / 20 He 1916 | geschliffen | *Münze* | >99 | 0,030 | 0,16 | 0,012 | 0,006 | 0,15 | 0,032 | <0,001 | <0,001 | <0,01 |
| J727 a / 20 He 1916 | orginal | *größere* | 96,5 | 0,015 | 0,035 | 0,050 | 0,051 | <0,01 | 0,032 | 0,002 | 1,8 | 0,02 |
| J727 a / 20 He 1916 | geschliffen | *Münze* | >99 | 0,008 | 0,042 | 0,073 | 0,010 | <0,01 | 0,030 | 0,002 | <0,001 | <0,01 |

Figure 21, X-ray fluorescence analysis of two copper coins

The accompanying comment:

a -Differences between results before and after filing are small, except for surface pollution (Oberflächen-Verunreinigungen).
b – The coins have different feedstock (As, Ag & Ni values).
c – Interesting are the differences found for the same coin for values of Fe, Pb & As before and after filing. It seems Iron gets richer at the surface while Pb & As get poorer.

A complete list of the results is only available for surface XRFs of these coins. Higher values are only found for aluminium (0.21 / 1.78). Since they don't figure in the table this may indicate that they disappeared like silicon after filing. More interesting are figures for titanium (Ti) 0.025 (J724a)/ 0.022% (J727a). Titanium is a worse EC killer than phosphor, cobalt, iron or arsenic. With such small amounts though one should not disregard other external sources for their appearance. Only very small amounts of phosphor were found on the surface (< 0.00067 / 0.00325%) so phosphor doesn't seem to have been used for deoxidizing.

XRF results for five different coins from renowned institutes show following results for Cu, Zn & Sn

| | EC | Cu % | Zn % | Sn % | |
|---|---|---|---|---|---|
| J724 – HA4b-DA10a | 32 | 89.54 | 0.007 | 0.001 | |
| J724 – HA4b-DA10a | 43.5 | 97.47 | 0.007 | 0.309 | |
| J725 – HB5z-DA9c | 44 | 93.85 | 0.008 | 0.27 | Si 3.48, Al 0.92 |
| J726 – HA4d-DB3b | ? | > 96 | < 0.01 | 0.32-0.30 | Fe 0.14-0.13 |
| J726 – HA4d-DB3b* | 42 | 97.95-95.7 | 0.008-0.007 | 0.351-0.275 | Si 2.25-0.23, Ni 0.01 |
| * tests on different spots | | | | | |

Figure 22, X-ray fluorescence analysis of five copper coins

Four coins were tested by Pavel Kartashov

| | EC | Zeno.ru | Tested on filed part of rim, full comment see Zeno |
|---|---|---|---|
| J727 – HB5l-DB3l* | 35 | 155055 | Cu 99.71-99.21%, Ni 0.18-0.12, As 0.12-0,62, rest see Zeno |
| J727 – HB5d-DB3g | 58 | 112762 | Extremely pure copper |
| J727 – HB5g-DB3i | 26 | 121661 | Cu 100%, Zn,Sn,Pb,As,Sb,Fe,Co,Ni were analysed but not detected or below standard deviation level. Colour of metal dark purple-pink |
| J727 – HB5g-DB3i | 35 | 121662 | Cu 99.77%, Sn 0.23, Zn,Pb,As,Sb,Fe,Co,Ni were analysed but not detected or below standard deviation level |
| * XRF tests of same coin on other machine see Zeno 155055 | | | |

Figure 23, X-ray fluorescence analysis of four copper coins

Ernst Balke gives in his article “Die Notmünzen von Deutsch-Ostafrika” (Moneytrend # 3 1988) XRF results for 7 copper coins. All test more than 99% copper, less than 0.1% zinc, all other elements including zinc less than 1%. EC was not tested.

Many more XRF data were obtained by Florian Kreul and Kees Uitenbroek with simular results.

Three HB5z-DA9c-Cu – J725a contain 0.27-0.30% tin, EC 43.4-44.1 (highest values from those measured on both sides). One HB5-DB3-Cu is known with EC 23 MS/m, this will be arsenical copper (see below). One HB5z-DA9c-Cu, EC unknown, contains 0.37-0.40%

arsenic but no tin. One dirty and corroded HB5z-DA9c-Cu ( 61336 right side) EC 34.7-27.7, renders a bewildering amount of different XRF results at different places of the coin: 0-11.0% zinc, 0-4.1% tin, 0-1.0 lead, 0-3.1% iron and 0-13.5% calcium. Density is 8.87 gr/cm3.

Ten HA4d-DB3b-Cu – J726a contain 0.28-0.32% tin, EC 42.5-44.8 MS/m. The coin left in the picture below contains no tin but 0.47-0.50% arsenic, EC 23.9-24.5 MS/m. Another corroded coin, 63522 top left, much similar to thecorroded HB5z-DA9c, shows the same bewildering results, except that no zinc and iron were found. EC is 25.6-30.9 MS/m, density is 8.88 gr/cm3.
Aside there is the coin on the right side in the figure 23 below, EC 25.4-31 MS/m, where the H-side is clearly polluted with tin and lead, while the D-side is not affected. Both coins in the picture are arsenical copper.




X-ray fluorescence analysis
elements analysed, zinc and bismuth probably not correct (to high)

| | | Cu[%] | Zn[%] | Sn[%] | Ni[%] | Fe[%] | Pb[%] | Ag[%] | As[%] | Co[%] | Sb[%] | Bi[%] | Cd[%] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H-side | 99.24 | 0.013 | - | 0.046 | 0.009 | 0.124 | 0.018 | 0.465 | - | 0.015 | 0.085 | 0.011 |
| left | D-side | 99.16 | 0.023 | - | 0.034 | 0.003 | 0.166 | 0.025 | 0.501 | - | 0.019 | 0.096 | - |
| | | 96.42 | 0.034 | 1.479 | 0.005 | 0.028 | 1.248 | 0.062 | 0.701 | - | - | 0.035 | - |
| | H-side | 95.16 | 0.045 | 1.877 | - | 0.035 | 2.049 | 0.065 | 0.742 | - | 0.010 | 0.027 | - |
| | | 99.54 | 0.029 | - | 0.012 | 0.029 | 0.019 | 0.045 | 0.333 | - | - | 0.020 | 0.002 |
| right | D-side | 99.36 | 0.027 | - | 0.010 | 0.050 | 0.043 | 0.049 | 0.460 | - | 0.007 | 0.014 | - |

Figure 24, X-ray fluorescence analysis of two copper HA4d-DB3b coins

If the copper were deoxidized 0.3% tin is enough to account for an EC around 42 MS/m. Probably these low tin copper coins all stem from the same batch of sheets or tubes and might well have been struck simultaneously.
Tin content around 0.3% is found only sporadically at J724a – HA4b-DA10a and J727a – copper HB5-DB3

Most HA4b-DA10a – J724a are arsenical copper coins, As 0.16-0.7%, EC 19.6- 37.7 MS/m. Only one HA4b-DA10a has been found yet, containing no arsenic but 0.31% tin, EC 42.2-45.4.
Of six HA4b-DA10a without arsenic and tin, four rendered EC 56.0-58.3 MS/m. The two others did render 38.1-38.4 MS/m. Although the difference in EC clearly indicates two different materials, the XRF results give no answer to the question which substance causes the difference in EC. Possibly a deoxidizing agent, like phosphor, is involved that could not be tested for.

Also some J727a HB5-DB3-Cu coins are proven to be made of arsenical copper.
In addition, some HB5-DB3-Cu coins tested 0.4% nickel, EC 24,9-46.4 MS/m

Many coins though, like the two HA4b-DA10a, give no clue why they would have low EC. More XRF results of very clean or filed coins could perhaps shed more light on the origin

of low EC of so many of the coins. Especially if deoxidizing agents like phosphor would be found.
Flan errors caused by rolling, like doubling, which are offen noticeable on the coins, might also be one of the causes.

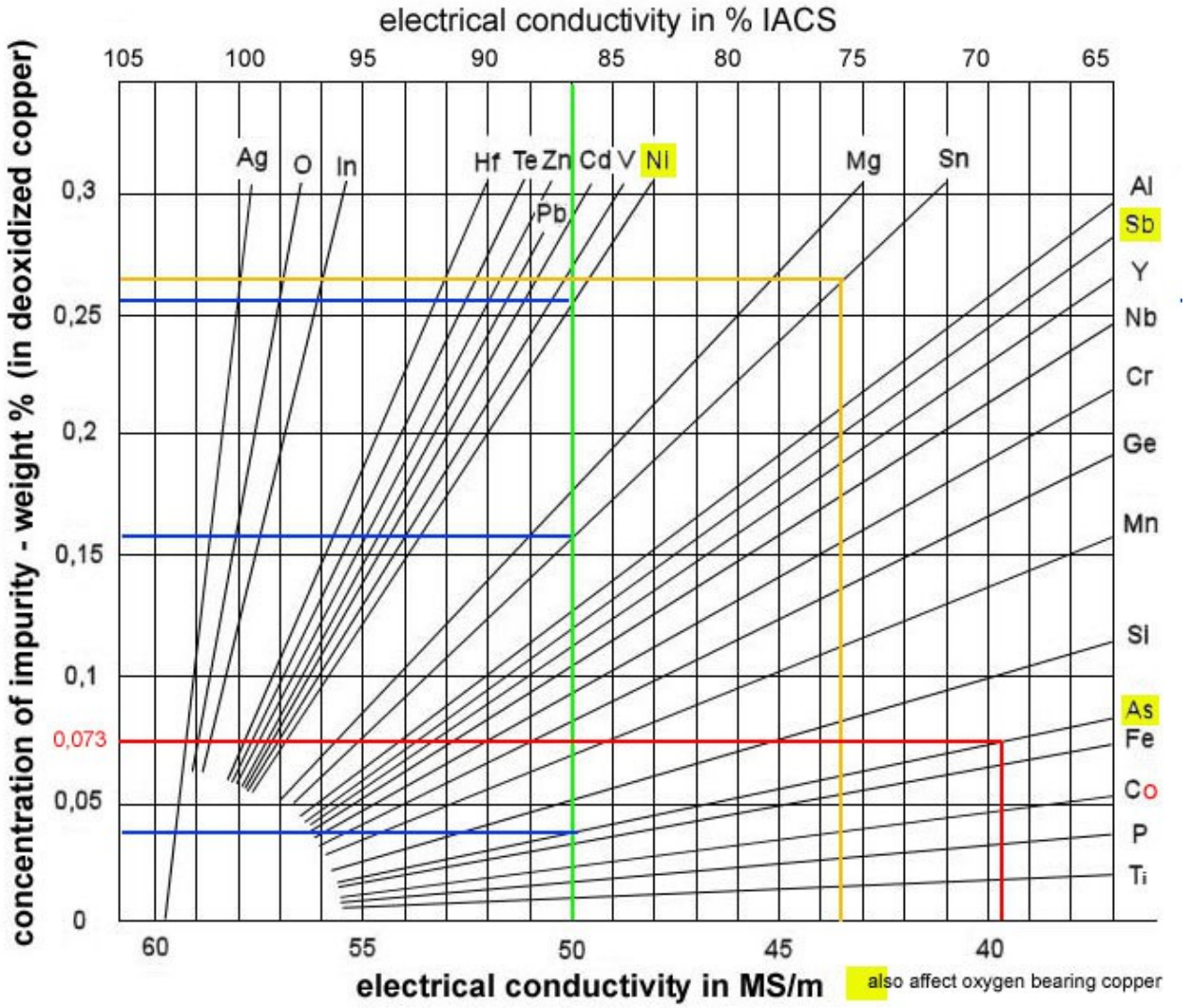



Figure 25, effect of impurities on electrical conductivity of deoxidized copper

**Electrical conductivity (EC) of 20-Heller copper coins**

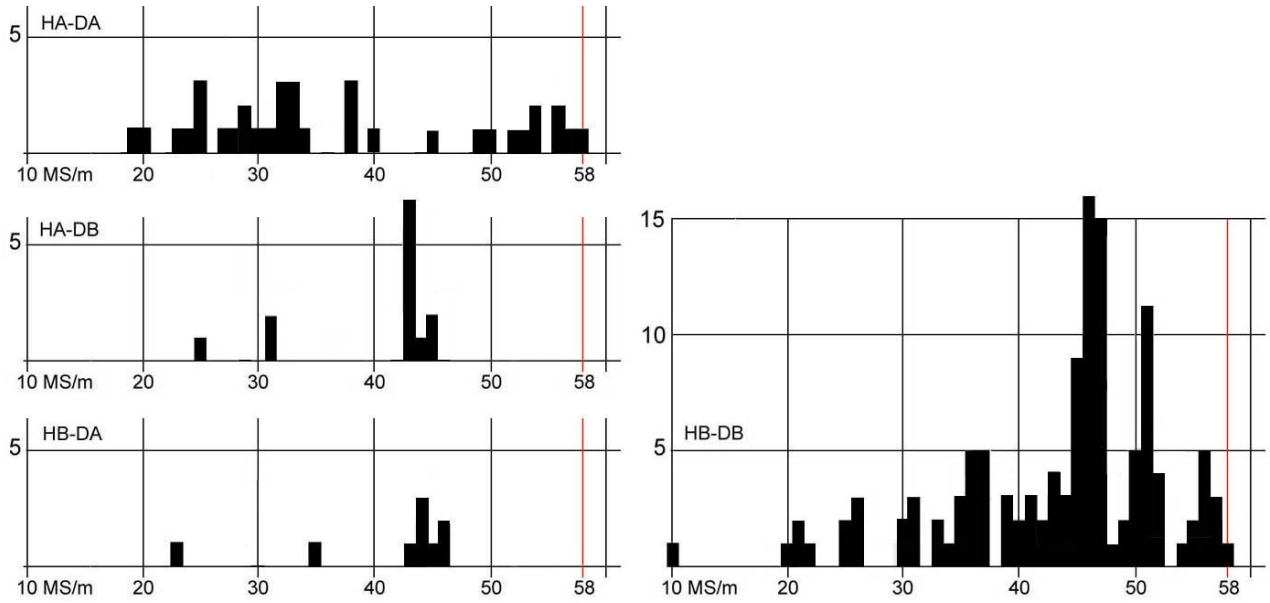



Figure 26, distribution of electrical conductivity of copper 20 Heller coins

Figure 26 shows the results of tests of coins of which the die combinations are known.

Peter Hammer and Guy Franquinet give in their article EC values of 39 unspecified coins, of which 14 with EC between 20 and 45 MS/m, 1 with EC of 51 MS/m and 1 with EC of 55 MS/m.
Another series of tests by Franquinet of 208 coins rendered 4 J724 – HA-DA with EC between 20 and 50 and 2 with EC of 50 or more and 25 J727 – HB-DB with EC between 20 and 50 and 11 with EC of 50 or more.
208 – 6 – 36 = 166 had EC below 20 MS/m. EC of individual coins was not specified.
Kahnt, Münzen und Sammeln 2008 nr 2 page 67, Deutsch-Ostafrika (DOA), 20 Heller, Münzstätte Tabora, mentions a dealer's stock of 243 pieces tested on EC with a Sigmatest D produced by Institut Dr Förster. On the total of 243 there were 6 J724 – HA-DA, of which 2 with EC between 20 and 50 and 1 with EC of 50 or more, 20 J725 – HB-DA, of which 2 with EC between 20 and 50, 4 J726, of which 2 with EC between 20 and 50 and 213 J727 – HB-DB , of which 68 with EC between 20 and 50 and 21 with EC of 50 or more.

Tested copper J724a – HA4b-DA10a-Cu, J725a – HB5z-DA9c-Cu and J726a – HB4d-DB3b-Cu, of which pictures are available, are known from only one specific die combination each.
Being rarer types, more RFA from different sources may be expected for these combinations than for specific J727a – HB5-DB3-Cu combinations.
No tested brass HA4b-DA10a are known, all are copper.
One picture (figure 27) is known on which a HA4b-DA10a looks quite convincingly to be (and was offered as) a brass one, as does the one bottom left, which was offered as (and most probably is) copper.



Figure 27, possibly brass HA4b-DA10a

A rough estimate of the amount of J725a – HB5z-DA9c-Cu and J726a – HA4d-DB3b-Cu produced would be 12.000 coins. Taking 900 blanks from a square meter, 14 square meter of plate thick 2 mm (= 7 plates 1 x 2 meter) would have been sufficient to produce these coins. As HA4d-DB3b was preceded by four die related die combinations for which no copper coins are attested, it is probable that the first copper coins were largely struck on this low tin copper by HA4d-DB3b and HB5z-DA9c die-combinations.

A coin scoring 62 MS/m did so only on certain spots of the coin. It shows EC measured does not allways corresponds to the material tested.
Also EC measured on one side of a coin may differ several MS/m from that measured on the other side.

CuZn5, brass with 5% zinc Messing/CuZn5.pdf would have a EC of around 33 MS/m, density 8,86 gr/cm3, CuZn15 CuZn15 EC more than 18 MS/m, density 8,75 gr/cm3.
One coin 121768 tested 4.5% zinc, 0.35% tin, EC 16 MS/m, density unknown. Most probably this coin will have more zinc inside, although the coin was tested on a filed part of the rim. It seems improbable that a piece of copper did get brass or zinc clad while being annealed. This coin is a HB5b-DB3e. Three tested copper HB5b-DB3e scored EC 45.3-46.2 MS/m. Seven other brass HB5b-DB3e tested rendered 27.6 to 35.2% zinc but no tin.

Some coins tested between 15 and 20% zinc. There are no reasons to believe that this was also their original zinc content. One of the reasons we find less zinc could be selective leaching wiki/Selective_leaching

Modern CuSn1,3 Datasheet contains 1 to 1,7% tin and some phosphor, indicating that it is oxygen free. EC more than 20 in soft condition, density 8.9 gr/cm3.
No coins containing more than 0.4% tin were found with XRF

Aluminiumbronzes kupferinstitut.de with less then 2% aluminium would have EC of more than 15 MS/m and density over 8.6 gr/cm3.

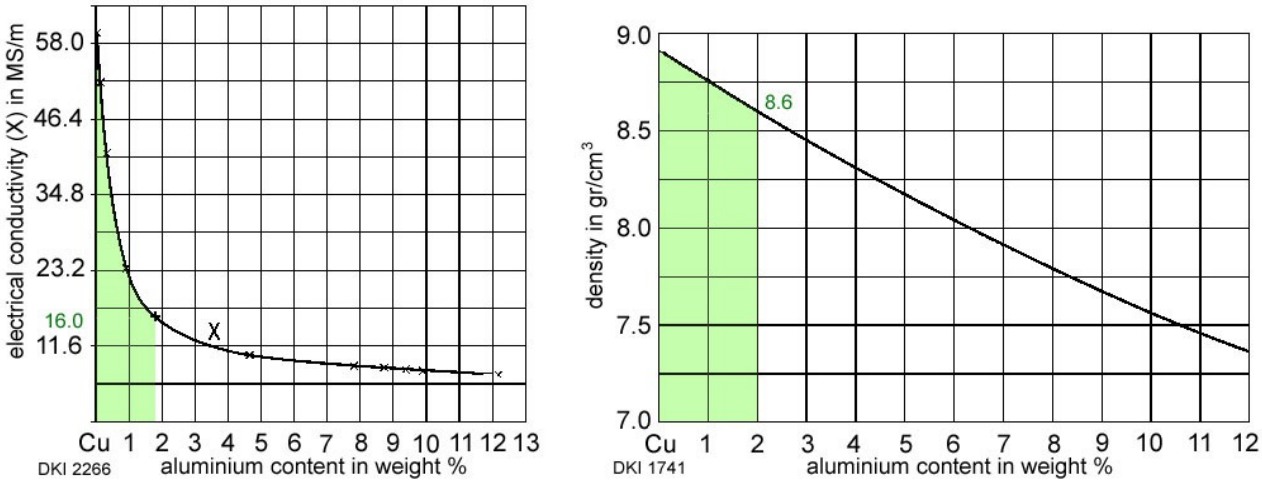



Figure 28, density and electrical conductivity of aluminiumbronzes

Aluminium and silicon are the main ingredients of external pollution of the surface of the coins. XRF indicating 6.5% aluminium and 8.0% silicon is found on a coin testing 58 MS/m. Comparing XRF results for aluminium and silicon on copper coins with those for brass HB5-DB3 there are no indications any of the tested copper coins might contain aluminium.

Most surprsingly one HB5l-BB3l-Cu scored only 10.6-9.4 MS/m.




H-side 10,6 MS/m D-side 9,4 MS/m

X-ray fluorescence analysis

elements analysed, zinc and bismuth probably not correct (to high)

| | Cu[%] | Zn[%] | Sn[%] | Ni[%] | Fe[%] | Pb[%] | Ag[%] | As[%] | Co[%] | Sb[%] | Bi[%] | Cd[%] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 99.25 | 0.030 | - | 0.071 | 0.060 | 0.025 | 0.016 | 0.534 | - | 0.033 | 0.016 | - |
| | 99.30 | 0.042 | - | 0.071 | 0.164 | 0.024 | 0.015 | 0.356 | - | 0.017 | 0.029 | 0.006 |
| H-side | 99.05 | 0.038 | - | 0.069 | 0.179 | 0.035 | 0.013 | 0.557 | - | 0.053 | 0.033 | - |
| | 98.50 | 0.108 | - | 0.063 | 0.095 | 0.035 | 0.019 | 1.124 | - | 0.036 | 0.022 | 0.007 |
| | 98.72 | 0.083 | - | 0.082 | 0.117 | 0.042 | 0.031 | 0.907 | - | 0.010 | 0.013 | 0.006 |
| D-side | 98.69 | 0.085 | - | 0.078 | 0.180 | 0.069 | 0.020 | 0.853 | - | 0.022 | 0.020 | 0.003 |

Figure 29, X-ray fluorescence analysis of low electrical conductive copper coin

XRF analyses on six spots rendered copper 98.50-99.30%, arsenic 0.36-1.12%.
Density is 8,85 gr/cm3.
The high arsenic content of this coin can't in itself explain the sinking of EC to such a low level. According to the graph below, borrowed from Über die Leitfähigkeit der Legierungen by W. Guertler, published in Metallographische Mitteillungen aus dem Institut für

anorganische Chemie der Universität Göttingen XXXVII, nearly 3% arsenic would be needed to diminish EC to 10 MS/m, if only that metal was involved.

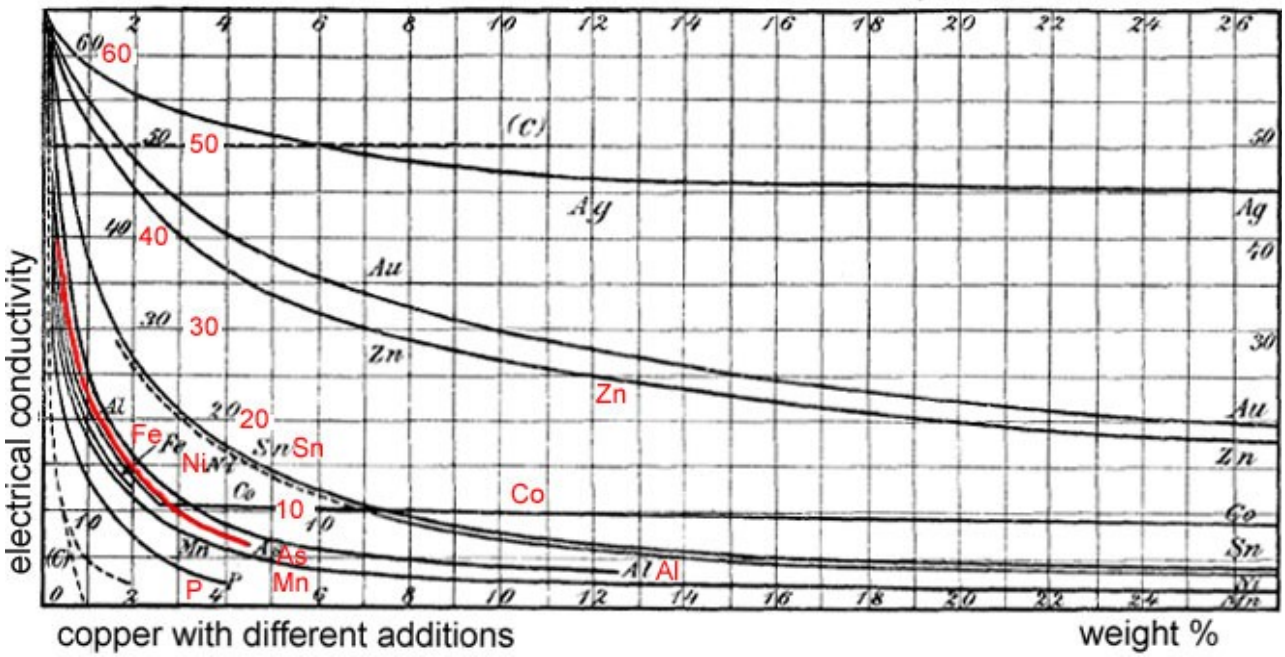



Figure 30, influence of alloyed metals on electrical conductivity of copper alloys

Tests of four other HB5l-DB3l coins revealed that two of them also contain arsenic (0.09%, EC 42.3-43.3 MS/m and 0.2%, EC 39.9-40.3 MS/m respectively). The third coin contains 0.3-0.4% tin and 0.2% zinc, EC 42.5-43.0 MS/m and the forth rendered an EC of 55.3-56.6 MS/m.

**PGAA**

A beam of neutrons from a nuclear reactor is directed at an object. If a neutron hits the nucleus of an atom in the object this results in gamma radiation which is specific for the hit atom. Kernchemie



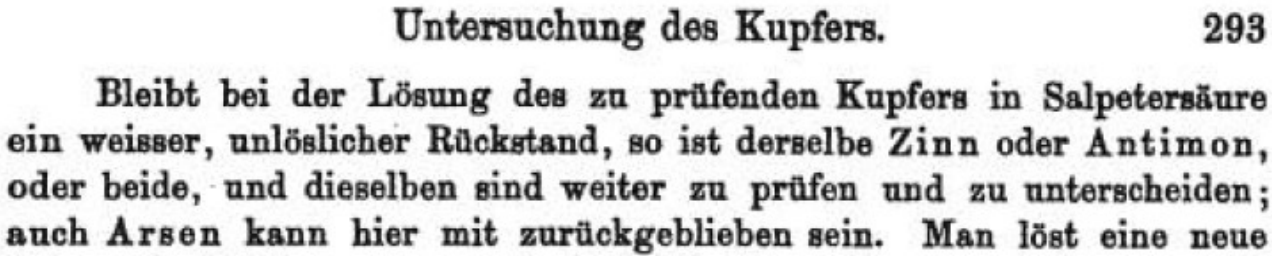

Figure 31, HB5o-DB3o (left) and filed HB5k-DB3k tested with PGAA

Two coins were tested January 16th 2014 by PGAA with surprising results. The two coins were chosen because, on XRF testing in 2012, one, a HB5o-DB3o, EC 37.9-38.5 MS/m, had shown 0,3-0,4% tin and the other, a HB5k-DB3k, EC 38.7-38.8, before and after filing on both sides, 100% copper (measured erroneously with a program that did not render minimal amounts of materials below certain limits, e.g. 0.3% for lead).
PGAA results seemed to confirm that RFA is a lousy way to test copper 20 Heller coins. According to PGAA the coin with 0.3-0.4% tin contained 98% copper, 2.3% tin and 0.7 ppm cadmium, the filed coin 97% copper, 2.5% tin, 26 ppm cadmium, 130 ppm chlorine. It was suggested that chlorine could be caused by sweaty hands.
Hard to live with, this outcome was hard to deny.

June 2014 the coins were tested again with an Olympus Delta XRF analyser, that could detect aluminium, silicon, phosphor and sulphur. The first coin rendered 0.29-0.37% tin and large amounts of what must be surface pollution. The second, filed, coin, showed (H-side/D-side) 99.69-99.69% copper, 0.07-0.08% lead, 0.13-0.10% silicon, 0.09-no% nickel, no aluminium, sulphur or phosphor.
January 2015 the filed coin, after being filed anew with a Diapad, was analysed again on three spots with the same machine with different types of radiation . The result was this time copper 98.69-99.37-99.41% copper, 0.04-0.04-0.04% lead, 1.11-0.53-0.46% silicon, 0,07-no-no% iron, 0.04-0.06-0.09% nickel, no aluminium, phosphor or sulphur. The Diapad, with an abrasive surface made of carbon, was not analysed, but experience learns contamination of material through filing instruments is not impossible.

**Chemical analysis**

A way out of the dilemma, whether PGAA or XRF was wrong, was found in Die Probierkunde by Carl A,M, Balling books.google where a simple chemical test is provided to prove the presence of tin in a copper alloy. If copper is solved in concentrated nitric acid, tin, antimony and maybe arsenic will fall out, as the tin and antimony oxides that form are insolvable in water.



Untersuchung des Kupfers. 293

Bleibt bei der Lösung des zu prüfenden Kupfers in Salpetersäure ein weisser, unlöslicher Rückstand, so ist derselbe Zinn oder Antimon, oder beide, und dieselben sind weiter zu prüfen und zu unterscheiden; auch Arsen kann hier mit zurückgeblieben sein. Man löst eine neue

Figure 32, test for tin in copper, from Die Probierkunde by Carl Balling

Just as preliminary test were made, a call made with Garching learned that the PGAA installation had been closed for a considerable time, because it had been contaminated with indium, the signal of which was very simular to that of tin and might well have caused a misreading. Such things may happen, pitty that those whose research is thus contaminated are not warned something may have gone wrong as soon as the problem becomes clear.
In the preliminary test a 10 eurocents coin (weight +/- 4.1 grams, 1% tin), two old Dutch cents (together +/- 4.0 grams, +/- 4% tin), half of a filed HB5l-DB3l (3,33 grams, XRF arsenic 0.17-0.21%, tin less then 0.04%, EC 35 MS/m) and an uncleaned HB5h-DB3i (10.98 grams, XRF +/- 0.1 iron, 0.1 nickel, arsenic not tested, EC 45 MS/m) were solved in nitric acid.
Next day a white sludge had been deposited at the bottom of both the glass container with the solution of the 10 eurocents and that with the Dutch cents. In the containers with the 20 Heller coins only a miniscule half moon of black particles had been deposited, in the container with the HB5h-DB3i surrounded by a faint halo of white stuff.
The white stuff of the Dutch cents solution was separated and dried. XRF confirmed it to contain tin. The black stuff from the HB5h-DB3i was also separated and dried, but the fluid that was dried with it contained still to much copper nitrate. Copper nitrate is so hygroscopic that the dried stuff had become fluid again by the time it could be XRFed. The thickness of the glass it had been dried on did prohibit proper XRF. Later this problem could be solved by adding water and separating again.

In the final chemical tests half of the filed HB5k-DB3k PGAA tested before in Garching (weight 5.24 grams), half of another HB5o-DB3o than the one tested in Garching, but also

with about 0.35% tin according to XRF, EC 45.6-47.9 MS/m (weight 4.14 grams) and again a 10 eurocent were solved in nitric acid.
In the solution of the 10 cents again a white substance did deposit. The solution of the HB5o-DB3o coin stayed cristal clear at first. However after more than a week a thin layer of white stuff formed at the bottom. No white stuff appeared in the container with the half HB5k-DB3k, just the same miniscule black half-moon as seen in the preliminary tests was formed.
The white stuff from the HB5o-DB3o was separated and dried. The total dry weight is 0.017 grams. At a ratio between weight of tin dioxide and tin of 150/118, the 0.017 grams of deposit would correspond to 0.0134 grams of tin. That again corresponds to 0.32% of the original weight of 4.14 grams. This corresponds pretty well to the XRF results of 0.35% tin.
Also the black stuff that rested of the PGAA HB5k-DB3k coin was extracted and dried. Total dry weight is 0,008 grams. Some of this will be copper nitrate that was solved in the extracted fluid.

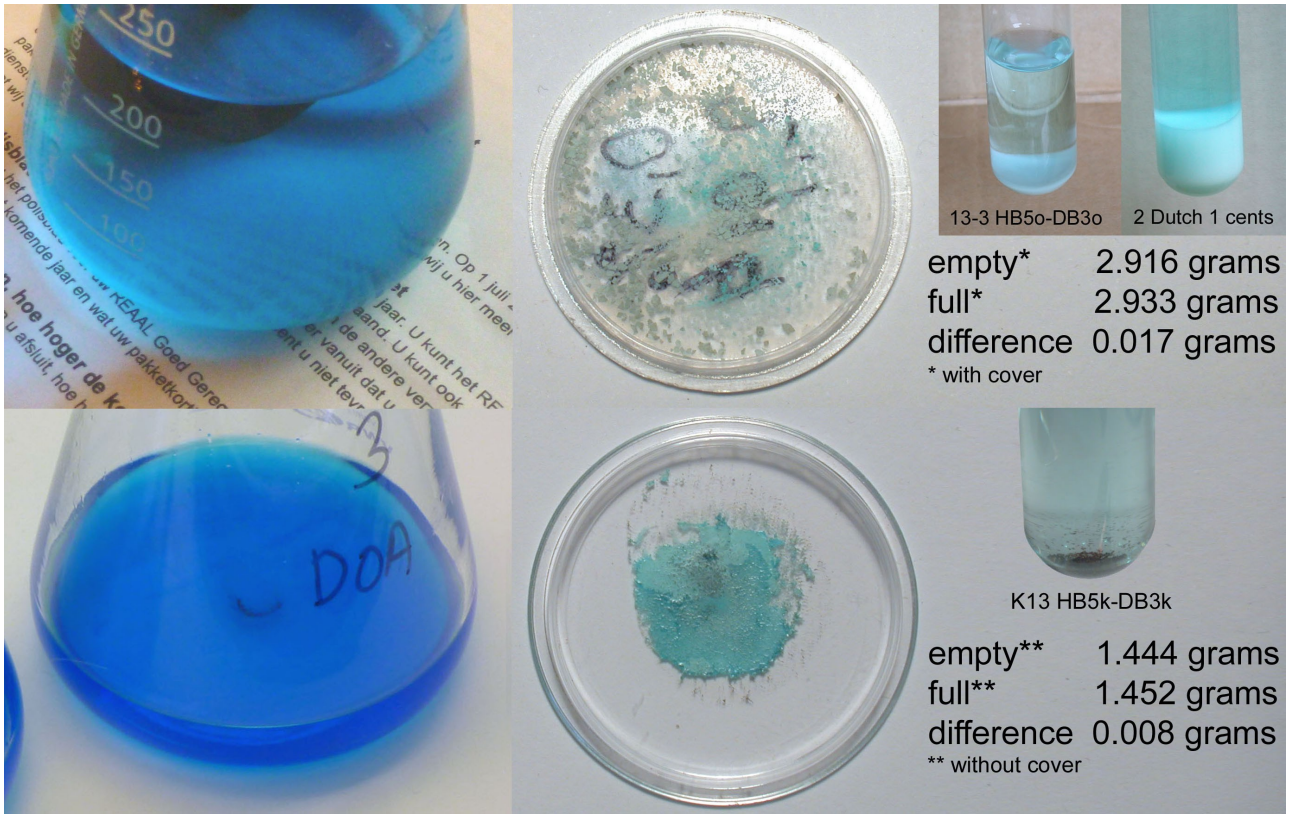


Figure 33, residues of the solved HB5o-DB3o and PGAA HB5k-DB3k copper coins

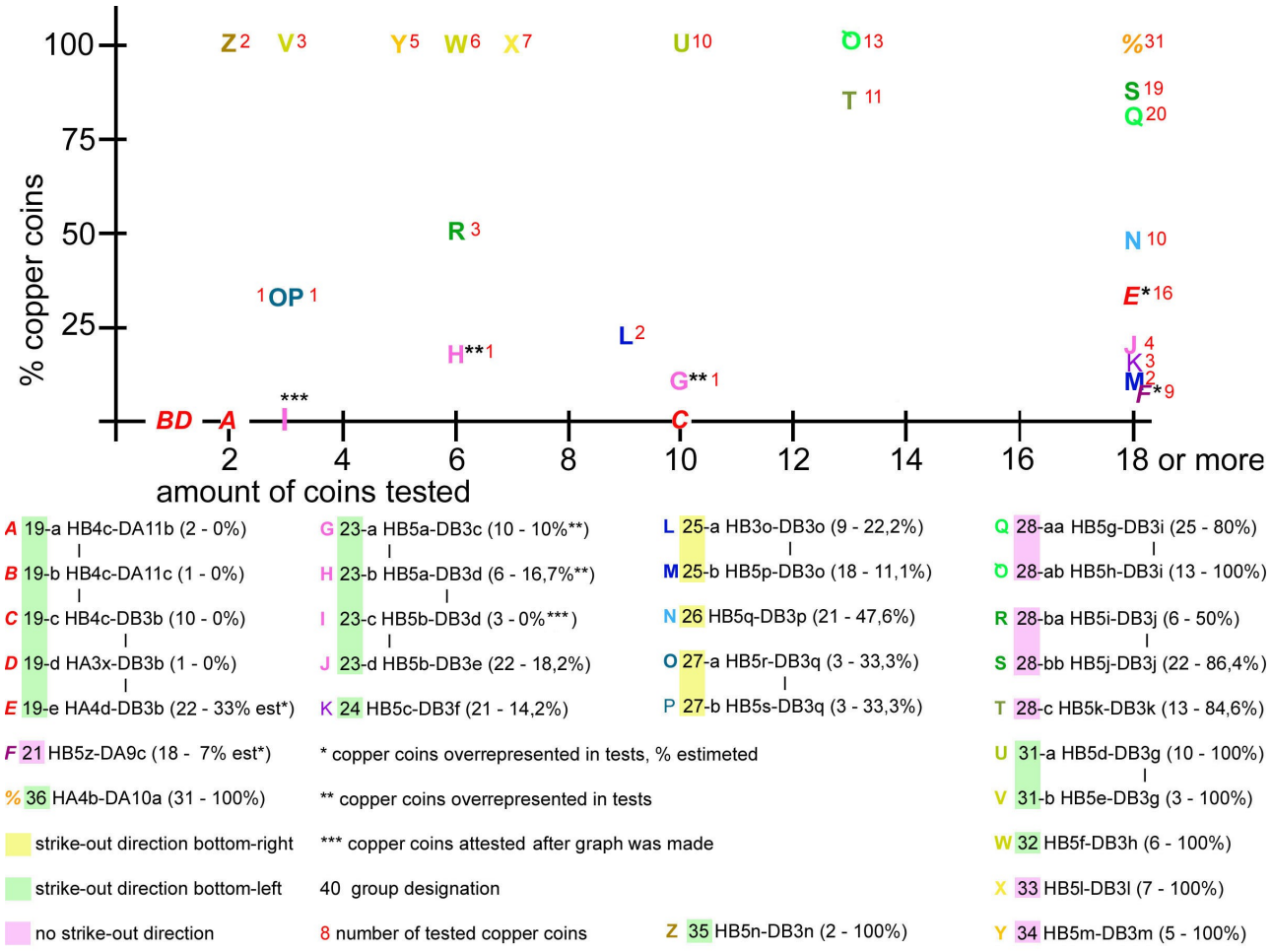
The 0.008 grams corresponds to 0.15% of the original weight of 5.24 grams of the solved coin.

May 1, 2016 at the Hannover Coin Fair, the remains were tested using a hand held XRF analyser. A large part of the results exists of unidentified elements with low atomic numbers from the plastic containers. The opened container with the remains of 13-3 HB5o-DB3o was accidently held upside down before being tested, resulting in the loss of +/- 40% of the material.
It was remarked by the people handling the machine that the following results are not accurate and should be regarded more as an indication of which elements are present.
– Dutch cents: tin 6.36%, copper 1.79%, other elements less than 0.013% or unidentified.
– HB5h-DB3i: copper 3.06%, nickel 0.094%, iron 0.048%, zinc 0.031%, lead 0.021%, no

tin, rest unidentified.
– HB5k-DB3k: copper 1.81%, iron 0.113%, platinum 0,050%, nickel 0.054%, no tin, rest unidentified.
– HB5o-DB3o: copper 0.267%, tin 0.087%, rest unidentified.
The XRF results show that the white deposits indeed contain tin and that where no such deposit was formed no tin was part of the alloy.

The chemical tests show that the results of XRF were valid and that the results of PGAA had been corrupted. There was no tin hidden inside the HB5k-DB3k coin.

**Ratio between copper and brass for different copper-striking die combinations**



Ratio between copper and brass for different copper-striking die combinations

Figure 34, percentage of copper coins struck by different die combinations

Sixteen die combinations are known to have struck copper as well as brass coins, eight combinations seem to have struck only copper coins. Of these sixteen copper-brass combinations ten seem to have struck mainly brass coins and six mainly copper coins Leaving out G, H and I (see below), an estimate based on the above ratios and on the blue figures for die production in the spreadsheet 2015a incl MPO, which may be downloaded from the first entry in praegezahlen-deutsch-ost-afrika-doa-1916 , gives a total of 264.000 copper coins for 100% copper combinations, 121.600 copper and 49.100 brass coins (total 170.700) for the five combinations with a copper-brass ratio over 45% and 39.500 copper and 157.100 brass coins (total 196.600) for eight combinations with copper-brass ratio below 45%.
Overall total for copper coins would then be more than 425.000 pieces, about 29% more

than the total of 330.000 given by Schumacher praegezahlen-schumacher.
G, H, I and the 4 undetermined HB5-DB3 would together account for some 42.200 coins, including some copper ones.

As mentioned before, it may be questioned if the amounts of coins offered nowadays on internet, and the copper-brass ratio of the coins available for testing, are representative for the coins originally produced.

Certain though is that copper and brass coins were produced simultaneously during a considerable period of time. If the figures above are correct a total of 410.000 copper and brass coins produced by the 16 copper-brass combinations would be equal to 92% of the total production of the month of July and be larger than the total production of June.
Thus the impression that the transition from brass to copper had been a swift one, caused by complete exhaustion of brass stocks can't be sustained.

Of most die-combinations not enough full tests of coins are available to allow a suggestion on relations between certain die combinations, based on material properties, other than those already mentioned before.

**Strike-out directions of the dies**

In figure 34 the strike-out direction of the different die combinations is indicated. While the coins were struck the upper die did not only move downwards, but also a little sideways. This second movement left traces on the dies and on the coins. The direction of these traces on the on the H-side of the coins has been defined as strike-out direction. As two machines were used for striking, it might be possible side movement was more pronounced on one of the machines. However nothing usefull has been found to distinguish the these two machines yet.
Copper coins are found with strike-out directions bottom left and bottom right, as well as without a strike-out direction. To change strike-out direction from bottom left to bottom right, in one and the same machine, it would have been necessary to consciously change the way the die axis of the dies in the machine was orientated. Another possibility is that bottom left and bottom right were struck on different machines.
To understand the relation of strike-out direction with die combination sequence more study will be needed.

**Conclusion**
According to our results there are no indications that non-brass 20 Heller coins were struck on other material than more or less pure copper, some of which may be designated arsenical copper that would have complied to contemporary British Standards for tubes and railway applications.
Coins with about 0.3% tin are characteristic for copper HA4d-DB3b and HB5z-DA9c and are found only sporadically for other die combinations. Possibly this copper is recycled copper containig traces of solder. Coins from both die combinations probably belong among the first copper coins struck. Near simultaneously the production of the extensive HB5-DB3 series may have been started.
Electrical conductivity below 50 MS/m of some of the copper coins can't be fully explained by X-ray fluorescence test results. Probably their material is (phosphor) deoxidized copper.

Distinguishing between more or less pure copper with different kinds and amounts of impurities seems of little numismatic interest, except for the possibility of confirming falsifications in those cases where for some die combinations exact impurity compositions

might be established. As yet the existence of HA-DB and HB-DA coins with EC over 50MS/m could not be confirmed.

The transition from the striking of only brass to only copper coins could have taken about one month, supposing the striking of only copper coins took place near the end of the production period of 20 Heller coins.

A rough estimate of the total mintage of copper coins would be between 395,000 and 455,000 coins.

**Distinguishing copper and brass 20 Heller coins**

**Using your eyes**

Using your eyes is in most cases the simplest way to distinguish copper and brass.
If it looks like brass it most probably is brass.
For normal coins, if it really looks like copper it most probably is copper. If you doubt, look in the list below. If it is not conform the list or is a really rare type, consider testing.

HB-DB – J727 – KM 15/15a-B-B
No tested copper coins are known for die combinations with HB0 through HB4. It can not be excluded that such copper coins exist, but they must be vary rare. Please inform if you find one that survives testing.



Figure 35, characteristics of HB5-DB3

Copper coins are known for all HB5-DB3 die combinations. If you want to be sure buying a copper HB5-DB3 for your collection, choose one that looks like copper and there is little chance you will be mistaken. HB5 is easily recognized by the slender shape of the first leaf from the top at the outside of the left twig, DB3 by the missing part of the right lappet of the crown which makes it look like there is a small bulb at the bottom.
There is little harm in trusting your eyes, as there is little difference in value between brass and copper coins. It are mostly the less well preserved examples that pose a problem to differentiate between brass and copper and you could stay away from them. If you are in doubt about such a coin you own already and you really want to know, you could either put

it to one of the tests mentioned below, or scratch a little bit with a sharp knife at the edge. Rub the yellow or red spot with sweaty hands and after a few days in open air you will have difficulty to find the spot.

HA-DA – J724 – KM 15/15a-(A/C)-A
No tested brass coins are known for HA4b-DA10a coins photo=62395 . It can not be excluded that such brass coins exist, but they must be very rare. Please inform if you find one that survives testing. As HA4b-DA10a coins are easy to recognize and hard to confuse with other die combinations, there is little reason for further testing.
No tested copper coins are known for any other HA-DA combination. It can't be excluded that such copper coins exist, but they must be very rare. Please inform if you find one that survives testing.

HA-DB – J726 – KM 15/15a-(A/C)-B
Tested copper coins are known only for HA4d-DB3b at a very specific stage of die wear photo=63522 . Buying an untested copper looking coin of this die combination with the right characteristics might be called an educated guess, but still is a kind of gamble. Please inform of any positive or negative tests for copper of HA4d-DB3b.
No tested copper coins are known for any other HA-DB combination. It can not be excluded that such copper coins exist, but they must be very rare. Please inform if you find one that survives testing.

HB-DA – J725 – KM 15/15a-B-A
Tested copper coins are known only for HAB5z-DA9c at a very specific stage of die wear photo=69131 at which also brass coins were struck photo=158970 . Buying an untested copper looking coin of this die combination with the right characteristics might be compared with educated gambling at an outsider at horse racing, high risk – high profit. Please inform of any positive or negative tests for copper of HB5z-DA9c.
No tested copper coins are known for any other HB-DA combination. It can't be excluded that such copper coins exist, but they must be extremely rare. Please inform if you find one that survives testing.
Buying a HB-DA a market price without proper testing must be considered foolish.

**Testing**

Copper and brass can be distinguished by differences in density wiki/Density , EC and XRF.
As seen above the properties of the material which we find when we test the coins do not allways correspond to the properties as described for this material in the textbooks. The range of values we find is larger then we would like. Sometimes they even overlap for the two materials we like to distinguish.

Further complicating is the fact that some other materials, like bronze with 5% tin or brass with 5% zinc, that might have been used, would, upon testing, fall into the same range of values, if only one or two properties were tested. Reassuring fact is that coins struck on these materials, if they exist, must be extremely rare. Their occurrence will be limited to one or two die combinations. These combinations can be further researched if ever a coin is without doubt positively tested for one of these materials.

A special case are forgeries like copper plated brass coins, electrotypes, cast copies, manipulated real coins and struck Chinese copies. When skilfully done, they could fool any of the testing methods described here. Luckily these will stay exceptions as it would be by

far easier to forge other coins.

**Density**

For our purposes it suffices to describe density as the weight of one cubic centimeter (cm3) of an object. Distilled water of four degrees Celsius has a density of 1 gr/cm3. If you measure the weight of an object submerged in distilled water of four degrees Celsius its weight will be 1 gr/cm3 less per cubic centimeter than its weight outside of the water. The amount of cubic centimeters can thus be calculated by subtracting the weight below water (WB) from the weight above water (WA). Density (D) is then calculated by dividng the weight above water by the amount of cubic centimeters: D = WA / (WA – WB) gr/cm3

Density measurement is a simple and quick way to distinguish between copper and brass. All you need is a scale at least 0.001 grams accurate and a device to measure a coin both dry and immersed in water incl-dichteset (Kern EMB-200-3v inclusive density set - 459 euro tax incl.). Even more accurate analitical scales, with the same features, would be less 1500 euros. Most density measurements referred to here were done with a self build density set, which could be attached to a hook at the bottom of the scales, which saved 234 euros.



Figure 36, density measurement of a 20 Heller coin

Looking at the amount of money auctioneers earn on any coin they auction, it is near criminal that they don't check the density of the 20 Heller coins they offer as copper.

Peter Hammer gives a fine description of density measurement and its problems in: Dichtebestimmung von Edelmetallegierungen nach der Auftriebmethode und die dabei auftretenden Fehler (Uhren und Schmuck 6/1987, pages 182,183 &185).
Some errors are inherent to the inaccuracy of the scales and variety in water density. For scales 0.001 accurate and an object of 10 grams the error could be in the order of 0.01 gr/cm3. An air bubble of 1 kubic mm inside this object or adhering to it would lower measured density with 0.01 gr/cm3. Calculating with a density for water of 1 gr/cm3 while measuring in water of 22 degrees Celsius results in a seemingly 0,02 gr/cm3 higher density for this object.
As the margin between the density of the two materials considered here is in the order of 0,45 gr/cm3 this kind of possible errors may be neglected.

In Vergleichende Dichtemessung von Münzmetallen [Münzen & Papiergeld (7+8/2001, pages 75-76) results are presented of density measurements done by 3 persons who each measured the same object 3 times.

| | 1-1 | 1-2 | 1-3 | average | 2-1 | 2-2 | 2-3 | average | 3-1 | 3-2 | 3-3 | average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copper disk | 8.904 | 8.890 | 8.895 | 8.896 | 8.977 | 8.889 | 8.854 | 8.907 | 8.906 | 8.944 | 8.903 | 8.918 |
| CuZn37 disk | 8.647 | 8.619 | 8.648 | 8.638 | 8.646 | 8.813 | 8.523 | 8.661 | 8.676 | 8.674 | 8.681 | 8.677 |

Figure 37, extract from Vergleichende Dichtebestimmung von Münzmetallen

If we leave out lowest and highest values for copper and brass, which differ 0.123 and 0.290 gr/cm3, second highest and lowest differ 0.054 and 0.062 gr/cm3. Although the brass disk has CuZn37 punched into it, it may be doubted if it really is CuZn37, as commercial data sheets on CuZn37 give densities of 8,4-8.45 gr/m3.
The value of 8.813 gr/cm3 for CuZn37, given at 2-2, must be due to a mistake in reading of the weights or calculation of the density. If using density measurement for testing it should thus be remembered that measured values are not absolute and that care must be taken in performing the test. If in doubt, testing could be redone, or one of the other test methods could be used for confirmation.

Hammer and Franquinet zeno.ru show densities of 16 copper and 23 brass coins. The range of the density of the brass coins is 8.311 to 8.544 gr/cm3.
Balke (Die Notmünzen von Deutsch Ostafrika, Moneytrend no. 3, 1988), testing 14 brass 20 and 5 Heller coins, found densities between 8.083 and 8.574 gr/cm3.
Interestingly there seems to be little correlation between density and EC in Hammer and Franquinet's coins or between density and zinc content (16-31%) in the coins tested by Balke.
In the figure 37 below the results for brass from both sources are presented. Both graphs show the measured value of density which are considerably lower than might be expected based on figures obtained from data sheets for different brasses.
Although Hammer and Franquinet didn't publish pictures of the coins they tested, it may be presumed that the two coins with density over 8.50 gr/cm3 were LHH coins (low zinc content around 25%, high EC and high density).
Balke published pictures of seven of his nine 20 Heller brass coins. Something has gone wrong with the coin left in the last row on page 17. The coin is a J727 – HB5r-DB3q, but description says J726b with a density of 8.57 gr/cm3. The same description is found below the coin at the right side of the row above, which is indeed a J726, struck by HA(C)1c-DB3v die combination, which combination did strike LHH brass coins.
In the table at page 14 only one brass J727 is mentioned, with a density of 8,495..
On average, Balke's coins have a low zinc content.

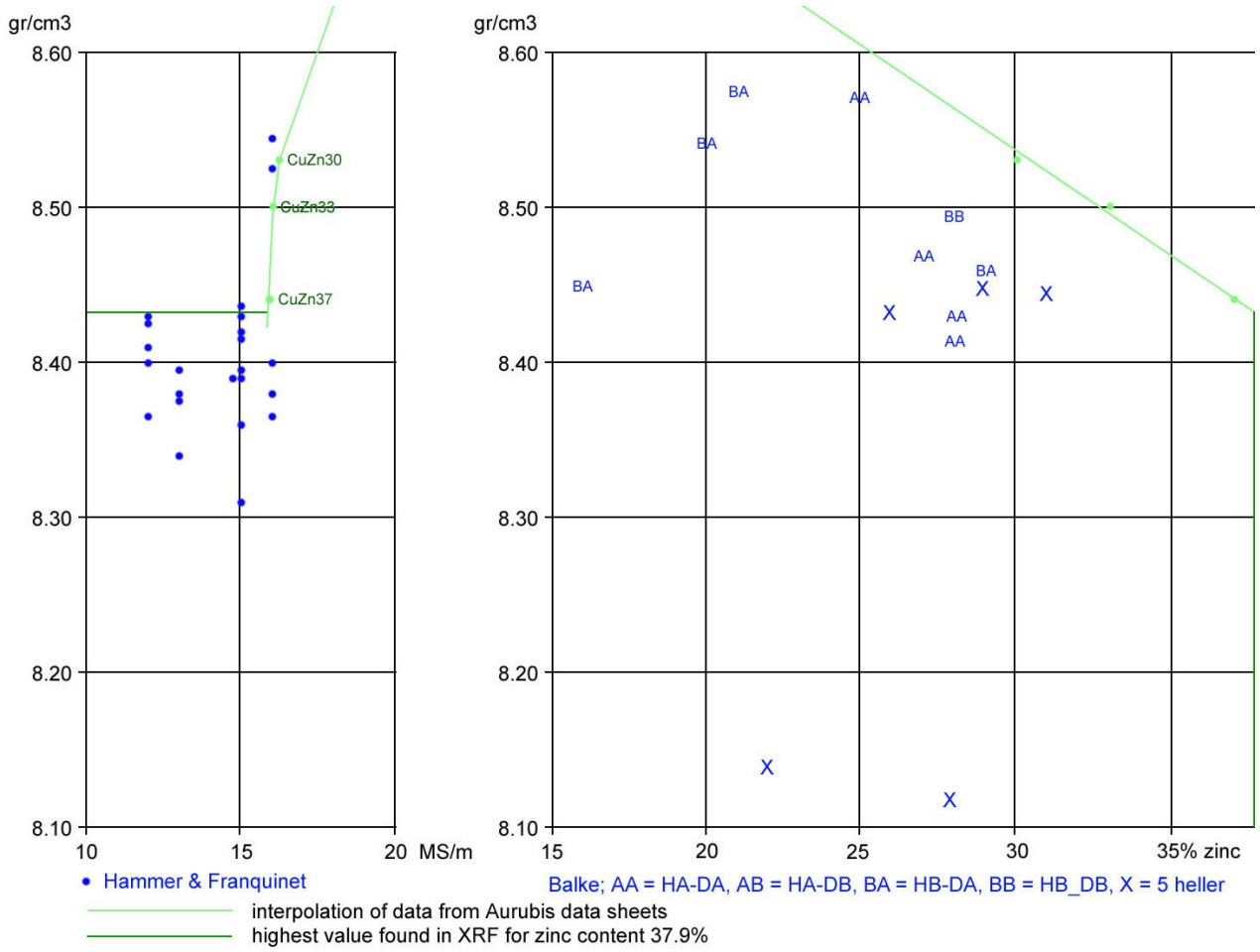



Figure 38, density and EC or zinc content from Balke and Hammer & Franquinet

The results of tests of density of 20 Heller coins by Kees Uitenbroek show the same type of results as presented in figure 38 above. For brass HB5-DB3 coins densities from 7.95 (a very dirty coin) to 8.45 gr/cm3 are found. For non-LHH brass HA-DA, HA-DB & HB-DA from 8.15 to 8.46 gr/cm3 and for idem LHH brass (EC over 16.0, 11 coins) from 8.46 to 8.55 gr/cm3.

As yet no 20 Heller brass coin has been attested with a density over 8.574 gr/cm3.

Balke's seven copper coins tested between 8.869-8.929 gr/cm3. Hammer and Franquinet's sixteen coppers: density once 8.804 gr/cm3, rest 8.857-8.965.
wiki/Copper gives 8.96 gr/cm3 as density of copper.
Kees Uitenbroek's 120 tests of copper coins rendered values between 8.73 and 8.93 gr/cm3.




Figure 39, low density copper coins

Immersed in water it looked like the surface layers of some coins were water repellent and a very thin layer of air had formed on them. Another dirty coin, left on photo=60965 EC 56.0-56,3 rendered density 8.76. The coin left on photo=61275 combines low EC 20.6-21.5 MS/m (arsenic 0.4%) with low density 8.74-8.79 gr/cm3. In total 18 out of 120 scored 8.80 gr/cm3 or lower.

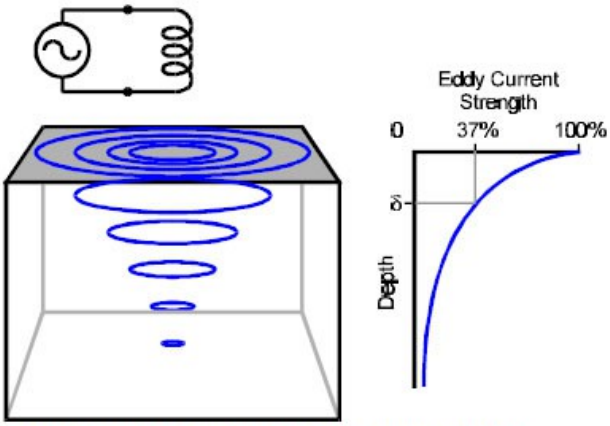
Where no brass coins with density above 8.57 gr/cm3 are known and with no density lower than 8.73 gr/cm3 for 143 copper coins it seems safe to say: 20 Heller coins with density below 8.60 are most probably brass and those with density above 8.70 are most probably copper.

For a quick scan the method described on gold-test.de/pruefung could be used. A mistake made there is that the volume of the thread below the surface of the water is not subtracted from the total volume measured to get the real volume of the object. This could be overcome by hanging a small container on the thread, in which to place the coin after the scales have been set on zero. Using scales of 0.01 accuracy introduces a possible error in the order of 0,05 gr/cm3. Much care should be taken no water escapes while performing the test in this way.

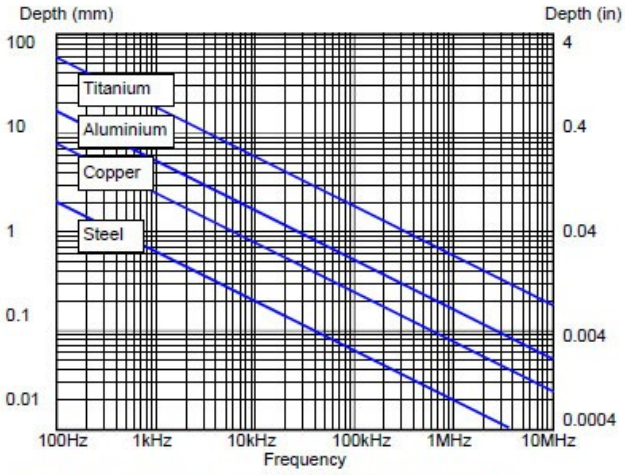
**Electrical conductivity**
archaeometrie , joe.buckley , zeno

Measuring electrical conductivity is a fast and easy way to distinguish between brass and copper .helmut-fischer. A disadvantage is that the tool is expensive: Alibaba Pulani Electronic current-conductivity-meter wholesale price (min. 5 pieces) $ 3180.- a piece + postage $ 543.72 per order. As with telephones price might be sinking fast: Dalian Teren Industry electric-conduction-meter $ 200-800 ??

For interpreting the results a little knowledge of what you are measuring comes in handy. First of all you are measuring EC of a coin at a certain spot, and this is not necessarily the same as the EC of the material of the coin. By measuring EC of 20-Heller coins you may find different results for different spots on the coin and for different sides of a coin. One of the reasons may be cracks or inclusions of different materials in the coin which disturb the eddy currents in the coin. Also important to know is that EC you are measuring is more influenced by the EC of the surface near to the probe than by EC of material further down.




The eddy current density, and thus the strength of the response from a flaw, is greatest on the surface of the metal being tested and declines with depth. It is mathematically convenient to define the "standard depth of penetration" where the eddy current is 1/e (37%) of its surface value.




effect of frequency on standard depth of penetration

source: http://www.joe.buckley.net/papers/eddyc.pdf

Figure 40, penetration depth of electrical conductivity measurement

Most coins were EC tested with a frequency of 250 kHz, some with a frequency of 60 kHz. Standard depth of penetration for copper at these frequencies would be nearly the same, 0.1 and 0.12 mm.




Figure 41, local differences in electrical conductivity measurements

Some coins show remarkable difference in EC of obverse and reverse, for which no proper explanation has yet been found. At the top of the pictures in figure 40 are data obtained by Guy Franquinet (F), at the bottom the results from tests in July (first row) and August 2015 (second row). July measurements were made with a 6 mm probe at 250 kHz on the crown of the D-side and either H or the top of 2 of the H-side. The coin bottom right was measured on three different places each side, highest values are given. Between the test in July and August the coins top right and bottom left were harshly cleaned with citric acid. In August measurements were done at 60 kHz with a larger probe
As it may be supposed that the alloy of both sides was roughly the same and showed little

local variations when the material was delivered to the mint, there must be other external sources for the differences in EC in one and the same coin. Knowing such sources would help to understand why some copper coins score lower on EC than might be expected in view of the small amounts of alloying elements found in XRF.

Highest EC found for brass coins in a first test series by Franquinet is 18 MS/m for two HB5a-DB3d, one of which contains according to XRF test 31.8% zinc. Three coins tested 17 MS/m: two more HB5a-DB3d and one HB5b-DB3e, zinc content 32.5-34.5%. 16 MS/m was found frequently.
In the second test series July 2015 the 18 MS/m coin with 31.8% zinc rendered EC 16.7-16.4 MS/m and the three 17 MS/m coins 16.4-16.4, 16.4-16.1 and 16.6-16.6. Highest value in the second series was 16.9 for a coin that was given 16 in the first series.
In the first series data had been rounded to whole numbers.

Second lowest EC found for copper is also 18 MS/m, measured by Franquinet. A second test by Kees Uitenbroek rendered 20 MS/m (HB5h-DB3i 61275 top) XRF 99.6% copper, 0.4% arsenic, lead not tested. Retesting July 2015 gave H-side 20.6, D-side 21.5 MS/m. Density 8.74-8,79 gr/cm3.
Another coin (HB5m-DB3m 73929 middle) with EC 20 MS/m (July 2015 19.7-19.8) showed in XRF 99.3% copper, iron 0.1, arsenic 0.6, lead not tested. Density 8,86 gr/cm3
Hammer and Franquinet found one coin with EC 20 MS/m, density 8.804 gr/cm3
The extremely low value of 10.6-9.4 MS/m for the copper HB5l-DB3l (figure 28) still lacks proper explanation.

The number of coins tested on EC makes it possible to presume no brass coins will produce test results of 20 MS/m or more. For results near this value multiple tests on both sides could help to ward off mistakes. If you are still in doubt test density and or XRF.
The one copper coin with EC of about 10 MS/m and three copper coins with around 20 MS/m, of which one was also tested as 18 MS/m don't permit to put a lower limit to the EC of copper coins. If in doubt test density and or XRF.

As shown above values of EC measurement are only reproduceable within certain sometimes rather wide margins, as they may depend on the spot that is measured and the kind of probe that is used.

**X-ray fluorescence analysis**

Performing XRF analyses on tools designed for gold dealers helmut-fischer , olympus is an easy and fast way to distinguish copper and brass. Trouble is to find one, as they are expensive (stock clearing sales lagerverkauf.php NH EDX600plus 8900 euro – 50% (excl. taxes)). If you find one you will have to make sure it will also search for small amounts of all the elements you are looking for.

As it is suspected that +/- 0,3% tin might be part of the alloy of most J725a – HB5z-DA9c-Cu and J726a – HA4d-DB3b-Cu coins, tin content found in XRF could be used as additional verification for these coins. However, of thirteen XRF analysed copper HA4d-DB3b coins at least two contain arsenic instead of tin. One XRF analysed copper HB5z-DA9c with unknown EC contains 0,37-0,40% arsenic. Another non-XRF analysed J725a – HB5z-DA9c-Cu with EC 23 MS/m probably also contains arsenic instead of tin.




H-side 23,9 MS/m D-side 24,5 Ms/m (60 kHz)
H-side 25.4 MS/m D-side 31.0 Ms/m (250 kHz)

X-ray fluorescence analysis
elements analysed, zinc and bismuth probably not correct (to high)

| | | Cu[%] | Zn[%] | Sn[%] | Ni[%] | Fe[%] | Pb[%] | Ag[%] | As[%] | Co[%] | Sb[%] | Bi[%] | Cd[%] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H-side | 99.24 | 0.013 | - | 0.046 | 0.009 | 0.124 | 0.018 | 0.465 | - | 0.015 | 0.085 | 0.011 |
| left | D-side | 99.16 | 0.023 | - | 0.034 | 0.003 | 0.166 | 0.025 | 0.501 | - | 0.019 | 0.096 | - |
| | H-side | 96.42<br>95.16 | 0.034<br>0.045 | 1.479<br>1.877 | 0.005<br>- | 0.028<br>0.035 | 1.248<br>2.049 | 0.062<br>0.065 | 0.701<br>0.742 | -<br>- | -<br>0.010 | 0.035<br>0.027 | -<br>- |
| right | D-side | 99.54<br>99.36 | 0.029<br>0.027 | -<br>- | 0.012<br>0.010 | 0.029<br>0.050 | 0.019<br>0.043 | 0.045<br>0.049 | 0.333<br>0.460 | -<br>- | -<br>0.007 | 0.020<br>0.014 | 0.002<br>- |

Figure 42, two arsenical copper HA4d-DB3b

According to the data of figure 42 the H-side of the second coin seems to be covered by a layer of tin, lead and arsenic of uncertain origin.

The major advantage of XRF over the other methods is that low zink alloys like CuZn5, or other alloys of which it is presumed they were not used, could be detected. This keeping in mind that, to accept that the XRF reflects the real alloy of the coin, EC and density would have to comply to the standards of such an alloy. Even so, as these values for copper and CuZn5 are very similar, the possibility of surface contamination with zinc (or any other material in similar alloys) would have to be contemplated.

Disadvantage of RFA is its very low penetration depth. Copper plated brass coins and electrotypes would easily pass testing. One coin tested with RFA rendered 4,5% zinc. The EC of 16 MS/m of this coin shows this seeming composition of the coin must have been caused by leeching of zinc from the surface of the coin, since EC of an alloy of copper with 5% zinc would have been 32 MS/m.

**Sound**

Lack of sound would reveal electrotypes.

Acoustic microscopy wiki/Acoustic_microscopy might reveal inhomogeneities in coins like air bubbles and doubling. One coin tested with an ultrasonic flaw detector olympus didn't show irregularities. More experiments would be needed to see if this method might find something to explain low EC of some coins.

**Conclusion**

With some knowledge of die combinations that produced copper 20 Heller, visual inspection will be sufficient in most cases for J727a – HB5-DB3-Cu and J724a – HA4b-DA10a-Cu coins. If there is no match between what you see and what you might expect, further testing can be done.

If you suspect a J726 – HA4d-DB3b to be made of copper you might trust your eyes if the coin exactly conforms to the state of wear to be expected and the colour is a nice red-brown, or test the coin on density or EC. Testing of course is always better, but also a lot of

trouble if you don't have the right equipment.
If you suspect a J725 – HB5z-DA9c to be made of copper and the coin exactly conforms to the state of wear to be expected and the colour is a nice red-brown you still will have to test on density and better still test on EC and/or XRF too to be absolutely sure. Be aware that even then a good forger could have found a way around all three testing methods.

If a J725 – HB-DA or J726 – HA-DB you suspect to be made of copper is no HA4d-DB3b or HB5z-DA9c that exactly conforms to the state of wear to be expected, the coin should be tested and, if the result is positive, it would be much appreciated if test results and a picture were made available.
Coins that have been fabricated by combining sides of copper J724a – HA4b-DA10a-Cu and J727a – HB5-DB3-Cu would pass all tests and can be only recognized because the dies were never used in that specific combination..




Figure 43, fake HB5f-DA10a, combination of H-side from HB5f-DB3h with D-side of HA4b-DA10a

If you are pretty sure the rarer copper 20 Heller in your collection are copper, don't spoil the joy by testing but send a picture to info@ptbvhrokerspartij.nl .
If you have any questions left or any test results of 20 Heller coins, please send a mail to the same adress.

**Some books on internet**

Copper and copper alloys – ASM specialty handbook books.google
Nichteisenmetalle – R. Hinzmann springer.
Die Legierungen in ihre Anwendung für gewerbliche Zwecke – A. Ledebur us.archive
Copper – Editor A. Butts krishikosh