# UNITED STATES PATENT OFFICE.

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## IMPROVING THE CONDUCTIVITY AND TENSILE STRENGTH OF COPPER AND ITS ALLOYS.

**990,040.** Specification of Letters Patent. **Patented Apr. 18, 1911.**

No Drawing. Application filed April 4, 1910. Serial No. 553,339.

*To all whom it may concern:*

Be it known that I, Rudolf Franke, a German subject, residing at and whose post-office address is No. 44 Zeisingstrasse, Eisleben, Germany, have invented certain new and useful Improvements in Improving the Conductivity and Tensile Strength of Copper and Its Alloys; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

The object of this invention is to improve copper and its alloys for electrical conductors in such manner as to increase both the tensile strength and the electrical conductivity thereof.

The sales department of the German Copper Wire Association deals in copper wires having the following physical characteristics:

| | Conductivity per cent., cc. | Tensile strength per per sq. mm., kg. | |
|---|---|---|---|
| | | Soft wires, cc. | Hard drawn wires, cc. |
| 1. Chemically pure copper wires. | 95–100 | 24 | 40–45 |
| 2. Bronze wires for telephone and telegraph circuits: | | | |
| (a) | 95 | .......... | 40–46 |
| (b) | 85 | .......... | 50–52 |
| (c) | 60 | .......... | 68–71 |
| (d) | 40 | .......... | 65–78 |
| (e) | 30 | .......... | 78–84 |
| 3. Double bronze wires of any desired quality. | | | |

The grades designated under 2 (*b*) and (*c*) are mainly used by the German Imperial Postal Department and by other governmental postal and telegraphic bureaus,—2 (*b*) in sizes from 2 to 4 mm., to connect the several telephone systems with each other, and 2 (*c*) of the size of 1.5 mm. for the connections within the telephone systems themselves.

The tensile strength of the several grades of bronze wire differs according to the size of the wire; it increases as the diameter diminishes, and decreases as the diameter increases.

Phosphorus or phosphor-copper serves as an addition for the chemically pure copper wires; a composition, together with a partial addition of tin, for the harder wires; and, for the double bronze wires, always said composition and tin. The composition referred to consists of 64% aluminum and 36% magnesium. Whether said composition is capable of being replaced by calcium, or by molybdenum has been made the subject of the tests hereinafter referred to. In these tests, electrolytic copper of the best quality was exclusively employed, and hard-drawn wire as well as soft (annealed) wire was produced by the drawing operation, as follows: 1. Wires without any addition. 2. Wires with the addition of calcium in the form of calcium-copper. 3. Wires with the addition of molybdenum in the form of molybdenum powder. 4. Wires with the addition of aluminum and calcium. 5. Wires with the addition of molybdenum and calcium, (the calcium in the form of calcium-copper); and 6. Wires with the addition of aluminum-molybdenum-calcium, (the calcium in the form of aluminum-calcium, and the molybdenum as a powder.) The one portion of the wires remained hard-drawn, the other was annealed, and both kinds, in the hard-drawn and soft condition respectively, were tested with regard to their physical properties. With the facilities at hand the wires could only be drawn 3/4 hard, for which reason it has been found necessary to revise the calculation to 1/1. The additions had the following composition: (*a*) calcium-copper=12.2% of Ca; (*b*) molybdenum powder=97.1% of Mo and 3–4% of oxid, 1.4% insoluble matter, 0.65% Fe and Al as carbid; (*c*) aluminum-calcium=42.3% of Ca, 55.85% of Al, 1.85% insoluble matter. It may be noted here that, as is well known, molybdenum has the property of making copper harder.

The results obtained are summarized in the following tables:

| Serial number. | Copper wires. | | | Soft wires. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Additions. | | | Weight per m. | Cross section. | Tensile strength. | | Resistance. | | Bendings over radius 5. | Torsion at 75 mm. |
| | Ca. | Mo. | AlCa. | | | At 150 mm. | Per sq. mm. | Ω 1000 m. | Conductivity. | | |
| | % | % | % | g. | Sq. mm. | Kg. | Kg. | | % | | |
| 1 | ...... | ...... | ...... | 14.51 | 1.44 | 40 | 24.6 | 10.6 | 98.2 | 20 | 40 |
| 2 | 0.05 | ...... | ...... | 14.52 | 1.44 | 38 | 23.4 | 10.6 | 98.2 | 26 | 42 |
| 3 | 0.35 | ...... | ...... | 13.57 | 1.392 | 42 | 27.7 | 11.3 | 98.6 | 22 | 38 |
| 4 | 1.00 | ...... | ...... | 13.44 | 1.387 | 34 | 22.6 | 11.6 | 97.0 | 19 | 52 |
| 5 | ...... | 0.05 | ...... | 13.77 | 1.40 | 38 | 24.7 | 11.1 | 99.2 | 24 | 40 |
| 6 | ...... | 0.35 | ...... | 14.72 | 1.45 | 44 | 26.7 | 10.5 | 97.8 | 24 | 42 |
| 7 | ...... | 1.00 | ...... | 14.32 | 1.43 | 34 | 21.2 | 10.6 | 100.0 | 20 | 40 |
| 8 | ...... | ...... | 0.05 | 13.90 | 1.41 | 38 | 24.4 | 11.2 | 97.1 | 20 | 38 |
| 9 | ...... | ...... | 0.35 | 14.07 | 1.42 | 42 | 26.6 | 11.2 | 96.0 | 22 | 36 |
| 10 | ...... | ...... | 1.00 | 14.23 | 1.427 | 40 | 25.0 | 12.3 | 86.3 | 24 | 32 |
| 11 | 0.35 | 0.35 | ...... | 14.63 | 1.445 | 46 | 28.0 | 10.3 | 99.8 | 23 | 60 |
| 12 | ...... | 0.35 | 0.35 | 14.85 | 1.456 | 37 | 22.2 | 10.3 | 98.4 | ...... | ...... |

| Serial number. | Copper wires. | | | Hard-drawn wires. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Additions. | | | Weight per m. | Cross section. | Tensile strength. | | | Resistance. | | | |
| | Ca. | Mo. | AlCa. | | | 3/4 hard. | | 1/1 hd. | Ω 1000 m. | Conductivity. | Bendings over radius 5. | Torsion at 75 mm. |
| | | | | | | At 150 mm. | Per sq. mm. | Per sq. mm. | | | | |
| | % | % | % | Sq.mm. | | Kg. | Kg. | Kg. | | % | | |
| 1 | ...... | ...... | ...... | 14.88 | 1.457 | 60 | 36.0 | 48.0 | 10.8 | 94.3 | 11 | 18 |
| 2 | 0.05 | ...... | ...... | 14.65 | 1.447 | 62 | 37.8 | 50.4 | 10.8 | 95.7 | 8 | 8 |
| 3 | 0.35 | ...... | ...... | 13.65 | 1.397 | 62 | 40.5 | 54.0 | 11.3 | 98.0 | 8 | 10 |
| 4 | 1.00 | ...... | ...... | 13.85 | 1.407 | 58 | 37.3 | 49.7 | 11.5 | 95.0 | 9 | 12 |
| 5 | ...... | 0.05 | ...... | 14.01 | 1,415 | 62 | 39.7 | 52.9 | 11.2 | 96.2 | 9 | 10 |
| 6 | ...... | 0.35 | ...... | 15.22 | 1.475 | 62 | 36.1 | 48.1 | 10.5 | 94.5 | 9 | 10 |
| 7 | ...... | 1.00 | ...... | 14.92 | 1.460 | 64 | 38.3 | 51.1 | 10.5 | 97.0 | 8 | 10 |
| 8 | ...... | ...... | 0.05 | 14.50 | 1.440 | 62 | 38.2 | 51.1 | 11.1 | 94.0 | 9 | 14 |
| 9 | ...... | ...... | 0.35 | 14.46 | 1.438 | 60 | 37.0 | 49.3 | 11.1 | 94.0 | 10 | 8 |
| 10 | ...... | ...... | 1.00 | 14.48 | 1.440 | 58 | 35.7 | 47.6 | 12.2 | 85.2 | 8 | 12 |
| 11 | 0.35 | 0.35 | ...... | 14.55 | 1.442 | 63 | 38.6 | 51.5 | 10.6 | 98.0 | 13 | 17 |
| 12 | ...... | 0.35 | 0.35 | 14.87 | 1.457 | 60 | 36.0 | 48.0 | 10.5 | 96.5 | 12–13 | 13 |

From the foregoing tables it appears;

1. The wires designated by Serial No. 1, and without any addition, correspond to the requirements of the chemically pure copper wires listed in the first instance under 1, which have been customarily produced by the addition of a certain amount of phosphorus or phosphor-copper, and for which the requirements are:

| Conductivity. | Tensile strength. | |
|---|---|---|
| | Soft. | Hard. |
| % 95–100 | Kg. 24 | Kg. 40–45 |

These requirements are fulfilled with:

| Conductivity. | Tensile strength. | |
|---|---|---|
| | Soft. | Hard. |
| % 94.3–98.2 | Kg. 24.6 | Kg. 48 |

This determination serves as an assurance of the purity of the electrolytic copper employed, and shows what physical value can be obtained, without any addition whatever, from such a grade of copper.

2. The hard-drawn wires produced with the addition of calcium-copper and bearing the Serial Nos. 2 to 4, correspond to the hard-drawn bronze wires designated in the first instance under 2 *a* and *b* heretofore produced by the addition of corresponding quantities of the aluminum-magnesium composition, for which the requirements are;

| | Conductivity. | Tensile strength per sq. mm., hard. |
|---|---|---|
| | % | Kg. |
| 2a | 95 | 40–46 |
| 2b | 85 | 50–52 |

These requirements are fulfilled by:

| Conductivity. | Tensile strength per sq. mm., hard. |
|---|---|
| % 98 | Kg. 54 |

This determination shows that with an addition of calcium up to 0.35% we are able to produce hard-drawn wires not only of the conditions under 2 *a* and *b*, but even of a tensile strength up to 54 kg. per sq. mm. with a conductivity of about 98%. That is, while with the aluminum-magnesium composition, the aluminum constituent is favorable to the tensile strength and unfavorable to the conductivity, the calcium addition likewise exerts a favorable influence upon the tensile strength and in no wise detracts from the conductivity. This determination shows that calcium as calcium-copper is far superior to the aluminum-magnesium composition.

3. The hard-drawn wires produced with the addition of molybdenum and bearing Serial Nos. 5 to 7 correspond, with a molybdenum addition up to 0.35% maximum to the requirements of the hard-drawn bronze wires heretofore produced with the addition of corresponding quantities of the aluminum-magnesium composition and listed in the first instance under 2 *a* and 2 *b*, for which the conditions are as follows;

| | Conductivity. | Tensile strength per sq. mm., hard. |
|---|---|---|
| | % | Kg. |
| Under 2*a*... | 95 | 40-46 |
| Under 2*b*... | 85 | 50-52 |

These conditions are fulfilled by:

| Conductivity. | Tensile strength per sq. mm., hard. |
|---|---|
| % | Kg. |
| 96.2 | 52.9 |

This determination shows, that, with an addition of molybdenum up to a maximum of 0.35%, we are enabled to produce hard-drawn wires not only satisfying the requirements under 2*a* and 2*b*, but even of a tensile strength up to say 53 sq. mm. and with a conductivity of say 96%. While, therefore, with the aluminum-magnesium composition, the aluminum addition is favorable to tensile strength and prejudicial to conductivity, the addition of molybdenum likewise exerts a favorable influence upon the tensile strength and is in no wise prejudicial to conductivity. This determination shows that molybdenum (preferably to be added as molybdenum-copper) is far superior to the aluminum-magnesium composition and has properties quite similar to those of calcium.

4. The hard-drawn wires produced with the addition of aluminum-calcium and bearing Serial Nos. 8 to 10 correspond, it is true, in general with the hard-drawn wires produced with the addition of corresponding quantities of the aluminum-magnesium composition listed in the first instance under 2*a* and 2*b*, but show the unfavorable influence of the aluminum upon their conductivity. For this reason, this addition should not be employed.

5. The hard-drawn wire produced with a calcium-molybdenum addition and bearing Serial No. 11 corresponds, with an addition of molybdenum and calcium addition (of each 0.35%,) to the requirements of the hard-drawn bronze wires produced by the addition of corresponding quantities of the aluminum-magnesium composition listed in the first instance under 2*a* and 2*b*, and combines the good qualities which calcium and molybdenum develop when individually employed. With this combined addition of say 0.35% (as against the addition of the aluminum-magnesium composition), hard-drawn wires of a tensile strength up to 52 kg. per sq. mm. and with a conductivity of 98% can be produced.

6. The hard-drawn wire produced with an addition of aluminum-calcium-molybdenum, (made up of 0.35% each of aluminum-calcium and molybdenum) manifests the favorable influence due to molybdenum and calcium, but, in consequence of the presence of the aluminum, does not exhibit those good qualities which calcium and molybdenum when employed alone develop. For this reason, this addition should not be used.

These tests have established the extraordinarily valuable proposition, (1), that calcium and molybdenum addition can be advantageously substituted for the aluminum-magnesium composition heretofore employed for hard-drawn bronze wires, (2) that, (in contrast to additions heretofore employed) with an addition of at the most 0.35% of calcium, or of molybdenum, or of both metals, hard-drawn wires can be produced with at least 50 to 52 kg. per sq. mm. tensile strength and with a conductivity of 95%, and (3) that, in view of the good qualities of calcium and molybdenum, it is advisable to produce the conditions referred to in the first instance under 1 corresponding to chemically pure copper wires, not by the addition of phosphorus or phosphor copper, but by means of a moderate (say 0.05 to 0.10%) addition of calcium or molybdenum or an addition of both metals. For telephone and telegraph purposes these results, which have never before been obtained, are of the most far-reaching importance.

As hereinbefore stated, the sales branch of the German Copper Wire Association also deals in bronze wires, for telephone and telegraph circuits, having the following physical properties:

*Hard-drawn bronze wires.*—2*c* with 60% conductivity and 68–71 kg. tensile strength per sq. mm., 2*d* with 40% conductivity and 65–78 kg. tensile strength per sq. mm. 2*e* with 30% conductivity and 78–84 kg. tensile strength per sq. mm. For these bronze wires, a composition of 64% aluminum and 36% magnesium serve as the addition in connection with tin. By the following tests, it was to be determined, whether, in the presence of tin, the said composition should be supplanted by calcium or molybdenum or by both metals. In these tests, electrolytic copper and tin of the best quality were employed, and hard-drawn wires as well as soft (annealed) wires were produced, in such manner, that there were drawn, (1) bronze wires of Cu and Sn with the addition of Ca, (2) bronze wires of Cu and Sn with the addition of Mo, (3) bronze wires of Cu and Sn with the addition of Ca and Mo. The one portion of the wires remained hard-drawn, and the other portion was annealed, and both kinds in their hard-drawn and soft condition were investigated as to their physical properties. With the facilities at hand the wires could only be drawn 3/4 hard; it was therefore necessary to revise the calculation to 1/1. The calcium was used in the form of calcium-copper, and the molybdenum in the form of molybdenum powder. The additions had the following composition; (*a*) Calcium-copper=12.2% calcium,=97.2% Mo, with 3–4% oxid; molybdenum = 1.4% insoluble matter, = 0.65% Fe and Al as carbid.

The results obtained are summarized in the following tables:

| Serial No. | Composition. | | | | | | Hard-drawn bronze wires. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu. | Ca. | Mo. | Sn. | Weight per m. | Cross section. | Tensile strength. 3/4 hard. | | 1/1 hard. | Resistance. | | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | | | | | At 150 mm. | Per sq. mm. | Per sq. mm. | Ω 1000 m. | Conductivity. | | |
| | % | % | % | % | *G.* | *Sq. mm.* | *Kg.* | *Kg.* | *Kg.* | | % | | |
| 1 | 100 | 0.35 | ....... | 0.5 | 17.8 | 1.595 | 88 | 44 | 58.7 | 10.2 | 84 | 11 | 13 |
| 2 | 100 | 0.35 | ....... | 1.0 | 17.9 | 1.6 | 99 | 49.3 | 65.7 | 11.3 | 75.5 | 13 | 14 |
| 3 | 100 | 0.35 | ....... | 1.05 | 18 | 1.6 | 100 | 49.8 | 66.4 | 14.9 | 57 | 7 | 9 |
| 4 | 100 | 0.35 | ....... | 2.0 | 18.15 | 1.61 | 114 | 56 | 74.7 | 18.4 | 45.5 | 12 | 9 |
| 5 | 100 | ....... | 0.35 | 0.5 | 17.8 | 1.595 | 88 | 44.3 | 59.1 | 10.5 | 81 | 9 | 11 |
| 6 | 100 | ....... | 0.35 | 1.0 | 17.5 | 1.58 | 98 | 50 | 66.7 | 15.2 | 57 | 12 | 12 |
| 7 | 100 | ....... | 0.35 | 1.5 | 17.1 | 1.56 | 106 | 55.5 | 74 | 18.5 | 48 | 11 | 13 |
| 8 | 100 | ....... | 0.35 | 2.0 | 17.25 | 1.57 | 114 | 59 | 78.7 | 21.1 | 42 | 11 | 9 |
| 9 | 100 | 0.35 | 0.35 | 0.5 | 17.75 | 1.59 | 96 | 48.4 | 64.5 | 12.2 | 70.5 | 10 | 10 |
| 10 | 100 | 0.35 | 0.35 | 1.0 | 17.2 | 1.57 | 98 | 50.7 | 67.6 | 16.4 | 54 | 12 | 13 |
| 11 | 100 | 0.35 | 0.35 | 1.5 | 17.6 | 1.585 | 116 | 59 | 78.7 | 20.1 | 43 | 8 | 13 |
| 12 | 100 | 0.35 | 0.35 | 2.0 | 17.85 | 1.595 | 110 | 55 | 73.3 | 21.8 | 39 | 9 | 9 |

| Ser. No. | Composition. | | | | | | Soft (annealed) bronze wires. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu. | Ca. | Mo. | Sn. | Wgt. per m. | Cross section. | Tensile strength. | | Resistance. | | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | | | | | At 50 mm. | Per sq. mm. | Ω 1000 m. | Conductivity. | | |
| | % | % | % | % | *G.* | *Sq. mm.* | *Kg.* | *Kg.* | | % | | |
| 1 | 100 | 0.35 | ....... | 0.5 | 18 | 1.6 | 58 | 28.8 | 9.9 | 85.5 | 18 | 48 |
| 2 | 100 | 0.35 | ....... | 1.0 | 16.3 | 1.525 | 56 | 30.8 | 12.2 | 77 | 14 | 50 |
| 3 | 100 | 0.35 | ....... | 1.5 | 18.05 | 1.605 | 60 | 29.7 | 14.7 | 57.5 | 17 | 49 |
| 4 | 100 | 0.35 | ....... | 2.0 | 17.85 | 1.595 | 68 | 34 | 18.4 | 46.5 | 16 | 42 |
| 5 | 100 | ....... | 0.35 | 0.5 | 17.55 | 1.58 | 68 | 34.6 | 10.6 | 82 | 16 | 42 |
| 6 | 100 | ....... | 0.35 | 1.0 | 16.55 | 1.535 | 64 | 34.7 | 15.8 | 58.5 | 16 | 30 |
| 7 | 100 | ....... | 0.35 | 1.5 | 16.65 | 1.545 | 76 | 40.5 | 19.2 | 47.5 | 18 | 46 |
| 8 | 100 | ....... | 0.35 | 2.0 | 16.15 | 1.515 | 66 | 36.7 | 25.4 | 40.5 | 17 | 40 |
| 9 | 100 | 0.35 | 0.35 | 0.5 | 18.2 | 1.61 | 62 | 30.5 | 11.7 | 71.5 | 18 | 55 |
| 10 | 100 | 0.35 | 0.35 | 1.0 | 15.75 | 1.5 | 76 | 43 | 17.6 | 55 | 18 | 36 |
| 11 | 100 | 0.35 | 0.35 | 1.5 | 16.1 | 1.51 | 70 | 39 | 21.3 | 44.5 | 20 | 23 |
| 12 | 100 | 0.35 | 0.35 | 2.0 | 17.2 | 1.57 | 72 | 37.2 | 23.1 | 38.5 | 18 | 19 |

If we arrange the drawn wire grades according to the tin additions, we obtain the following groups:

*I. Wires with 0.5 % Sn.*

| Serial number. | Ca. | Mo. | Hard-drawn bronze wires. | | | | | Soft (annealed) bronze wires. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tensile strength per sq. mm. | | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. | Tensile strength per sq. mm. | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | 3/4 hrd. | 1/1 hrd. | | | | | | | |
| | % | % | *Kg.* | *Kg.* | % | | | *Kg.* | % | | |
| 1...... | 0.35 | ...... | 44 | 58.7 | 84 | 11 | 13 | 28.8 | 85.5 | 18 | 48 |
| 5...... | ...... | 0.35 | 44.3 | 59.1 | 81 | 9 | 11 | 34.6 | 82 | 16 | 42 |
| 9...... | 0.35 | 0.35 | 48.4 | 64.5 | 70.5 | 10 | 10 | 30.5 | 71.5 | 18 | 55 |

*II. Wires with 1% Sn.*

| Serial number. | Ca. | Mo. | Hard-drawn bronze wires. | | | | | Soft (annealed) bronze wires. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tensile strength per sq. mm. | | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. | Tensile strength per sq. mm. | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | 3/4 hrd. | 1/1 hrd. | | | | | | | |
| | % | % | *Kg.* | *Kg.* | % | | | *Kg.* | % | | |
| 2...... | 0.35 | ...... | 49.3 | 65.7 | 75.5 | 13 | 14 | 30.8 | 77 | 14 | 50 |
| 6...... | ...... | 0.35 | 50 | 66.7 | 57 | 12 | 12 | 34.7 | 55.5 | 16 | 30 |
| 10...... | 0.35 | 0.35 | 50.7 | 67.6 | 54 | 12 | 13 | 43 | 55 | 18 | 36 |

*III. Wires with 1.5% Sn.*

| Serial number. | Ca. | Mo. | Hard-drawn bronze wires. | | | | | Soft (annealed) bronze wires. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tensile strength per sq. mm. | | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. | Tensile strength per sq. mm. | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | 3/4 hrd. | 1/1 hrd. | | | | | | | |
| | % | % | *Kg.* | *Kg.* | % | | | *Kg.* | % | | |
| 3...... | 0.35 | ...... | 49.8 | 66.4 | 57 | 7 | 9 | 29.7 | 57.5 | 17 | 49 |
| 7...... | ...... | 0.35 | 55.5 | 74 | 48 | 11 | 13 | 40.5 | 47.5 | 18 | 46 |
| 11...... | 0.35 | 0.35 | 59 | 78.8 | 43 | 8 | 13 | 39 | 44.5 | 20 | 23 |

*IV. Wires with 2% Sn.*

| Serial number. | Ca. | Mo. | Hard-drawn bronze wires. | | | | | Soft (annealed) bronze wires. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tensile strength per sq. mm. | | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. | Tensile strength per sq. mm. | Conductivity. | Flexures upon a radius 5. | Torsion at 75 mm. |
| | | | 3/4 hrd. | 1/1 hrd. | | | | | | | |
| | % | % | *Kg.* | *Kg.* | % | | | *Kg.* | % | | |
| 4...... | 0.35 | ...... | 56 | 74.7 | 45.5 | 12 | 9 | 34 | 46.5 | 16 | 42 |
| 8...... | ...... | 0.35 | 59 | 78.7 | 42 | 11 | 9 | 36.7 | 40.5 | 17 | 40 |
| 12...... | 0.35 | 0.35 | 55 | 73.3 | 39 | 9 | 9 | 37.2 | 38.5 | 18 | 19 |

From a practical standpoint, in arriving at a determination of the quality of these bronze wires, only the results as to the hard drawn wires need be considered. Nevertheless, although the results as to the soft bronze wires are without practical importance, they are theoretically significant inasmuch as they justify direct conclusions as to the effect of the foreign ingredients.

The results as to the hard drawn wires permit the following conclusions: 1. Qualities may be obtained which not only meet the conditions prescribed by 2*c* to 2*e* of the German Copper Wire Association, but which, together with extraordinary tensile strength, exhibit even higher conductivities. 2. In the presence of tin, the composition of 64% aluminum and 36% magnesium may be supplanted by calcium, or by molybdenum, or by both metals. 3. In the production of the wires, according as it is desired to impart thereto (1) tensile strength, or (2) conductivity, the procedure should be as follows: (*a*) If we desire higher conductivity with appropriate tensile strength, we should use as the addition tin in quantities of 0.5 to 2.0%, and constant quantities of calcium of 0.35%. (*b*) If we desire higher tensile strength with appropriate conductivity, we should use as the addition tin in quantities of 0.5 to 2.0% and constant quantities of molybdenum of 0.35%. (*c*) If we desire specially high tensile strength we should use as the addition tin (in quantities of 0.5 to 2.0%) and both calcium and molybdenum, in constant quantities of each 0.35%.

The making up of the alloys for hard drawn bronze wire, takes the following shape, according to the foregoing conclusions:

| Stress is laid upon: | Serial No. | Conductivity. | Tensile strength. | Sn. | Ca. | Mo. |
|---|---|---|---|---|---|---|
| | | % | *Kg.* | % | % | % |
| Higher conductivity.... | 1 | ↑84 | ↓58.7 | 0.5 | 0.35 | ..... |
| Higher tensile strength.. | 3 | 81 | 59.1 | 0.5 | ...... | 0.35 |
| Specially high tensile strength.............. | 9 | 70.5 | 64.5 | 0.5 | 0.35 | 0.35 |
| Higher conductivity.... | 2 | ↑75.5 | ↓65.7 | 1.0 | 0.35 | ..... |
| Higher tensile strength.. | 6 | 57 | 66.7 | 1.0 | ...... | 0.35 |
| Specially high tensile strength.............. | 10 | 54 | 67.6 | 1.0 | 0.35 | 0.35 |
| Higher conductivity.... | 3 | ↑57 | ↓66.4 | 1.5 | 0.35 | ..... |
| Higher tensile strength.. | 7 | 48 | 74 | 1.5 | ...... | 0.35 |
| Specially high tensile strength.............. | 11 | 43 | 78.7 | 1.5 | 0.35 | 0.35 |
| Higher conductivity.... | 4 | ↑45.5 | ↓74.7 | 2.0 | 0.35 | ..... |
| Higher tensile strength.. | 8 | 42 | 78.8 | 2.0 | ...... | 0.35 |
| ..................... | 12 | 39 | 73.3 | 2.0 | 0.35 | 0.35 |

While retaining the 0.35% calcium or molybdenum additions, new intermediate grades as to conductivity and tensile strength may be produced, by using tin additions of 0.25, 0.75, 1.25 and 1.75%. This affords the possibility of not only fulfilling the conditions of 2*c* to 2*e* of the German Copper Wire Association, but of producing a great number of new grades wherein conductivity and tensile strength stand in a more advantageous relationship to each other.

In the appended claims it is to be understood that by "copper" I mean any alloy wherein copper preponderates.

Having thus described my invention, what I claim is:

1. The method of improving copper for the purpose described, which comprises adding calcium thereto in such proportion as to increase the tensile strength and conductivity thereof; substantially as described.

2. The method of increasing the tensile strength and conductivity of copper, which comprises adding less than 1 per cent. of calcium thereto; substantially as described.

3. The method of increasing the tensile strength and conductivity of copper, which comprises adding substantially .35 per cent. of calcium thereto; substantially as described.

4. The method of improving copper for the purpose described, which comprises adding calcium and molybdenum thereto in such proportions as to increase the tensile strength and conductivity thereof; substantially as described.

5. The method of increasing the tensile strength and conductivity of copper, which comprises adding less than 1 per cent. of calcium and less than 1 per cent. of molybdenum thereto; substantially as described.

6. The method of increasing the tensile strength and conductivity of copper, which comprises adding substantially .35 per cent. of calcium and substantially .35 per cent. of molybdenum thereto; substantially as described.

7. An alloy for electrical conductors having a preponderating proportion of copper and such a proportion of calcium that the tensile strength and conductivity are increased; substantially as described.

8. An alloy for electrical conductors having a preponderating proportion of copper, and less than 1 per cent. of calcium, whereby the tensile strength and conductivity are increased; substantially as described.

9. An alloy for electrical conductors having a preponderating proportion of copper, and substantially .35 per cent. of calcium, whereby the tensile strength and conductivity are increased; substantially as described.

10. An alloy for electrical conductors having a preponderating proportion of copper and such a proportion of calcium and molybdenum that the tensile strength and conductivity are increased; substantially as described.

11. An alloy for electrical conductors having a preponderating proportion of copper,

less than 1 per cent. of calcium and less than 1 per cent. of molybdenum, whereby the tensile strength and conductivity are increased; substantially as described.

12. An alloy for electrical conductors having a preponderating proportion of copper, substantially .35 per cent. of calcium and substantially .35 per cent. of molybdenum, whereby the tensile strength and conductivity are increased; substantially as described.

In testimony whereof I affix my signature, in presence of two witnesses.

RUDOLF FRANKE.

Witnesses:

RUDOLPH FRICKE,

SOUTHARD P. WARNER.