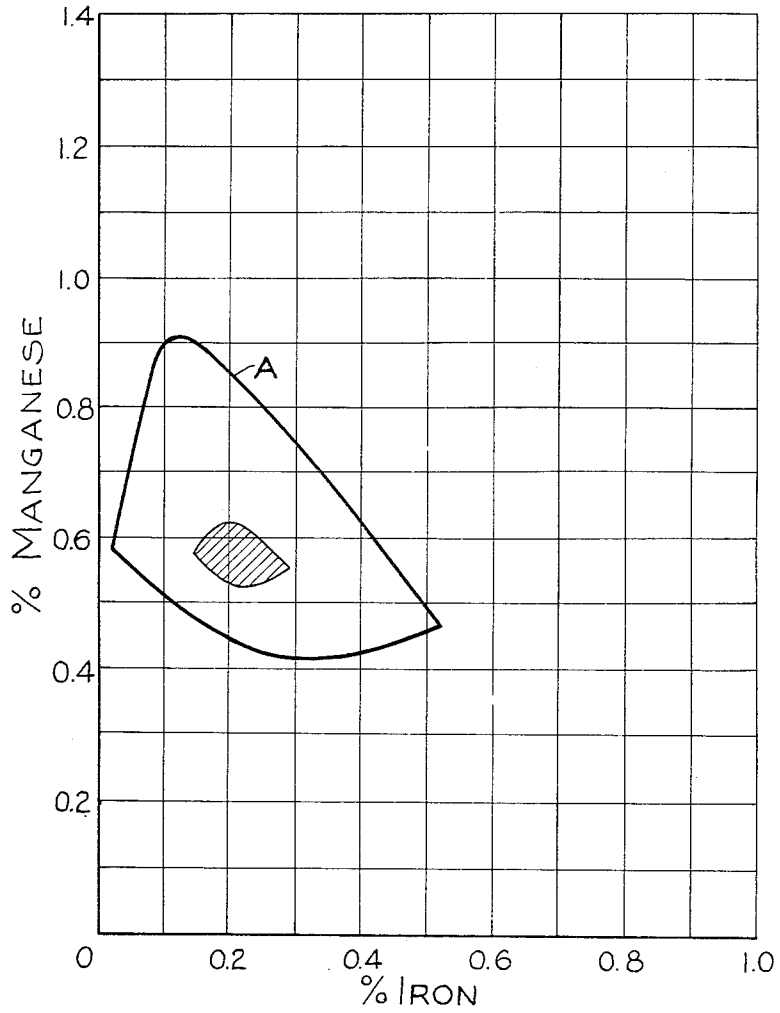
July 12, 1955 V. PULSIFER ET AL 2,712,992

COPPER-BASE ALLOY

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Fig. 1



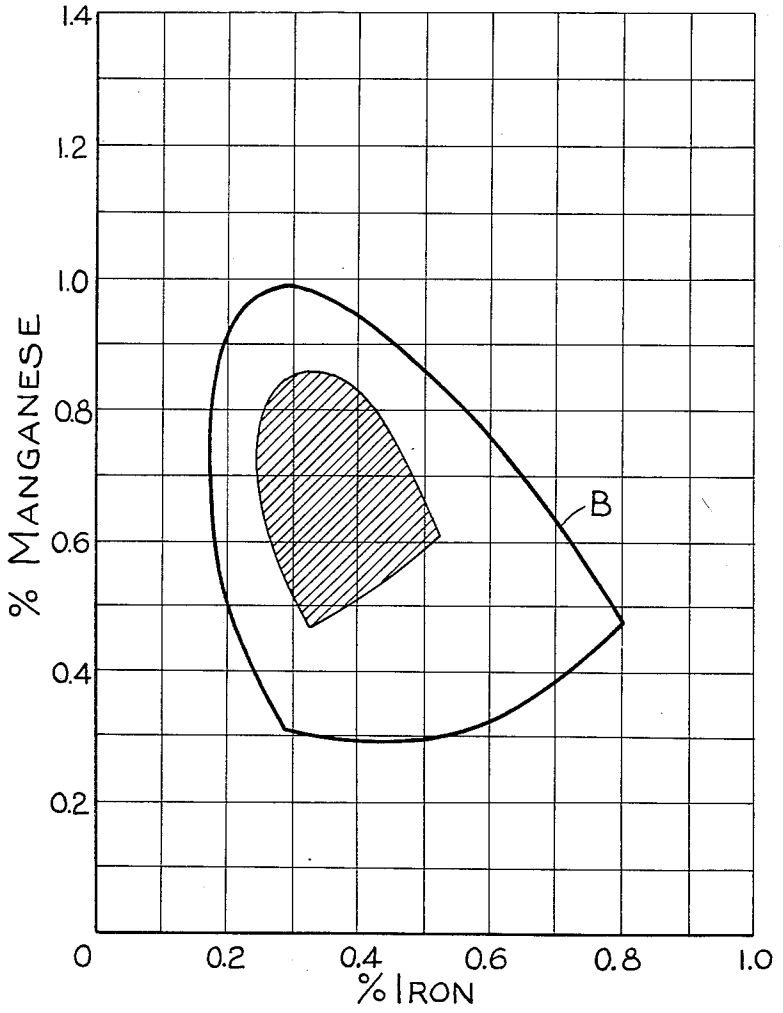
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COPPER-BASE ALLOY

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Fig. 2



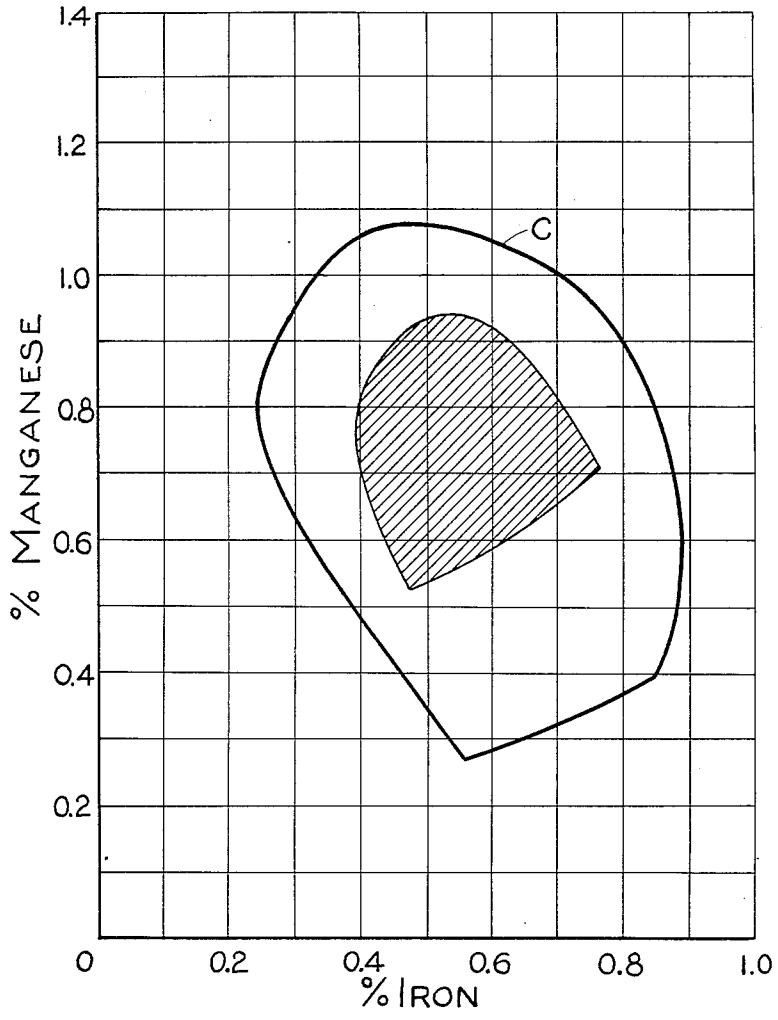
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COPPER-BASE ALLOY

Filed Nov. 16, 1953 6 Sheets-Sheet 3

Fig. 3



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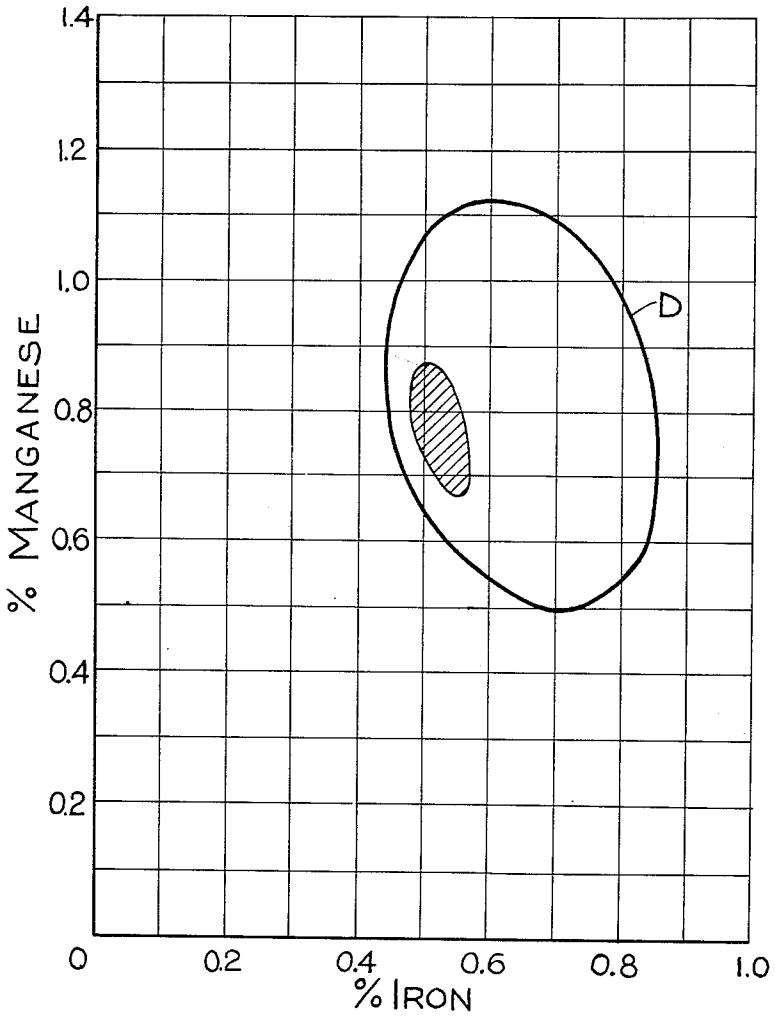
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COPPER-BASE ALLOY

Filed Nov. 16, 1953 6 Sheets-Sheet 4

Fig. 4



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COPPER-BASE ALLOY

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Fig. 6

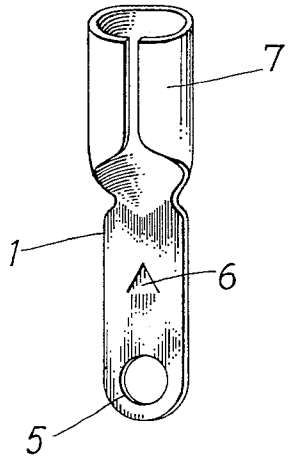
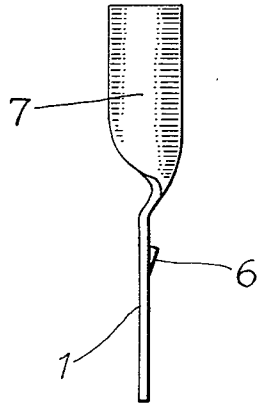


Fig. 7



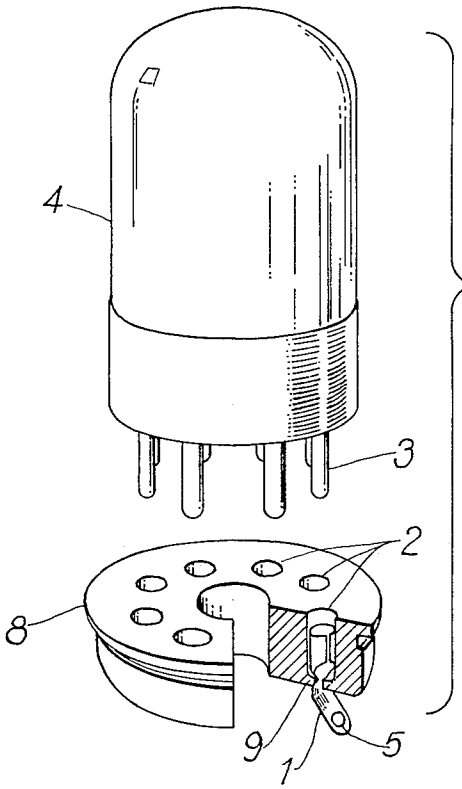


Fig. 5

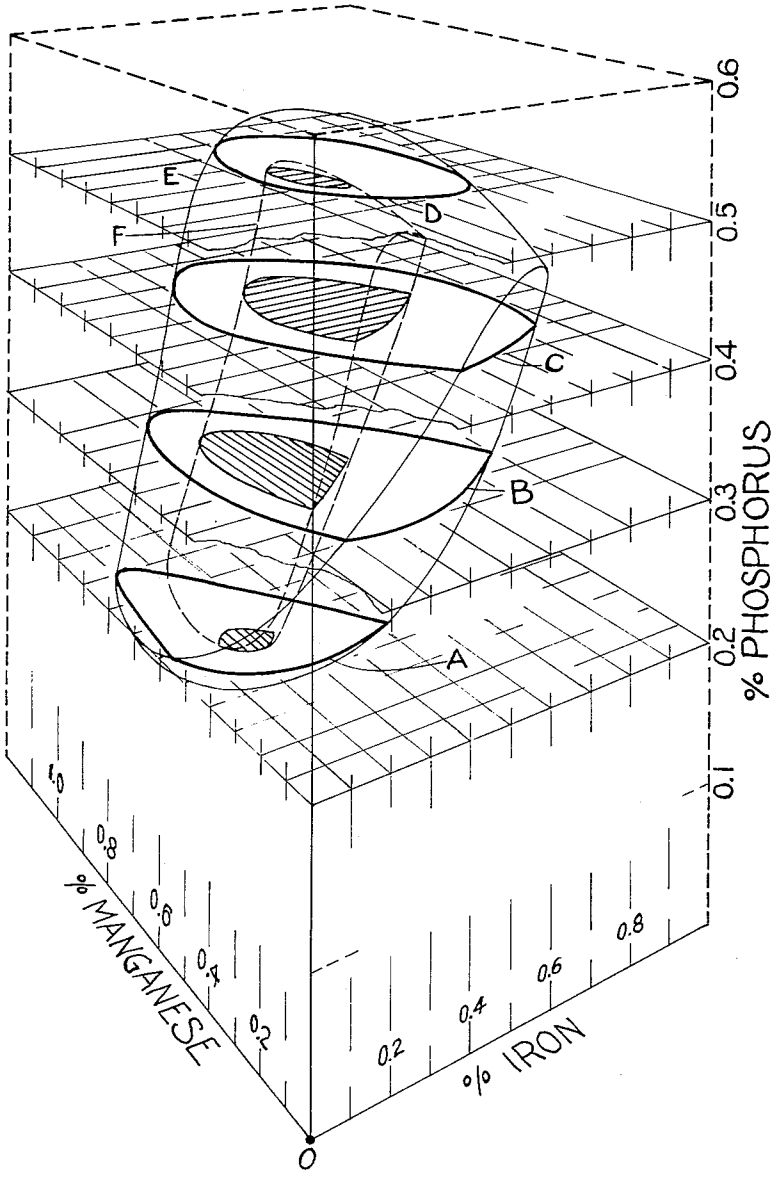
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COPPER-BASE ALLOY

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Fig. 8



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United States Patent Office 2,712,992 Patented July 12, 1955

2,712,992

COPPER-BASE ALLOY

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Application November 16, 1953, Serial No. 392,076

13 Claims. (Cl. 75—161)

This invention relates to electrical conductors formed of copper-base alloys and more particularly to such alloys suitable for use in electric spring conductors, and the like.

Heretofore spring members for electrical connectors have ordinarily been formed of such metals as copper-cadmium alloys, copper-tin alloys, and copper-nickel-phosphorus alloys. Electrical connectors formed of such alloys are, however, relatively expensive, due in some instances to the high cost of the alloying elements and in other instances to the high cost of the age-hardening treatments and the like necessary to provide the requisite electrical conductivity and strength. Such connectors have also been formed of less expensive alloys having relatively low electrical conductivity, but little economy is effected by this method, since it is then necessary to employ a greater amount of such metal in order to make the member of relatively thick cross section to avoid excessive electrical resistance. The present invention has among its objects to provide an electrical connector composed of relatively inexpensive alloying elements and having the electrical conductivity and strength requisite for electric switches and the like without any age-hardening treatments.

Another object of the invention is to provide an improved electrical conductor formed largely of copper.

Still another object is to provide a copper-manganese-iron-phorphorus alloy of novel composition particularly suited for use in electrical conductors for electrical switch members, electrical connectors, and the like.

A further object is to provide an inexpensive alloy having suitable strength and conductivity after cold working for use in electrical spring contact members and the like.

Other objects and advantages of the invention will become apparent from the following detailed description and the accompanying drawing, in which

Figure 1 is a diagram illustrating the relationship between the manganese and iron contents of compositions prepared in accordance with this invention when the phosphorus content of the alloy is about 0.2%,

Figure 2 is a diagram similarly illustrating the relationship between manganese and iron contents when the phosphorus content of the alloy is about 0.3%,

Figure 3 is a diagram similarly illustrating the relationship between manganese and iron contents when the phosphorus content of the alloy is about 0.4%,

Figure 4 is a diagram similarly illustrating the relationship between manganese and iron contents when the phosphorus content of the alloy is about 0.5%,

Figure 5 is a diagrammatic view of a radio tube and the tube socket, partly in section, containing a connector illustrating one embodiment of this invention,

Figure 6 is an enlarged view of the electrical connector shown in Figure 5,

Figure 7 is a side view of the connector shown in Figure 6, and

Figure 8 is a perspective view of a three-dimensional diagrammatic representation of the rather complex bulbous volume E and the inner volume F containing all

points representing the percentage values of the constituents phosphorus, manganese and iron as variables in the proportions to be found in an alloy having, respectively, at least the minimal essential physical characteristics sought and having the preferred characteristics. The vertical coordinant of phosphorus content is plotted on a scale enlarged by a factor of about three so as to more widely space and more clearly show the horizontal traces A, B, C and D.

The foregoing objects and advantages are accomplished in accordance with this invention by providing as the metal for the electrical conductor an alloy having a phosphorus content in the range from 0.16% to 0.58%, an iron content in the range from 0.02% to 0.89%, and a manganese content in the range from 0.27% to 1.12%, with the balance copper. A preferred composition for the conductor in accordance with this invention is a phosphorus content in the range from about 0.19% to 0.51%, an iron content in the range from about 0.15% to 0.76%, and a manganese content in the range from about 0.47% to 0.94%, with the balance copper. Within the preferred range, the composition with optimum properties has been found to be one consisting of from about 0.33% to about 0.36% phosphorus, from about 0.42% to about 0.49% iron, from about 0.67% to about 0.72% manganese and the balance copper.

In order that the conductor can be made relatively thin, it is preferred that the copper alloy have an electrical conductance of at least 50% I. A. C. S., and in order that the conductor have the necessary resilience and physical characteristics requisite for electrical spring connectors, it is preferred that the copper alloy have a tensile strength of at least 75000 pounds per square inch when measured by A. S. T. M. method E8–46. Such a combination of strength and conductance has not been attained heretofore with copper alloy strip without expensive alloying ingredients or age-hardening treatments. Such a combination of high strength and conductance is obtained, however, in accordance with this invention by holding the phosphorus, iron, and manganese contents of the alloy within the relatively narrow ranges specified hereinbefore and described in greater detail hereinafter and cold working the alloy from an annealed structure to about a 70% reduction in thickness. Thus, in accordance with this invention, the alloy is brought to a dimension about three and one-third times that desired for the electrical connector either by hot working, or cold working followed by annealing, or both, and is then reduced to the desired dimension by cold working.

Referring now to the drawing, the amounts of manganese and iron permissible in the copper-alloy having a conductivity of at least 50% I. A. C. S. and a tensile strength of at least 75,000 pounds per square inch after cold working from an annealed structure to 70% reduction in thickness fall within the area bounded by the line A, Figure 1, when the phosphorus content of the alloy is about 0.2%, within the area bounded by the line B, Figure 2, when the phosphorus content of the alloy is about 0.3%, within the area bounded by the line C, Figure 3, when the phosphorus content of the alloy is about 0.4%, and within the area bounded by the line D, Figure 4, when the phosphorus content of the alloy is about 0.5%.

By way of example, a casting one-half inch thick formed of an alloy composed of 0.37% phosphorus, 0.80% iron, and 0.58% manganese, with the balance copper was heated to 900° C. for thirty minutes and was then hot rolled in three steps, the first being to a thickness of 0.375", the second being to a thickness of 0.300" and the third being to a thickness of 0.200". The 0.200" thick strip was then cold rolled to a thickness of 0.100" and annealed at 600° C. for one-half hour. The 0.100" thick strip was then cold rolled to a thickness of 0.035" in three passes

through the work rolls and then annealed at 535° C. for one-half hour to provide an annealed structure. The 0.035" thick annealed strip was then finally cold rolled in three passes through the work rolls to a thickness of 0.010", which amounts to a cold working to 71% reduction in thickness. The cold worked strip had a Rockwell F hardness of 100, a tensile strength of 78,500 pounds per square inch and a conductivity of 66.8% I. A. C. S. A similar casting formed of an alloy composed of 0.29% phosphorus, 0.69% iron and 0.40% manganese with the balance copper, when treated as above, after cold working from the annealed structure to about 70% reduction in thickness had a Rockwell F hardness of 99, a tensile strength of 77,200 pounds per square inch and a conductivity of 59.9% I. A. C. S. A similar casting formed of an alloy composed of 0.19% phosphorus, 0.14% iron, and 0.63% manganese, with the balance copper, when treated as above, after annealing and a cold reduction of about 70% in thickness had a Rockwell F hardness of 101, a tensile strength of 80,200 pounds per square inch and a conductivity of 58.6% I. A. C. S.

Referring to the drawing, the areas bounded by the lines A, B, C, and D, in Figure 1 through 4 and 8, respectively, represent cross-sectional areas of an imaginary three-dimensional volume E, Figure 8, wherein the content of phosphorus is measured in the direction perpendicular to the planes shown in the respective figures. As indicated hereinbefore, the boundary lines A, B, C, and D of the respective figures indicate cross-sections of the phosphorus-iron-manganese volume E taken at 0.2%, 0.3%, 0.4%, and 0.5% phosphorus, respectively. The phosphorus axis of said volume terminates at a minimum of about 0.16% phosphorus and at a maximum of about 0.58% phosphorus. As will be seen from the drawing, this volume of compositions falls within the ranges set forth hereinbefore for the amounts of phosphorus, iron, and manganese, namely 0.16% to 0.58% phosphorus, 0.02% to 0.89% iron, and 0.27% to 1.12% manganese.

It has also been found that an electrical conductor of even further improved characteristics can be provided for the purpose if the permissible amounts of the alloying constituents are held within certain narrow ranges. Such improvement is obtained by providing as the metal for the electrical conductor an alloy preferably having an electrical conductivity of at least 60% I. A. C. S. and a tensile strength of at least 80,000 pounds per square inch after cold working from an annealed structure to about 70% reduction in thickness and having a phosphorus content in the range from about 0.19% to 0.51%, an iron content in the range from about 0.15% to 0.76%, and a manganese content in the range from about 0.47% to 0.94%, with the balance copper.

By way of example of such preferred alloy composition, a casting one-half inch thick formed of an alloy composed of 0.182% phosphorus, 0.21% iron, and 0.57% manganese, with the balance copper, when treated as hereinabove described, after annealing and then cold working to 71% reduction in thickness had a Rockwell F hardness of 101, a tensile strength of 82,200 pounds per square inch, and an electrical conductivity of 60.9% I. A. C. S. A similar casting formed of an alloy composed of 0.36% phosphorus, 0.44% iron, and 0.70% manganese, with the balance copper, when treated as described hereinabove, after annealing and then cold working to 71% reduction in thickness, had a Rockwell F hardness of 101, a tensile strength of 81,100 pounds per square inch, and an electrical conductivity of 69.7% I. A. C. S.

Within the preferred range an alloy having a composition of about 0.33–0.36% phosphorus, about 0.42–0.49% iron, and about 0.67–0.72% manganese, with the balance copper, was cast to a thickness of five inches and hot rolled at about 875° C. to a thickness of about half an inch. After milling, the bar was cold rolled, then annealed, at 650°–620° C., cold rolled again to a gage of 0.42 of an inch, annealed at about 540° C. and finally cold rolled in four passes to a total reduction of 70%. The cold worked strip had a tensile strength from 80,200 to 80,800 pounds per square inch and a conductivity of from 67.9% to 68.3% I. A. C. S.

While in the foregoing examples the annealed structure prior to the final cold working to about 70% reduction in dimension was obtained by actual annealing prior to said final cold working step, it is to be understood that the annealed structure referred to herein may likewise be obtained as a result of a hot working. The process of this invention, therefore, is to provide the alloy with an annealed structure and a dimension about three and one-third times greater than the desired final dimension and then to cold work to about 70% reduction in dimension.

Referring to the drawing, Figure 8, it may be seen that the shaded portion of the areas bounded by lines A, B, C and D in Figures 1 through 4, respectively, likewise represent cross-sectional areas of an imaginary volume F contained within the volume E of Figure 8, wherein the content of phosphorus is measured in the direction perpendicular to the planes shown in the respective Figures 1 through 4. The shaded areas in Figures 1 through 4 thus represent cross-sectional areas of the phosphorus-iron-manganese volume F taken at 0.2%, 0.3%, 0.4%, and 0.5%, respectively. The phosphorus axis of said volume terminates at a minimum of about 0.19% phosphorus and at a maximum of about 0.51% phosphorus. It will be likewise noted that this inner volume representing preferred compositions falls within the preferred ranges set forth hereinbefore, namely 0.19% to 0.51% phosphorus, 0.15% to 0.76% iron, and 0.47% to 0.94% manganese. As indicated hereinbefore, a point falling within the volume E defined by the areas bounded by lines A, B, C, and D in the drawing represents the percents by weight of the phosphorus, iron, and manganese permissible in the copper-alloy of this invention, which alloy after annealing and then cold working to about 70% reduction in thickness has the combination of an electrical conductivity of at least 50% I. A. C. S. with a tensile strength of at least 75,000 pounds per square inch. Similarly, a point within the inner volume F defined by the shaded portions of Figures 1 through 4 represents the percents by weight of manganese, iron and phosphorus permissible in the preferred copper-alloy composition, which alloy after annealing and then cold working to a reduction of about 70% in thickness has the combination of an electrical conductivity of at least 60% I. A. C. S. with a tensile strength of at least 80,000 pounds per square inch. Compositions represented by points falling outside these respective volumes have in general either a lower conductivity or a lower strength, or both.

In addition to the foregoing examples of copper base alloys of this invention there follows a table of some typical compositions which are illustrative of the invention and which when plotted as points fall upon the surface of or within either or both of the volumes E and F:

Example	Composition			Tensile (Strength) in p. s. i.	Conductivity, Percent I. A. C. S.
	Percent Phosphorus	Percent Iron	Percent Manganese		
1	0.38	0.40	0.51	81,500	54.2
2	0.34	0.45	0.72	80,000	64.5
3	0.32	0.35	0.67	81,700	61.0
4	0.29	0.52	0.75	81,100	51.5
5	0.28	0.41	0.97	78,500	54.4
6	0.22	0.14	0.66	80,500	57.7

It will be apparent that the alloying ingredients namely manganese, iron and phosphorus used with the copper are relatively inexpensive and that inasmuch as no age-hardening treatment is required in order to get the combination of strength and conductivity necessary, the elec-

trical connectors and the like provided in accordance with this invention are relatively inexpensive.

Referring to the drawing, Figures 5, 6 and 7, an electrical connector 1 is shown illustrating an embodiment of this invention. Such an electrical connector 1 is seated in each of the slightly larger diametered bores 2 of the radio or electronic tube socket 8. The bore 2 is provided with a shoulder 9 which prevents the connector 1 from being pushed completely down through the socket and the indent 6 on connector 1 engages the bottom of socket 8 to prevent the connector 1 from being pulled out of the bore 2. The wiring terminal portion 5 of the connector is perforated to facilitate soldered attachment to the wiring of any radio circuit. The expansible sleeve portion 7 is adapted for the reception of and frictional engagement with the terminal prong 3 of the radio tube 4. When made in accordance with this invention, the expansible sleeve portion 7 of the connector 1 has ample strength, resilience, and spring-like characteristics to expand and tightly engage the terminal prong 3. Such connectors may be formed, for example, by subjecting an ingot of the alloy to a series of hot and cold rolling treatments followed by annealing, as described hereinbefore, until the thickness is about three and one-third times that desired in the connector. The annealed sheet is then cold worked to final thickness, for instance about 0.015", and blanks of the desired shape stamped therefrom. The blanks are then perforated at 5, indented at 6, and bent to form the sleeve portion 7 of the electrical connector 1.

It is to be understood that small amounts of impurities may be permitted in the copper-manganese-iron-phosphorus alloy of this invention, provided such impurities are not present in sufficient amount to deleteriously alter the conductivity, strength and other desirable properties of the alloy. It is also to be understood that although the invention is described with particular reference to electrical connectors for electronic tubes, it may have other uses as connectors in switches and the like, all of which are contemplated to fall within the scope of the invention. Although many specific compositions and details are set forth in the foregoing, it will be understood that various changes may be made without departing from the spirit and scope of this invention and that this invention is therefore not to be limited to such compositions and details except as set forth in the appended claims.

This application is a continuation-in-part of our copending application Serial No. 112,223, filed August 25, 1949, now abandoned.

Having thus described the invention, what is claimed and desired to secure by Letters Patent is:

1. A cold-worked alloy characterized by having a phosphorus content of from about 0.16% to 0.58%, an iron content of from about 0.02% to 0.89%, and a manganese content of from about 0.27% to 1.12%, with the balance substantially copper.

2. A cold-worked alloy characterized by having a phosphorus content of from about 0.19% to 0.51%, an iron content of from about 0.15% to 0.76%, and a manganese content of from about 0.47% to 0.94%, with the balance substantially copper.

3. A cold-worked alloy characterized by having a phosphorus content of from about 0.33% to 0.36%, an iron content of from about 0.42% to 0.49%, and a manganese content of from about 0.67% to 0.72%, with the balance substantially copper.

4. An electrical conductor characterized by an electrical conductivity of at least 50% I. A. C. S., a tensile strength of at least 75,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.16% to 0.58% phosphorus, from about 0.02% to 0.89% iron, and from about 0.27% to 1.12% manganese, with the balance substantially copper.

5. An electrical conductor characterized by an electrical conductivity of at least 60% I. A. C. S., a tensile strength of at least 80,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.19% to 0.51% phosphorus, from about 0.15% to 0.76% iron, and from about 0.47% to 0.94% manganese, with the balance substantially copper.

6. An electrical conductor characterized by an electrical conductivity of at least 60% I. A. C. S., a tensile strength of at least 80,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.33% to 0.36% phosphorus, from about 0.42% to 0.49% iron, and from about 0.67% to 0.72% manganese, with the balance substantially copper.

7. An electrical conductor characterized by an electrical conductivity of at least 50% I. A. C. S., a tensile strength of at least 75,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.16% to 0.58% phosphorus, from about 0.02% to 0.89% iron, and from about 0.27% to 1.12% manganese, with the balance substantially copper, the percentages of phosphorus, iron and manganese corresponding to a point within the volume E of the three-dimensional diagram of Figure 8 of the drawings.

8. An electrical conductor characterized by an electrical conductivity of at least 60% I. A. C. S., a tensile strength of at least 80,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.19% to 0.51% phosphorus, from about 0.15% to 0.76% iron, and from about 0.47% to 0.94% manganese, with the balance substantially copper, the percentages of phosphorus, iron and manganese corresponding to a point within the volume F of the three-dimensional diagram of Figure 8 of the drawings.

9. An electrical conductor characterized by an electrical conductivity of at least 60% I. A. C. S., a tensile strength of at least 80,000 pounds per square inch, and formed of a cold-worked copper-base alloy composed of from about 0.33% to 0.36% phosphorus, from about 0.42% to 0.49% iron, and from about 0.67% to 0.72% manganese, with the balance substantially copper, the percentages of phosphorus, iron and manganese corresponding to a point within the volume F of the three-dimensional diagram of Figure 8 of the drawings.

10. An electrical conductor characterized by having a phosphorus content in the range of 0.13% to 0.58%, an iron content of from 0.15% to 0.76%, and a manganese content of from 0.47% to 0.94%, with the balance substantially copper, the percentages of phosphorus, iron and manganese corresponding to a point within the volume E of the three-dimensional diagram of Figure 8 of the drawings, said conductor having an electrical conductivity of at least 50% I. A. C. S., and a tensile strength of at least 75,000 pounds per square inch.

11. An electrical conductor characterized by having a phosphorus content in the range of from about 0.16% to 0.58%, an iron content of from 0.42% to 0.49%, and a manganese content of from 0.67% to 0.72%, with the balance substantially copper, the percentages of phosphorus, iron and manganese corresponding to a point within the volume F of the three-dimensional diagram of Figure 8 of the drawings, said conductor having an electrical conductivity of at least 60% I. A. C. S., and a tensile strength of at least 80,000 pounds per square inch.

12. The method of making an electrical conductor having an electrical conductivity of at least 50% I. A. C. S., and a tensile strength of at least 75,000 pounds per square inch, which comprises providing an alloy having a phosphorus content of from about 0.16% to 0.58%, an iron content of from about 0.02% to 0.89%, and a manganese content of from about 0.27% to 1.12%, with the balance substantially copper, and with the percentages of phosphorus, iron and manganese corresponding to a point within the volume E of the three-dimensional diagram of Figure 8 of the drawings, with an annealed structure and a dimension about three and one-third times that de-

sired for the conductor, and cold-working the alloy to a reduction in said direction of about 70%.

13. The method of making an electrical conductor having an electrical conductivity of at least 60% I. A. C. S., and a tensile strength of at least 80,000 pounds per square inch, which comprises providing an alloy having a phosphorus content of from about 0.33% to 0.36%, an iron content of from about 0.42% to 0.49%, and a manganese content of from about 0.67% to 0.72%, with the balance substantially copper, and with the percentages of phosphorus, iron and manganese corresponding to a point within the volume F of the three-dimensional diagram of Figure 8 of the drawings, with an annealed structure and a dimension about three and one-third times that desired for the conductor, and cold-working the alloy to a reduction in said direction of about 70%.

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