

March 14, 1961

W. C. ELLIS ET AL

2,974,778

LOW TEMPERATURE DRAWING OF METAL WIRES

Filed Sept. 12, 1951

FIG. 1

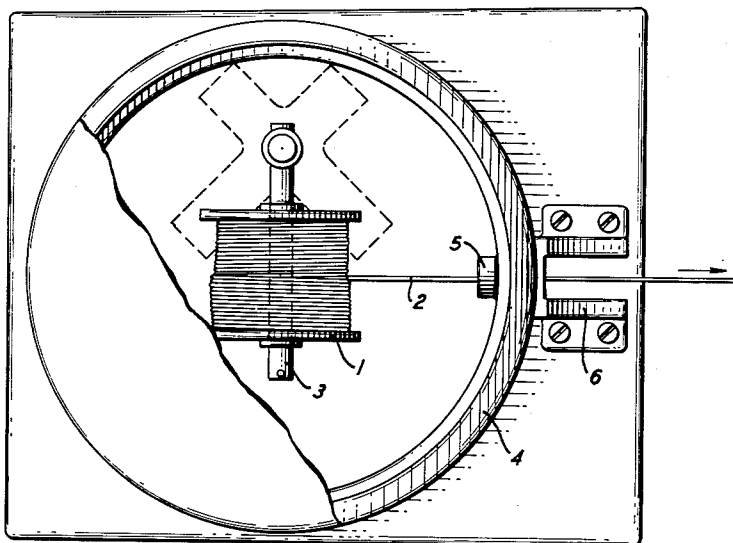
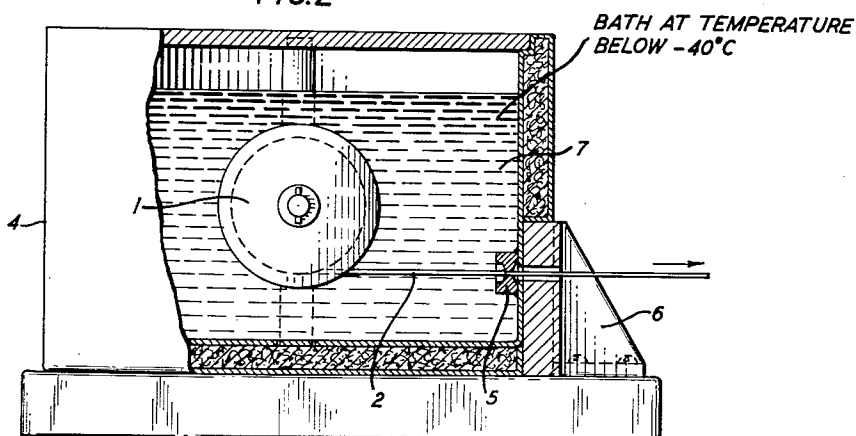


FIG. 2



INVENTORS W.C. ELLIS
E.S. GREINER
BY Edwin B. Cave
ATTORNEY

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LOW TEMPERATURE DRAWING OF
METAL WIRES

William C. Ellis, Maplewood, and Earl S. Greiner, Short Hills, N.J., assignors to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Sept. 12, 1951, Ser. No. 246,309

10 Claims. (Cl. 205—21)

This invention relates to methods of producing metal wires having improved mechanical properties and to wires so produced.

According to the invention, metal wires are drawn through drawing dies at temperatures below -40°C . and preferably below -60°C . It has been found that the wires produced in this manner from suitable metals have mechanical properties which are substantially better than those of similar wires drawn at conventional wire-drawing temperatures.

One manner in which this procedure can be carried out is shown in the accompanying drawing in which:

Fig. 1 is a plan view of apparatus for carrying out the wire-drawing of the present invention; and

Fig. 2 is a front elevation, in section, of the same apparatus.

In the apparatus shown in Figs. 1 and 2, a spool 1, having wound thereon a wire 2 which is to be drawn to a smaller diameter, is mounted on a spindle 3, suitably supported within a thermally insulated tank 4. A drawing die 5 is mounted on the wall of the tank and is braced by a supporting block 6. The wire 2 is drawn through the die 5 and passes to a take-up reel (not shown). The tank 4 is filled with a low temperature bath 7 which maintains the wire 2 and the die 5 at the temperatures required for the purposes of the present invention.

Metals having a close-packed atomic structure, namely those having a face centered cubic or a close-packed hexagonal crystalline structure, are sufficiently ductile to undergo drawing at the low temperatures at which the advantageous results of the present invention are obtained. The term metals, as used in this specification and in the appended claims, is to be understood as including alloys as well as single elemental metals.

Because of their widespread use as electrical conductors, copper and aluminum are particularly advantageous metals to be drawn into wires by the process of the present invention. Alloys of these metals, such as copper-beryllium and certain brasses and bronzes which possess a close-packed atomic structure, can also advantageously be used. Among other suitable metals may be mentioned nickel, titanium, silver, cobalt, palladium and platinum, as well as alloys of these metals with each other and with other face centered cubic or close-packed hexagonal metals. Similarly, alloys of these metals with metals from other crystalline systems, when these alloys retain the close-packed atomic structure, are suitable for use in the process of the present invention.

Inasmuch as the improvement in mechanical properties which results from drawing at the low temperatures referred to above is due to crystal deformation, it is apparent that in metals which recrystallize at room temperature or below, such as lead or zinc, any improvement in properties obtained by low temperature drawing will be lost by recrystallization when the drawn material is warmed to room temperature. The loss of its improved properties by the wire drawn at low temperatures can occur not only at or above the temperature of re-

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crystallization but also, at a slower rate, at temperatures somewhat below the temperature of recrystallization. Therefore, in order to achieve the advantageous results of the present invention, it is necessary that the metal which is drawn be one which recrystallizes at a temperature substantially above the temperature range to which the wire is to be subjected in normal use and, in any event, one which recrystallizes at a temperature substantially above room temperature, or about 25°C .

The degree to which this recovery of the metal occurs, with corresponding loss of improved properties, is dependent upon the purity of the metal. Thus a pure elemental metal shows a tendency to lose its improved properties at a temperature somewhat lower than does the same metal containing a substantial amount of impurities or alloying ingredients. In any event, it is desirable for the purposes of the present invention that the temperature of recrystallization of the metal employed be at least about 75°C ., preferably at least about 100°C . and more preferably at least 125°C . Metals, which in their pure state have lower recrystallization temperatures, may obviously be used in alloys where the alloys have suitably high recrystallization temperatures.

One of the most suitable sources of the low temperature for carrying out the drawing operation is solid carbon dioxide, having a temperature of -78°C . This material can be used by mixing it in comminuted form with a suitable heat transfer liquid to form the low temperature bath 7. Cellosolve acetate has been found to be a suitable liquid for mixing with the solid carbon dioxide. Any other liquid which does not attack the apparatus and which has a sufficiently low freezing point can be employed. By the use of such a low temperature bath, a drawing temperature of about -75°C . can readily be maintained in the metal.

Where lower drawing temperatures are desired, other low temperature baths can be employed. For instance, with liquid nitrogen as the low temperature bath, a drawing temperature of about -195°C . can be maintained.

The improvement in mechanical properties which is obtained is dependent upon the temperature at which the drawing takes place and upon the total decrease in cross-section accomplished by drawing. The improvement in properties, for any given area reduction, increases as the drawing temperature decreases. No substantial improvement over drawing at room temperature can be obtained by drawing at temperatures higher than about -40°C . Greater improvement, particularly at smaller area reductions, is obtained by drawing at temperatures below -60°C . As indicated above, one of the most practical operating temperatures is -75°C . The lower limit at which drawing can be carried out is set only by the difficulty of providing suitable apparatus.

At any given drawing temperature, the properties improve continuously with the degree of reduction in cross-sectional area, usually until an optimum degree of area reduction is reached, after which further area reduction may cause the properties to deteriorate somewhat below their optimum value. Drawing is carried out in the usual manner with any convenient area reduction, such as a reduction in area of between 1 percent and 20 percent, with each pass through a drawing die. The metal may be maintained at the low drawing temperature between passes through successive dies or may be allowed to warm to room temperature or any intermediate temperature between passes. To achieve the desirable result, it is only necessary that the low temperature be maintained during actual drawing.

The wire may be passed through successive dies until the total area reduction which is desired is obtained. At all degrees of area reduction, the metal drawn at the low temperatures is substantially superior in physical

properties to metal drawn at room temperature to a corresponding area reduction. However, it will ordinarily be desirable that the metal be drawn at low temperatures to an area reduction of at least 10 percent, and preferably at least 20 percent, in order to obtain an adequate improvement in physical properties to justify the low temperature drawing process. Substantially greater improvements in physical properties can be obtained by area reductions of at least 40 percent. With most metals, best results are obtained with area reductions between about 45 percent and about 85 percent. Greater area reductions, particularly with higher drawing temperatures such as between -60° and -40° C., will often be found desirable.

The effect of low temperature drawing upon relatively pure copper will illustrate the improved physical properties to be obtained by the process of the present invention with metals having a close-packed atomic structure and having recrystallization temperatures substantially above room temperature. Specimens of copper wire, 0.05 inch in diameter, in their annealed state possessed an ultimate strength of about 37,000 pounds per square inch (p.s.i.) a proportional limit of 13,000 p.s.i. and a yield strength (at 0.05 percent strain set) of 16,000 p.s.i. These wires were drawn, with reductions in diameter of 0.002 inch with each pass, through drawing dies until the desired total area reduction was achieved. With drawing at -195° C. the ultimate strength reached a value of 72,000 p.s.i. at an area reduction of 75 percent, representing a 26 percent higher value than was obtained by similar drawing at 25° C. With an area reduction of 51 percent, an ultimate strength of about 66,000 p.s.i. was obtained representing a value about 24 percent higher than that obtained by similar drawing at 25° C. At an area reduction of 22 percent, the value of ultimate strength was about 51,000 p.s.i. as compared with about 46,000 p.s.i. obtained by drawing at 25° C.

Similarly, the yield strength of the wire drawn at -195° C. reached a value of about 59,000 p.s.i. at an area reduction of 51 percent, representing an improvement of about 26 percent over the value obtained by drawing at 25° C.

Drawing at -75° C. gave an ultimate strength of 57,000 p.s.i. at an area reduction of 85 percent, representing a 22 percent improvement over that obtained by drawing at 25° C. Ultimate strengths of about 63,000 p.s.i. were obtained at a 74 percent area reduction and 60,000 p.s.i. at a 51 percent area reduction. Similarly, at an area reduction of 85 percent, a proportional limit of 52,000 p.s.i. was obtained as compared to a value of 43,500 p.s.i. obtained by drawing at 25° C. These improvements in physical properties by drawing at -75° C. were obtained with only a very small decrease in electrical conductivity below the values obtained by drawing at 25° C. Therefore, the drawing process of the present invention offers a means for providing copper wire, for overhead electrical lines, having substantially improved resistance to sagging due to temporary mechanical overload.

Similar improvements in physical properties are obtained by the low temperature drawing of the other metals referred to above.

The invention has been described in terms of certain specific embodiments and, to the extent that modifications and equivalents may be apparent to those skilled in the art, this description is intended to be illustrative of, but not necessarily to constitute a limitation upon, the scope of the invention.

What is claimed is:

1. The process which comprises drawing copper wire through a plurality of drawing dies having successively

smaller openings, while maintaining the temperature of the copper below -60° C. at the point of drawing until the cross-sectional area of the wire has been reduced by at least 20 percent.

2. The process of claim 1 wherein the copper is drawn at a temperature of about -75° C. and the area reduction is about 85 percent.

3. The process which comprises drawing a metal wire through a plurality of drawing dies having successively smaller openings, while maintaining the temperature of the wire below -60° C. at the point of drawing, until the cross-sectional area of said wire has been reduced by at least 40 percent, the metal of which said wire is formed being one which has a close-packed atomic structure, which has a recrystallization temperature of at least 100° C., and which consists essentially of at least one elemental metal, each said elemental metal being one which has a close-packed atomic structure.

4. The process which comprises drawing a metal wire through a plurality of drawing dies having successively smaller openings, while maintaining the temperature of the wire below -60° C. at the point of drawing, until the cross-sectional area of the wire has been reduced by at least 20 percent, the metal of which said wire is formed being one which has a close-packed atomic structure, which has a recrystallization temperature of at least 75° C., and the primary constituent of which is an elemental metal having a close-packed atomic structure.

5. The process of claim 4 wherein the metal of which the wire is formed is copper.

6. The process of claim 4 wherein the metal of which the wire is formed is aluminum.

7. The process of claim 4 wherein the metal of which the wire is formed is nickel.

8. The process of claim 4 wherein the metal of which the wire is formed is titanium.

9. The process of claim 4 wherein the metal of which the wire is formed is a copper-beryllium alloy.

10. In a wire drawing process in which a wire of a metal is cold drawn, which metal has a close-packed atomic structure and a recrystallization temperature of at least 75° C., and in which process any increase in tensile strength, upon cold drawing, is caused by crystal deformation, the improvement which consists in drawing said wire through at least one drawing die while maintaining said wire at a temperature below -40° C. at the point of drawing, wherein the metal of which the wire is composed has a close-packed hexagonal crystalline structure.

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