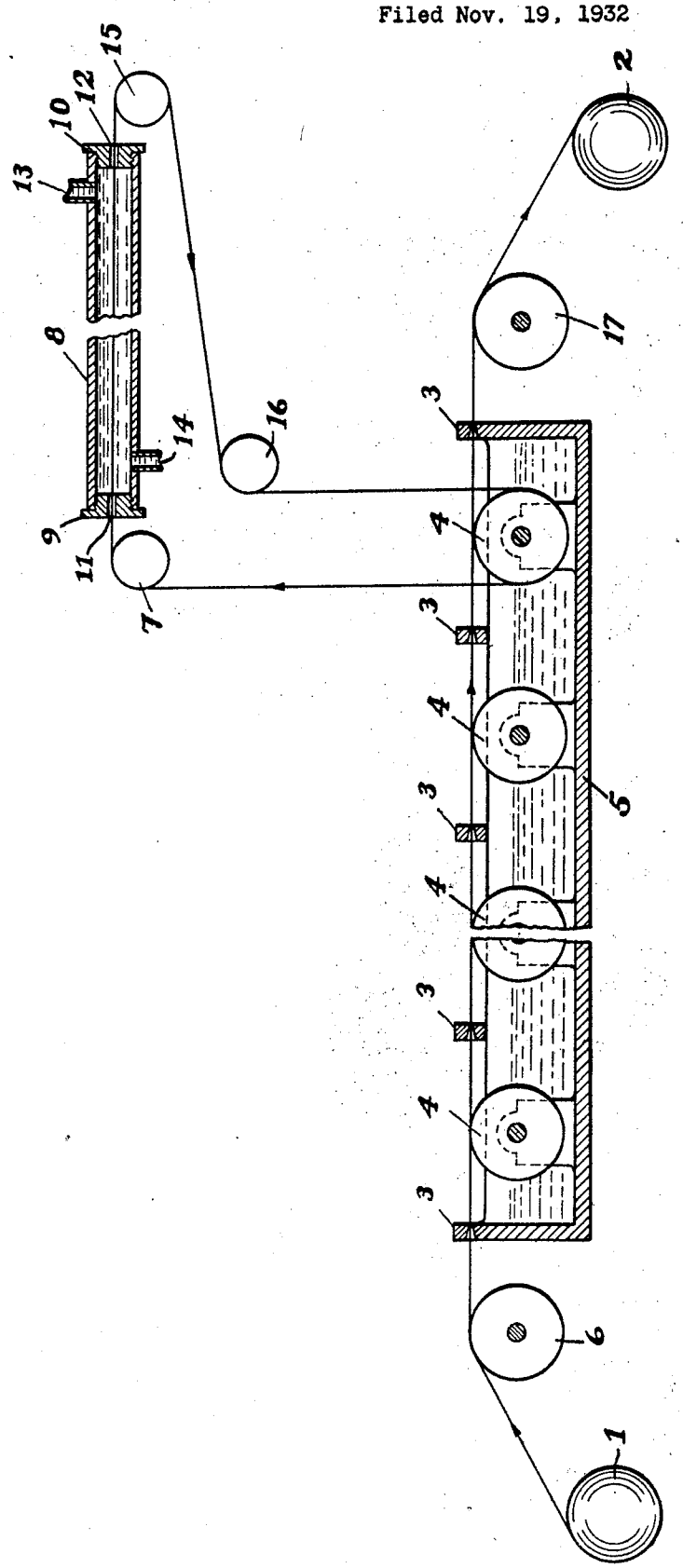
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METHOD OF METAL WORKING

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METHOD OF METAL WORKING

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This invention relates to the manufacture of aluminum products of small cross section and relatively extreme length, such as wire, small rod, ribbon and the like, by continuous cold working methods. In particular the invention relates to improved methods of this type by which the ductility of the aluminum is maintained to the extent that the final product is of comparatively high ductility.

The cold working of aluminum involves problems not encountered in the hot working of the metal. Hot working, as that term is used, denotes a working operation in which the principal deformation of the metal is accomplished with the metal heated to such temperatures that the grains of the metal reform or recrystallize. The recrystallization temperature range of a metal is the approximate boundary, therefore, between hot working and cold working; the one being carried out above and the other being carried out below that temperature range. Thus metal which is being hot worked retains its ductility and does not, relatively speaking, increase substantially in tensile strength. On the other hand, metal which is being cold worked decreases in ductility and materially increases in tensile strength since a substantial annealing effect is not exerted on the metal by the temperatures developed during working. This is not to say, however, that the cold worked metal does not become warm or even hot, the fact being that the heat induced in the metal by the cold working operation often causes the metal temperature to rise considerably but not to temperatures which lie above the recrystallization temperatures.

The propensity of aluminum to lose ductility during cold working is accentuated when that metal is worked in processes which comprise continuously, and usually rapidly, passing the metal through successive reducing mechanisms such as dies. While the heat generated in such processes may raise the metal temperature as high as 300° Fahrenheit or thereabouts, the recrystallization temperatures of the aluminum are not exceeded and the metal gradually loses ductility and gains in tensile strength. The final product of such processes is often deficient in ductility.

The general and leading object of this invention is the provision of a process of continuously cold working aluminum into a product of relatively small cross section and relatively extreme length which is, at once, of adequate ductility and adequate tensile strength.

The invention is predicated upon the discovery that when aluminum which is being continuously cold worked is subjected, between successive working steps in continuous working processes, to the action of a cooling medium and a substantial portion or all of the heat induced in the metal by working removed thereby, the ductility of the final metal product is increased. This increase in ductility caused by cooling the aluminum during working is contrary to the accepted laws of metal working which would indicate that a decrease rather than an increase of ductility of the metal would be expected and that any increase in ductility would be caused by a heating rather than a cooling of the metal.

The invention therefore contemplates processes of maintaining the ductility of aluminum as it is worked to a product of small cross section and extreme length which comprise continuously working the metal at temperatures below the temperature at which substantial metal recrystallization takes place, to a cross section greater than that finally desired, removing a substantial portion of the heat induced in the metal by such working and then working the metal to a product of desired cross section. This remarkable effect upon the ductility of the cold worked aluminum can apparently be obtained to the greatest extent as the metal is subjected to the cooling medium between the final die or working step and the die previous thereto, but it has been observed that a beneficial effect can be produced upon the ductility of the cold worked aluminum if the cooling medium be applied to the metal between successive dies which are comparatively remote in the process from the final die. The type of cooling medium employed is not important provided that it has sufficient effect upon the metal passing through it to transfer therefrom a substantial proportion of heat. Water will, in normal practice, be most convenient. While a continuous process is contemplated because it is in connection with such processes that serious loss of ductility is noted, a variation of such processing by coiling the metal after it leaves the continuous process, cooling it, and drawing it to final size through a detached die will produce some results but at a greater cost. The metal is usually cooled by the action of the cooling medium to room temperature or below and this is the preferred practice, but any substantial amount of cooling, such as from 300° Fahrenheit to below 200° Fahrenheit, will produce a marked beneficial effect on the ductility of the final aluminum product. The amount of cooling which will produce the most pronounced effect upon the

ductility of the finished product may be determined by experiment and will usually be found to be about room temperature.

In order to fully explain the remarkable results obtained by the practice of this invention, it is convenient to refer to the accompanying drawing in which is illustrated in schematic outline, a machine such as may be used in the continuous production of aluminum wire.

Referring to the drawing, a multiple die, tandem wire-drawing machine is illustrated, the purpose of the machine being to reduce, by a continuous drawing operation, aluminum wire supplied from a reel 1 located adjacent the feed end of the machine and to subsequently collect or coil the same upon a reel 2 adjacent the discharge end of the machine, after the wire has been drawn through a plurality of reducing dies 3 in the direction indicated by the arrows. The machine comprises in its organization the aforementioned dies 3 between each pair of which a power-driven sheave or drum 4 is suitably mounted. The sheaves 4 are operated at progressively higher speeds in a direction from the feed end of the machine toward the discharge end thereof to compensate for the elongation of the wire as it is progressively reduced in cross section by each of the dies 3. Preferably the sheaves 4 are mounted within a suitable lubricating bath 5 through which the aluminum wire or stock is permitted to pass in its contact with the sheaves 4.

In the operation of the machine the aluminum wire is threaded over a suitable guide pulley or sheave 6, through the initial die 3, and is thereafter given one or more wraps around the initial sheave 4. This procedure is followed at each subsequent die and sheave until the wire has reached the die preceding the last die in the machine. At this point the wire is taken off the sheave 4 and is threaded through the pulley 7 from whence it passes through a cooling apparatus in the form of a tubular member or pipe 8 provided with suitable end closure members 9 and 10 provided with ports 11 and 12 for the entrance and exit, respectively, of the wire. In the illustration shown, a liquid cooling medium, such as water or the like, is supplied to the pipe 8 through the conduit 13 and is permitted to leave through the conduit 14. It is to be understood, however, that any other suitable cooling medium may be advantageously employed. The wire leaves the pipe 8 and is directed over guide pulleys 15 and 16 and is thereafter again wrapped around the sheave preceding the last die prior to passing through this die. A final power-driven sheave 17 located outside the lubricating bath 5 draws the wire through the final die prior to its being coiled upon the collecting reel or spool 2.

It will be understood that the apparatus selected for purposes of illustrating the invention is not to be considered a part thereof and that numerous other schemes of a similar nature may be conveniently employed to obtain the advantages of the invention.

As illustrating the beneficial effects of the invention there may be chosen the continuous production by cold working of aluminum conductor wire, since the production of this particular product embodies in high degree the disadvantages which the invention is designed to overcome. Aluminum conductor wire must be, at once, of good strength and good ductility. The strength necessary in the product can be obtained only by hardening the metal by cold working and it is necessary that this strength be obtained without too much sacrifice of the important ductile properties of the metal. Heretofore, when such wire was produced on continuous wire drawing machines by cold working, the ductility of the final product was found to be below the standards which must necessarily be met in many instances. The ductility of the wire could be increased by annealing treatments but only at the expense of the likewise important tensile strength of the wire. By the processes of the present invention, an aluminum conductor wire product, satisfactory as to both tensile strength and ductility, can be readily and economically produced. For example, an aluminum wire 0.375 inch in diameter and annealed at temperatures of about 445 to 460° Fahrenheit was continuously drawn to wire of 0.113 inch in diameter on a tandem multiple die drawing machine similar to that schematically shown in the drawing. Two types of procedure were used. In one case, the metal was drawn directly through the dies without intermediate cooling. In the other case, the procedure was the same with the important exception that the wire was passed through a cooling medium, as previously explained with reference to the drawing, between the final die and the die previous thereto. In each case, more than 290 different coils of wire were produced and tested. The results of the tests are set forth in the table.

Method of production	Number of coils tested	Average elongation % in 10 inches
Wire produced by continuous drawing without intermediate cooling	294	1.92
Wire produced by continuous drawing with intermediate cooling	473	2.55

By reference to the table, it will be noted that wire produced according to the practice of the invention had an elongation (a measure of ductility) about 32.8 per cent greater than the elongation of the wire produced in accordance with prior practice.

The differences between the wire produced in accordance with the invention and that produced without intermediate cooling are further shown in an analysis of the properties of the individual coils of wire, the average properties of which are shown in the table. Of the coils of wire produced in accordance with prior practice, 10.0 per cent had an elongation less than 1.7 per cent in 10 inches. On the other hand, of the coils of wire produced in accordance with the invention, only 0.4 per cent had an elongation less than 1.7 per cent in 10 inches.

The advantages which are attendant upon the practice of the invention herein described are amply illustrated in the foregoing examples and their importance is evident. It will be understood that the examples herein given are by way of example only and the invention is not limited thereby except as expressed in the appended claims.

I claim:

1. The method of maintaining the ductility of aluminum as it is worked to a product of small cross section and extreme length which comprises continuously working the metal, at a temperature below the temperature at which substantial metal recrystallization takes place, to a cross section greater than that finally desired, removing a substantial portion of the heat induced in the metal

by such working and then working the metal to a product of desired cross section.

2. The method of maintaining the ductility of aluminum as it is worked to a product of small cross section and extreme length which comprises continuously working the metal, at a temperature below the temperature at which substantial metal recrystallization takes place, to a cross section greater than that finally desired, removing the heat induced in the metal by such working and then working the metal to a product of desired cross section.

3. The method of producing continuously drawn aluminum wire of high ductility comprising continuously drawing the wire at a temperature below the temperature at which substantial recrystallization of the aluminum takes place and to a size greater than the final size desired, removing a substantial portion of the heat induced in the wire by such drawing operations, and then drawing the wire to the final size desired.

4. A method of producing continuously drawn aluminum wire of high ductility comprising continuously drawing the wire at temperatures below the recrystallization temperature of aluminum and to a size greater than the final size desired, cooling the wire, and thereafter drawing the wire to final size.

5. The method of maintaining the ductility of aluminum as it is continuously cold drawn through a plurality of dies to produce a product of small cross section and extreme length, said method comprising working the metal, at a temperature below the temperature at which substantial metal recrystallization takes place, to a cross section greater than that finally desired, and thereafter subjecting the metal to a cooling medium between the final die and the die previous thereto.

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