May 19, 1942. F. F. FOWLE ET AL 2,283,868

HOT-GALVANIZED CARBON-STEEL ALTERNATING-CURRENT CONDUCTOR

Original Filed May 11, 1938

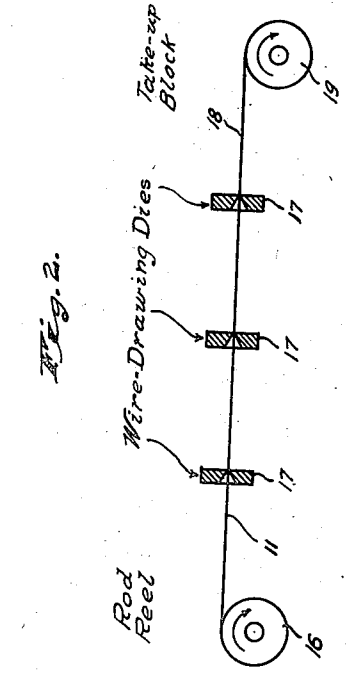


Fig. 2.

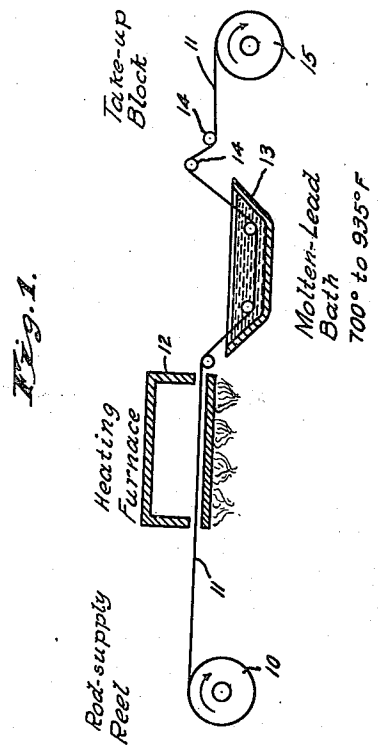


Fig. 1.

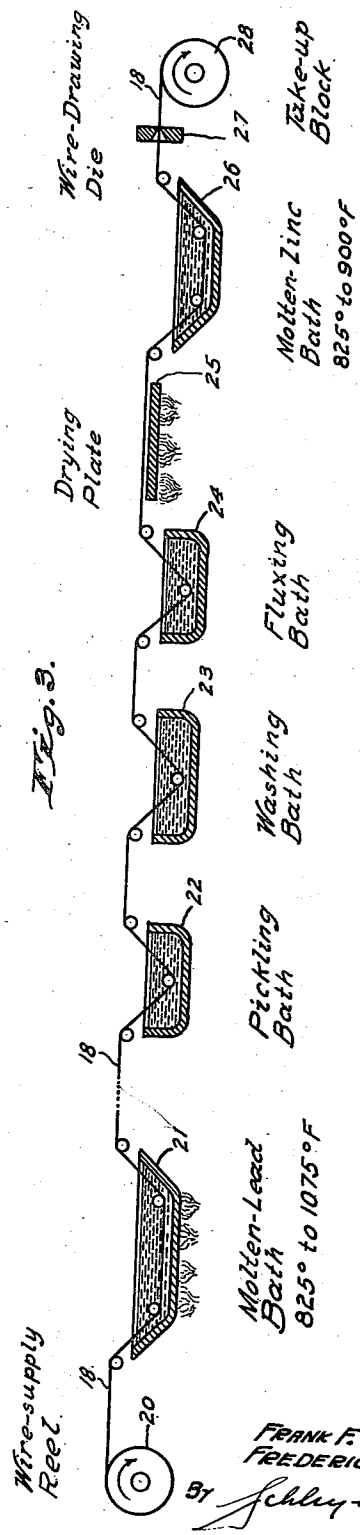


Fig. 3.

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Patented May 19, 1942 2,283,868

UNITED STATES PATENT OFFICE

2,283,868

HOT-GALVANIZED CARBON-STEEL ALTERNATING-CURRENT CONDUCTOR

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Original application May 11, 1938, Serial No. 207,351. Divided and this application February 13, 1939, Serial No. 256,112

5 Claims. (Cl. 174—134)

Our invention relates to hot-galvanized carbon-steel alternating-current conductors.

This present application is directed to the product. The process for making that product is set forth in our copending application Serial No. 207,351, filed May 11, 1938; and the present application is a division of that co-pending application Serial No. 207,351, filed as a division in response to a requirement by the Patent Office.

The object of our invention is to produce a carbon-steel conductor which is of a type suitable for overhead alternating-current transmission lines and which has an adherent hot-galvanized zinc coating. The term "alternating current" is used to include pulsating current.

The carbon-steel alternating-current conductor contemplated by the present application, for use in an overhead electric transmission line, is of hypo-eutectoid steel which contains at least 0.25% of carbon, not in excess of 0.30% of manganese, and silicon and phosphorus in sufficient amount to make a combined total of at least 0.05% but with the silicon not above 0.25% and desirably not above 0.15% and with the phosphorus not above 0.12%; and our invention contemplates such a conductor with high tensile strength and adequate elongation and with an effectively adherent hot-dip zinc coating.

We produce such a hot-galvanized carbon-steel conductor by the process set forth in the aforesaid co-pending application Serial No. 207,351. That process involves the following steps: We start with a hot-rolled hypo-eutectoid carbon-steel rod having the desired analysis—carbon above 0.25% but below the eutectoid point of 0.85%, manganese not in excess of 0.30% and desirably as low as possible within that range, silicon and phosphorus in sufficient amount to make a combined total of at least 0.05% but with the silicon not above 0.25% and desirably not above 0.15% and with the phosphorus not above 0.12%, sulfur low although not necessarily absent, and some copper present if it is desired to have a copper-bearing steel. We first "patent-anneal" such a rod (and by the term "rod" we include the larger wires which may have been produced from the original rod by not over one or two passages through wire-drawing dies); by heating it to a temperature above the critical range, and then quenching it through the critical range in a molten-material bath (as of molten lead or molten salt) having a temperature between 700° and 935° F. The patent-annealed rod, after suitable pickling and other preparation for wire-drawing, is then drawn to a wire of the desired size or substantially the desired size. This drawing usually produces a rather high tensile strength, perhaps of the order of 150,000 to 200,000 pounds per square inch; but this high tensile strength is accompanied by an undesirably low elongation, of the order of about 1% to 2% (measured in 10-inch lengths). The wire in this condition has undesirably low ductility for a conductor of an overhead electric transmission line.

To increase that ductility, and at the same time to increase that elongation, to desirable values, we now carefully process-temper the wire. To that end we carefully heat that wire to a selected temperature, which is well below the critical temperature. That selected temperature may vary somewhat, as with the analysis of the wire, being higher (other things being equal) for increased carbon content; and it may also vary according to the tensile strength and the elongation desired, being higher for greater elongation and less tensile strength. That temperature is between 825° and 1075° F. It is obtained most conveniently by passing the wire through a molten-lead or molten-salt bath of the desired temperature. After the wire has reached this selected temperature, it is then allowed to cool, as by being passed through the air; and is then desirably passed through various baths in preparation for zinc-coating, usually including a pickling bath, one or more water-washing baths, and a fluxing bath.

Then, after being dried, the wire is passed through a molten-zinc bath of relatively low temperature, of the order of 825° to 900° F., in which bath the wire takes on a hot-dip zinc coating. If desired, the wire may be further slightly drawn following the zinc coating, although we prefer not to do that.

The accompanying drawing illustrates an apparatus in which the process is performed for producing the carbon-steel alternating-current conductor contemplated by the present application. In such drawing: Fig. 1 is a diagrammatic view showing the patent-annealing step; Fig. 2 is a diagrammatic view showing the wire-drawing step or steps; and Fig. 3 is a diagrammatic view showing our special heat-treating step and the hot-galvanizing step, with some intervening steps.

The hot-rolled wire rod of the desired analysis, outlined above, is obtained from a rolling mill. This requires special heats of steel to get that desired analysis—selected between 0.25% and 0.85% carbon, between zero and 0.30% man-

ganese, at least 0.05% combined silicon and phosphorus but not above 0.25% and desirably not above 0.15% silicon and not above 0.12% phosphorus, suitably little sulfur, and if desired some copper.

A coil of rod, after some preliminary drawing if desired, is put on a supply reel 10, from which the rod 11 passes through a heating furnace 12, suitably heated so that the rod is raised to a temperature above the critical temperature range. From the heating furnace, the rod 11 is passed directly into a molten-material bath 13 (as of molten lead or molten salt) in which the temperature of the molten material is maintained at the desired temperature—between 700° and 935° F. From the molten-material bath 13, the rod 11, after passing if desired over reverse rollers 14 to remove scale, passes to a take-up block or reel 15.

The patent-annealed rod 11 is then removed from the take-up block 15, suitably cleaned and otherwise prepared for drawing, and put on a supply reel 16; from which it is fed through wire-drawing dies 17, in which the rod 11 is drawn to a wire 18. The wire is pulled through the dies 17 by a take-up block 19, on which the drawn wire is coiled. If there are a large number of wire-drawing dies 17, as there may be when the wire 18 is drawn to small diameter from a large rod, it may be desirable to do the wire-drawing in several steps; and even to repeat the patent-annealing at an intermediate stage in the drawing of the wire, with the quenching temperatures as set forth above, as in the apparatus shown in Fig. 1.

When the wire 18 has been drawn to the proper size, it is removed from the take-up block 19 and put on a wire-supply reel 20; from which it is fed to obtain the special process-tempering and then the zinc coating. To this end, the wire 18 passes from the wire-supply reel 20 into a molten-lead or molten-salt bath 21, in which the lead or salt is maintained at a temperature between 825° and 1075° F. For higher carbon contents the temperature of the molten lead or molten salt is usually in the upper part of this range, while for lower carbon contents it is usually in the lower part thereof. The molten lead or molten salt in the bath 21 is a temperature-raising liquid, as distinguished from the temperature-lowering liquid of the lead or salt of the bath 13.

The wire 18 before it is passed into the molten-material bath 21 has a very high tensile strength, but its elongation and its ductility are too low. In the molten-material bath 21 there is a tempering action that is very carefully controlled, both by the temperature of the molten material and by the duration of immersion of the wire in such molten material, to increase the ductility and the elongation to desired values without lowering the tensile strength too greatly. The duration of immersion, in continuous process, is controlled by the length of the molten-material bath and by the speed of the wire through the bath. By careful selection of the temperatures within the range indicated, it is possible to keep the tensile strength above 120,000 pounds per square inch, and in most cases above 135,000 pounds per square inch, and yet to increase the elongation to a final value of the order of 4% to 8%. With such tensile-strength and elongation values, the wire is eminently suitable for use as an alternating-current conductor in an overhead electric transmission line.

After passing through the molten-material bath 21, the wire 18 is passed through the air to cool it, and then may be passed successively through various baths in preparation for hot-dip zinc-coating. Such preparatory baths may include a pickling bath 22, a washing bath 23 containing washing water, and a fluxing bath 24 containing a suitable fluxing liquid (such as ammonium chloride); after which it is desirably passed over a drying plate 25, and thence into a molten-zinc bath 26 in which it takes on a coating of zinc. The temperature of the molten zinc is of the order of 825° to 900° F., and desirably between 840° and 860° F. The zinc coating taken on in the molten-zinc bath 26 is an adherent zinc coating, for we have found that such adherence is effectively obtained with the steel composition specified above. From the molten-zinc bath 26, the wire may pass if desired through another wire-drawing die 27, although this is frequently omitted. Whether or not there is this additional wire-drawing die 27, the wire 18 finally passes to a take-up block 28, which furnishes the power for pulling the wire through all the apparatus shown in Fig. 3.

The operation of patent-annealing described above serves a double useful purpose; first, it imparts to a steel rod a sorbitic structure which increases the toughness of the rod and its ability to withstand shock; second, it lowers the magnetic permeability of the rod when traversed by electric currents, and this in turn lowers the skin effect with alternating currents and so lowers the effective alternating-current resistance and reactance of the finished conductor. The operation of process-tempering in molten material, after drawing, at a temperature between 825° and 1075° F., tempers the extreme hardness produced by the cold-working involved in that drawing, and imparts the ductility and elongation desirable for an electrical conductor used in overhead spans of an outdoor transmission line. This process-tempering, in order to accomplish our desired purpose, must avoid both too much annealing as well as too little annealing; because in the former case the conductor would have inadequate tensile strength, and in the latter case it would have too little ductility and elongation. We accomplish this desired result by the control of the temperature limits in the process-tempering bath, as above described.

We claim as our invention:

1. A carbon-steel alternating-current conductor having lowered magnetic permeability and lowered skin effect, resulting in lowered effective alternating-current resistance and reactance, which conductor has an adherent hot-galvanized zinc coating and is made of hypo-eutectoid steel containing at least 0.25% of carbon, not in excess of 0.30% of manganese, and enough silicon and phosphorus to make a combined total of at least 0.05% but with silicon not in excess of 0.25% and phosphorus not in excess of 0.12%, and which has a sorbitic structure, and which has been subjected to cold-working and to subsequent partial annealing by which the effects of the cold-working have been partially but only partially eliminated so that effects of that cold-working in part persist, and which has a tensile strength above 120,000 pounds per square inch and an elongation of the order of 4% to 8%.

2. A carbon-steel alternating-current conductor having lowered magnetic permeability and lowered skin effect, resulting in lowered ef-

fective alternating-current resistance and reactance, which conductor has an adherent hot-galvanized zinc coating and is made of hypo-eutectoid steel containing at least 0.25% of carbon, not in excess of 0.30% of manganese, and enough silicon and phosphorus to make a combined total of at least 0.05% but with silicon not in excess of 0.25% and phosphorus not in excess of 0.12%, and which has persisting in its grain structure mechanical and electrical-resistance and electrical-reactance effects produced (*a*) by quenching through the critical range in a bath of molten material having a temperature between 700° and 935° F., (*b*) by cold-working, and (*c*) by subsequent partial-annealing.

3. A carbon-steel alternating-current conductor having lowered magnetic permeability and lowered skin effect, resulting in lowered effective alternating-current resistance and reactance, which conductor has an adherent hot-galvanized zinc coating and is made of hypo-eutectoid steel containing at least 0.25% of carbon, not in excess of 0.30% of manganese, and enough silicon and phosphorus to make a combined total of at least 0.05% but with silicon not in excess of 0.25% and phosphorus not in excess of 0.12%, and which has a sorbitic structure, and which has a tensile strength above 120,000 pounds per square inch and an elongation of the order of 4% to 8%.

4. A carbon-steel alternating-current conductor having lowered magnetic permeability and lowered skin effect, resulting in lowered effective alternating-current resistance and reactance, which conductor has an adherent hot-galvanized zinc coating and is made of hypo-eutectoid steel containing at least 0.25% of carbon, not in excess of 0.30% of manganese, and enough silicon and phosphorus to make a combined total of at least 0.05% but with silicon not in excess of 0.25% and phosphorus not in excess of 0.12%, and which has persisting in its grain structure mechanical and electrical-resistance and electrical-reactance effects produced by quenching through the critical range in a bath of molten material having a temperature between 700° and 935° F., and which has been subjected to cold-working and to subsequent partial annealing by which the effects of the cold-working have been partially but only partially eliminated so that effects of that cold-working in part persist, and which has a tensile strength of above 120,000 pounds per square inch.

5. A carbon-steel alternating-current conductor having lowered magnetic permeability and lowered skin effect, resulting in lowered effective alternating-current resistance and reactance, which conductor has an adherent hot-galvanized zinc coating and is made of hypo-eutectoid steel containing at least 0.25% of carbon, not in excess of 0.30% of manganese, and enough silicon and phosphorus to make a combined total of at least 0.05% but with silicon not in excess of 0.25% and phosphorus not in excess of 0.12%, and which has a sorbitic structure, and which has been subjected to cold-working and to subsequent partial annealing by which the effects of the cold-working have been partially but only partially eliminated so that effects of that cold-working in part persist.

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