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OVERHEAD ELECTRIC TRANSMISSION LINE

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Overhead electric transmission line, of cold-drawn carbon-steel conductor, patent-annealed before cold-drawing if desired. The carbon content of this conductor is less than 0.25%, not less than 0.12%, and preferably not less than 0.15%; and the manganese content thereof is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%, and advantageously is not in excess of the carbon content and is such that the sum of the carbon content and the manganese content is not in excess of 0.40%.

Fig. 1.

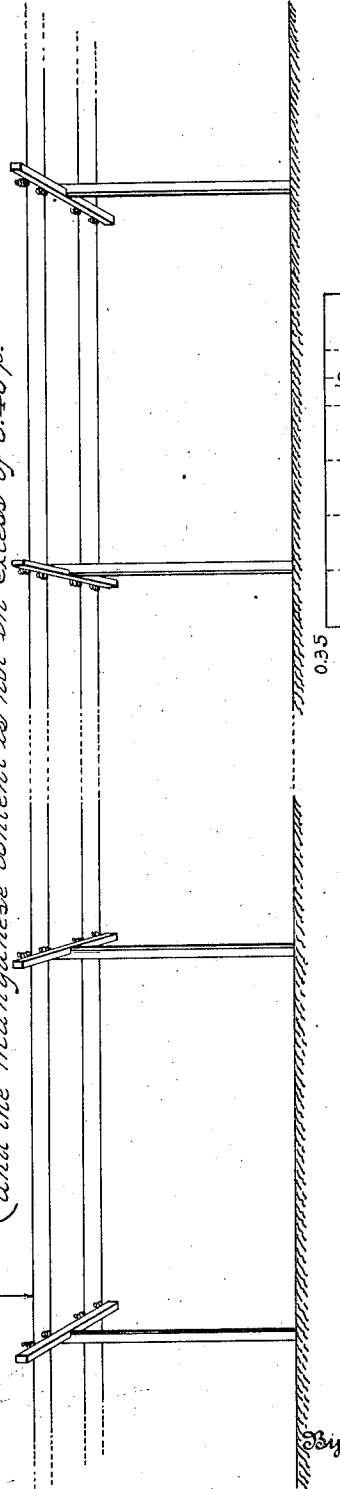
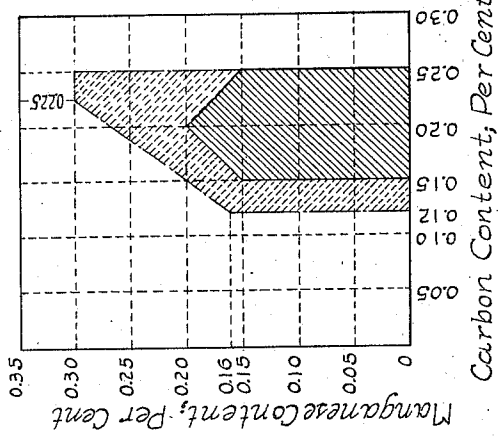


Fig. 2.

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OVERHEAD ELECTRIC TRANSMISSION LINE

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10 Claims. (Cl. 173-13)

My invention relates to overhead electric transmission lines using ferrous conductors, with particular reference to a—c. transmission lines although my invention is not limited to a—c. lines.

5 My invention is applicable for instance, for power lines, telephone lines, telegraph lines, signal lines, etc., and is of especial value for telephone transmission lines; and the conductors involved may be not only the wires of the transmission circuit proper, but also include various ancillary conductors, such as ground wires, shield wires, messenger cables, catenary supports, etc., which may be primarily for other than conducting purposes and/or may actually serve to conduct current only occasionally. Therefore, by the term "overhead electric transmission line", I mean an overhead line which may be required to carry electric current; and by the terms "ferrous conductor" or "carbon-steel conductor" I mean a conductor which may be required to serve as a current-carrier for an electrical system and of which the cross-section is mainly of ferrous material, specifically carbon steel in my invention, and any coating (as of zinc or copper) is a relatively small part of the cross-section. The term "carbon steel" is used in its accepted sense, (as shown by "The Making, Shaping, and Treating of Steel", by Camp and Francis, published by the Carnegie Steel Company, Fourth Edition, pages 259 and 707, generally accepted as authoritative,) as meaning steels in which carbon is the element fundamentally employed to control physical properties; and in which the manganese is less in amount than about 1.0%, although in previous hypo-eutectoid carbon steels it has usually been greater in amount than the carbon.

It is the object of my invention to produce a transmission line of carbon-steel conductor (uncoated or coated as with zinc or copper) which has its tensile strength and its electrical conductivity both relatively high. Generally in the prior art an increase in tensile strength in ferrous conductors has been obtained at the cost of decreased electrical conductivity, and an increase in electrical conductivity at the cost of decreased tensile strength; but by my invention I am able to get both relatively high.

The accompanying drawing illustrates my invention: In such drawing, Fig. 1 is a diagrammatic view of an overhead electric transmission line, of ferrous conductor, in accordance with my invention, the particular character of ferrous conductor being indicated by a legend on the drawing; and Fig. 2 is a diagram showing the contents of carbon and manganese in such fer-

rous conductor, the area in solid-line cross-hatching indicating the preferred area, and the area in broken-line cross-hatching indicating a permissive area.

Heretofore the ferrous conductors in general use for telephone, telegraph, and signal lines, and in some instances for power lines, have been of three general commercial grades known as "E. B. B." (Extra Best Best), "B. B." (Best Best), and "Steel". Approximate tensile strengths and d—c. resistivities of these grades are as follows:

Grade	Approximate d—c. resistivity in ohms per mile-pound	Approximate tensile strength in pounds per square inch
E. B. B.	4850	45,000
B. B.	5800	51,000
Steel.....	6750	55,000

Three other commercial grades of ferrous conductors have also been used in some instances for power lines; especially for overhead ground wires and/or shield wires, and for long spans such as wide river crossings. These other three grades are commonly known as "Siemens-Martin", "High strength", and "Extra-high strength", and are named in the order of increasing tensile strengths and d—c. resistivity. Approximate tensile strengths and d—c. resistivities of these three grades are as follows:

Grade	Approximate d—c. resistivity in ohms per mile-pound	Approximate tensile strength in pounds per square inch
Siemens-Martin.....	7280	90,000
High strength.....	8320	140,000
Extra-high strength.....	9360	200,000

In all the grades known as "Siemens-Martin", "High strength", and "Extra-high strength", the advantages of increased tensile strength have been obtained at the sacrifice of electrical conductivity; so that while the tensile strengths of such grades are substantially greater than those of "E. B. B.", "B. B.", or "Steel", above mentioned, their electrical conductivities are substantially less. Such increased tensile strengths have been obtained fundamentally by making the wires of steels which have high contents of carbon, and/or to some extent and in some cases by heat treatment and/or by cold-working the material in the process of wire drawing.

In the carbon-steel conductors of the prior art

of overhead electric transmission, however, the carbon content and the manganese content and the relation between them have been such that when an increase in tensile strength has been obtained it has been at the cost of a decrease in electrical conductivity. Generally speaking, increases in tensile strength have been obtained by increasing both the carbon content and the manganese content, with the manganese content generally materially exceeding the carbon content until the carbon rises well above 0.25%; for manganese is qualitatively like carbon in that an increase in it tends to increase the tensile strength.

Both an increase in carbon and an increase in manganese, however, not only tend to increase tensile strength but also tend to increase d-c. resistivity. But the effects of increases in carbon and manganese, respectively, differ as between themselves in their effects on tensile strength and on electrical conductivity; for the addition of carbon to carbon steel increases tensile strength in proportionately greater degree but increases d-c. resistivity in proportionately less degree than does the addition of an equal amount of manganese, and, conversely, the elimination of manganese decreases tensile strength in proportionately less degree but decreases d-c. resistivity in proportionately greater degree than does the elimination of an equal amount of carbon.

Heretofore high manganese has in general been assumed to be necessary in any medium-carbon and higher-carbon steels used in transmission lines, for various reasons and especially for cleansing the steel in the process of manufacture; and its effect in increasing the d-c. resistivity, if considered at all, either was deemed not seriously objectionable or was considered unavoidable.

I have done some previous work, partly in connection with Frank F. Fowle, in overcoming the difficulties of the general prior art referred to above; and either alone or jointly with him have filed certain patent applications relating thereto, as follows:

A. In the Crapo Patent No. 1,942,441, granted January 9, 1934, there is described a carbon-steel conductor in which the carbon content is not less than 0.25%.

B. In the co-pending Fowle & Crapo application, Serial No. 705,830, filed January 8, 1934, now Patent No. 2,019,447, granted October 29, 1935, there is described a carbon-steel conductor in which the carbon content is not less than 0.25%, and the manganese content is not in excess of 0.30%.

C. In the co-pending Crapo application, Serial No. 705,831, filed January 8, 1934, now Patent No. 2,019,445, granted October 29, 1935, there is described a carbon-steel conductor in which the carbon content is less than 0.50%, the manganese content is less than 0.30% when the carbon content exceeds 0.25%, and the carbon steel has the characteristics which are produced by quenching from above a critical temperature by a liquid medium having a temperature below the melting point of lead.

According to my present invention, the carbon-steel conductor has a carbon content of less than 0.25% and not less than 0.12%, and has a manganese content which is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%. In addition, I find it advantageous that such carbon content shall be not less than 0.15%, that such manganese content

shall be not in excess of the carbon content, and that the sum of the carbon content and the manganese content shall be not in excess of 0.40%. The conductor may have any suitable metallic protective coating, applied in any desired way, as by hot-dipping or by electro-deposition.

In addition to providing contents of carbon and manganese as above defined, I subject the carbon-steel conductor to cold working, most conveniently cold drawing, to produce an increased tensile strength. The amount of the cold working may vary, but my invention contemplates that there shall be at least some cold working either before or after the application of any protective metallic coating, and that effects of cold working shall persist in the final conductor.

The cold working may if desired be preceded by any desired annealing, either partial or complete, or by other desired heat treatment. Indeed, it is sometimes advantageous, especially when relatively high tensile strength is desired, to subject the conductor to patent-annealing prior to the final cold working; in which case the conductor will have properties characteristic of those produced by that combination of treatments.

It is not prohibitive to do some partial annealing after cold working; such as the partial annealing which incidentally occurs when a hard-drawn ferrous conductor is passed through a bath of molten zinc in the hot-dip process of galvanizing. It is sometimes desirable to avoid even that partial annealing; in which case any metallic protective coating which is applied after the final cold working may be applied by electro-deposition.

My present invention is thus concerned fundamentally with the carbon content and the manganese content, and the production of characteristics due to cold working, in the general class of carbon steels. Various other elements which may exist in carbon steels, such as silicon and phosphorous and sulphur, may also be present in varying small amounts; and the carbon steels may be copper-bearing steels. The phosphorous desirably does not exceed 0.04% if the conductor is to be coated by electro-deposition, and 0.08% if it is to be coated by hot-dipping as with zinc; the sulphur desirably does not exceed 0.05%; and the silicon desirably does not exceed 0.025% unless a zinc coating is to be applied by hot-dipping, and even then desirably should not exceed 0.12%. Even with hot-dipping, it is desirable that only phosphorous, or only silicon, but not both, exceed the lower limit given. Copper, if present, as to improve corrosion resistance, may be of the usual amount employed, commonly not over 0.30%.

Thus my transmission line comprises a carbon-steel conductor (coated or not) which has carbon and manganese contents and cold-worked characteristics as defined above.

Such a transmission line has the advantage of relatively high electrical conductivity, for both direct currents and alternating currents, as compared with previous ferrous transmission lines of corresponding carbon contents. It is especially advantageous for alternating or pulsating currents, because of the decreased magnetic permeability and the consequent decreased skin effect due to the carbon and to the cold working, and to the patent-annealing if used. At the same time, by having the carbon and manganese contents in the range noted, and by the cold

working, and by the patent-annealing if used, I get high tensile strength. Thus I combine high tensile strength with high electrical conductivity.

The following two examples are illustrative of my invention:

a. An example of carbon-steel conductor used in my invention is a No. 12 B. W. G. galvanized steel wire in which the steel contained approximately 0.21% of carbon, and approximately 0.17% of manganese; and in which the silicon was 0.014%, the phosphorous 0.014%, the sulphur 0.030%, and the copper 0.24%. This wire has been cold-drawn in the customary manner, and was then so galvanized by the hot-dip process that its temperature was not raised sufficiently high to eliminate the effects produced by the cold-drawing.

b. Another sample of this wire was processed in the same way, except that it was patent-annealed before cold-drawing.

The following table shows the properties of the two samples just discussed, in contrast to those of an example of commercial "B. B." telephone wire of the same No. 12 B. W. G. size:

	Tensile strength: in pounds per square inch	D—c. resistance: in ohms per 1000 feet	Effective a—c. resistance: in ohms per 1000 feet	Skin-effect resistance ratio	Ratio of tensile strength to effective a—c. resistance
Example of commercial "B. B." telephone wire.	57,500	6.35	9.97	1.570	5,767
Examples of telephone wires of this application:					
(a) non-patented before cold drawing.....	101,200	6.42	8.94	1.394	11,320
(b) Patented before cold drawing.....	114,000	6.44	8.93	1.386	12,770

The three wires compared are all galvanized wires. The a—c. currents used had a frequency of 1000 cycles per second, and a strength of 5 milliamperes. I took a frequency of 1000 cycles per second as a fair single-equivalent voice frequency; and I took a current of 5 milliamperes as being within the ordinary range of telephonic transmission currents.

Although the d—c. resistances of the wires embodying the present invention are very closely similar to the d—c. resistance of the "B. B." telephone wire, yet the effective a—c. resistances of the wires of the present invention are materially lower than the a—c. resistance of the "B. B." telephone wire, and the tensile strengths of the wires of the present invention are almost double the tensile strength of the "B. B." telephone wire; so that the ratio of tensile strength to effective a—c. resistance is about twice as great as that ratio for the "B. B." telephone wire.

By building an overhead transmission line of a carbon-steel conductor (coated or uncoated) conforming to the above requirements, it is possible to have both high tensile strength and high electrical conductivity. Such a transmission line is of value for both alternating and direct currents, and for the transmission of electric power as well as of telephone, signal, and telegraph currents.

It is also advantageous for ground wires, shield wires, messenger cables, catenary supports, etc.; and either as a single wire or in a stranded cable. But it is of special advantage for the transmission of relatively high-frequency currents, such as those used in telephonic transmission; where the frequency is voice frequency, of the order of 100 to 3000 cycles per second, and the currents are usually small, not exceeding about 50 milliamperes.

I claim as my invention:

1. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.12%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%.

2. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.12%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%, and the sum of the carbon content and manganese content is not over 0.40%.

3. An overhead electric transmission line, com-

prising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.12%, and the manganese content is not in excess of the carbon content.

4. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.12%, and the manganese content is not in excess of the carbon content, and the sum of the carbon content and manganese content is not over 0.40%.

5. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.15%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%.

6. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.15%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%, and the sum of the carbon content and manganese content is not over 0.40%.

7. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.15%, and the manganese content is not in excess of the carbon content. 5
8. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.15%, and the manganese content is not in excess of the carbon content, and the sum of the carbon content and manganese content is not over 0.40%. 10
9. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.12%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%; and which has been patent-annealed prior to the cold-working. 15
10. An overhead electric transmission line, comprising a conductor which is to carry current, and which is of carbon steel which has been cold-worked and in which substantial effects characteristic of those produced by such cold-working persist; and of which the carbon content is less than 0.25% but not less than 0.15%, and the manganese content is not in excess of $1\frac{1}{2}$ times the carbon content and in any case is not in excess of 0.30%; and which has been patent-annealed prior to the cold-working. 20

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