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METHOD OF MAKING ELECTRICAL STEEL HAVING SUPERIOR MAGNETIC PROPERTIES

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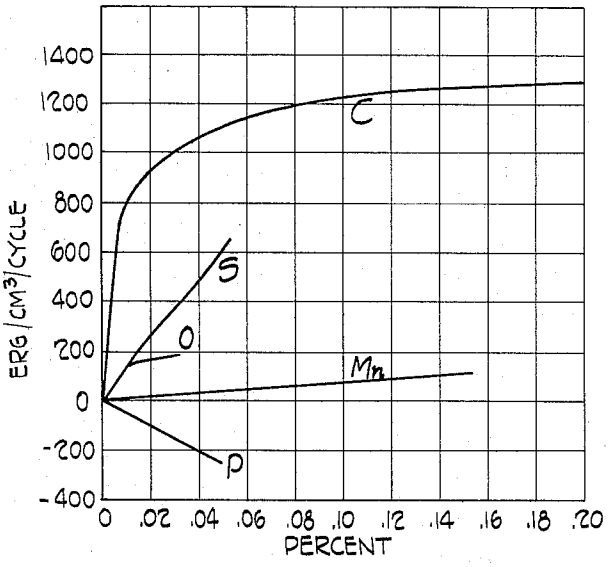


FIG. 1

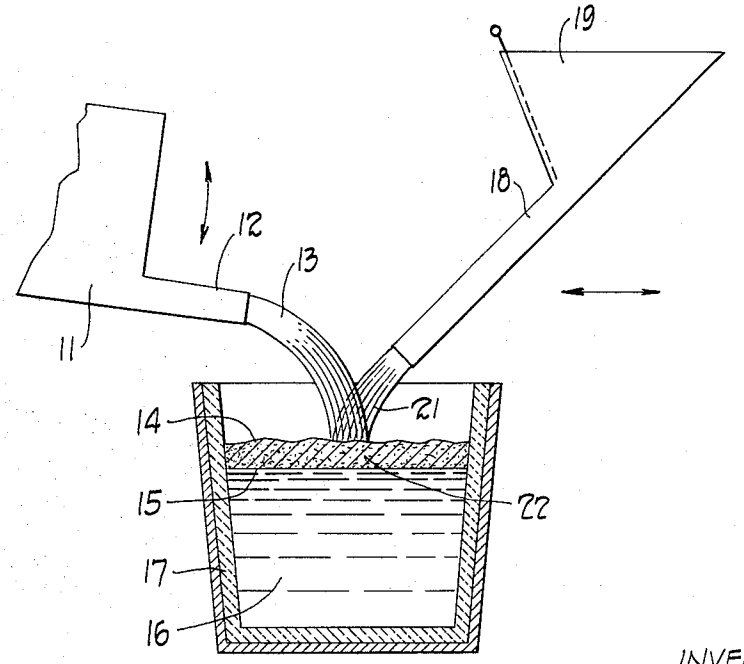


FIG. 2

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METHOD OF MAKING ELECTRICAL STEEL HAVING SUPERIOR MAGNETIC PROPERTIES

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This invention relates to the production of electrical steels which have superior magnetic properties. An object of the invention is to improve ladle practice in the production of electrical steels and to produce electrical steels having superior magnetic properties, with ease and without incurring a large amount of expenditure.

For magnetic materials to be used for electrical equipment and machinery, it is highly desirable to use materials of low watt loss and high permeability. Such materials are usually produced by rolling and heat-treating steels whose silicon content is 5% or under, e.g., between 0.25% and 3.0%. It is well known that the degree of purity of the steel has a marked effect upon their watt loss and permeability. FIG. 1 is a graph illustrating such effect. As is shown in the graph, the lower the carbon content and the lower the sulphur and oxygen contents, the lower will be the watt loss.

While it is comparatively easy to remove carbon from the steels to obtain lower watt loss and better permeability either by "open-coiled annealing" or by continuous annealing in an atmosphere of relatively high dew point, sulphur can be removed only by subjecting the steels to a high temperature annealing for a long time. Such treatment is both operationally difficult as well as expensive, especially for electrical steels of field-grade and motor-grade which are sold at relatively low prices.

As illustrated in FIG. 1, in order to obtain desirable magnetic properties, it is necessary to reduce carbon to 0.02% or under and sulphur to 0.01% or under. This can be achieved in the furnace by ordinary steelmaking process by selecting materials to be charged and by lengthening the refining period.

However, it is not easy to regulate the process so that sulphur in each heat be 0.010% or under constantly.

It is accordingly an object of our invention to provide a simple and economical operation of removing sulphur and reducing non-metallic inclusions in the electrical steels such as silicon steels during their melting, tapping, and reladling.

This invention is not limited to the use with a single fixed type of furnace. However, more satisfactory results have been found to be obtainable with the tilting open-hearth furnace than with the L–D oxygen converter or the stationary open-hearth furnace.

It is a matter of common practice to add deoxidizers such as aluminum, silicon, etc., singly or mixed, to the molten metal in the ladle in order to remove oxygen therefrom. The agents thus added react with the oxygen in the bath, or mass of molten metal, to form deoxidation products. The greater part of the deoxidation products is removed from the bath but not completely. If, however, the variety and quantity of the deoxidizers can be so regulated that the products which are formed as a result of the reaction of the deoxidizers with the oxygen in the bath be made highly fluid and their melting point be lowered, the formation of the residual products in the bath, especially that of the deoxidation products having a high melting point, which are evenly dispersed in the entire bath and affect adversely the magnetic properties of the steels, can be prevented.

It is also a well known practice to use soda ash, fluorspar, etc., for desulphurization. However, there has

been no case in which deoxidation and desulphurization are effected simultaneously. We have succeeded in effecting the two processes simultaneously with alloying and removing inclusions to limits never before attained, thereby removing almost completely the undesirable elements formed in the bath, so that electrical steels having superior magnetic characteristics may be produced easily and economically.

The following shows actual operations of the process:

FIG. 1 is a graph illustrating the influence of carbon, oxygen, sulphur, and phosphorus on the hysteresis loss of the electrical steels, and FIG. 2 is a diagram illustrating partial section of the apparatus used in connection with this invention.

The apparatus illustrated in FIG. 2 comprises a tilting open-hearth furnace **11** having a spout **12** from which a stream of slag free molten metal **13** issues, striking a slag layer **14** at the surface **15** of a body of molten metal **16** in a tap ladle **17** into which the molten metal **13** is poured. There is a hopper **19** containing agents to be added which are a mixture of solid particles or granules of aluminum, calcium, silicon, soda ash, fluorspar, cryolite, synthetic electric furnace slag, etc., and has a mechanism to regulate the pouring quantity and the pouring position. A chute **18** of the hopper is arranged so as to cause the stream of the addition agents, to be adjusted and to pour in the desired quantity, to continuously strike the bath of the ladle **17** at the same point as does the entering stream of molten metal. The addition agents in the ladle **17** contribute to deoxidation and desulphurization of the charge, while on the other hand the flux, which has a low melting point, melts instantly, and, because of its lower gravity, covers the bath surface forming a slag layer **14**.

In order to precipitate reaction of the addition agents, the size of the granules is preferably limited to 10–50 mm. in diameter for deoxidizers and 10 mm. or under for other slag forming and purifying agents: the smaller the size the more advantageous will they be for the actual operations of this invention. The molten metal poured afterwards now runs through this slag layer **14** into the bath, thus filtering out solid oxide inclusions.

The chute **18** is arranged so as to cause a stream of the mixture **21** to strike the slag surface **14** and the metal surface **15** at the same point as does the stream of entering molten metal so that complete and continuous mixing is accomplished at the point of entry of the streams into the molten metal bath **16**.

Silicon or silicon compound which may be added at this stage is selected and regulated quantitatively according to the requirements of the type of steel to be produced.

The quantity of aluminum and calcium is regulated according to the volume of silicon added, and it is fixed in consideration of the amount needed to realize complete deoxidization of the charge and low melting temperature of the deoxidized products.

The desulphurization is accomplished with a flux consisting of the sodium carbonate and calcium fluoride or cryolite, or the like.

Following are the results of actual operations.

The process of this invention on the molten metal containing C, 0.028%; Si, trace; S, 0.011%; Mn, 0.04%; and P, 0.010%; was carried out with the addition of deoxidizer, and 2–10 kgs. each of soda ash and fluorspar per ton of the molten metal. The result showed that the sulphur content has been reduced from 0.011% at the time of tapping to 0.006%. The total content of oxidized inclusions have also been reduced to 0.02% or under, which is approximately 50% lower than the reduction achieved by other conventional processes. Best results are obtained from a melt having a nitrogen content of 0.003% or less.

Silicon steel thus produced with content of 1.3% silicon, has been rolled to a sheet of 0.5 mm. thickness and the following superior magnetic characteristics have been obtained:

Watt loss (W10/50): 1.55–1.61 w./kg.—watts per kilogram at 10,000 gausses and 50 cycles.

Flux density (H25): 16.2–16.6 kg.—kilogausses at a field strength of 25 Gilberts per centimeter.

In producing silicon steel the solid particles of silicon together with other fluxing or purifying materials are added to the metal while it is still in the stream. The invention is not limited, however, to the producing of electrical silicon steel and other alloys may be produced from the molten metal by directing into the stream of molten metal a stream of solid particles including an alloying material such as particles of molybdenum or tungsten or chromium or nickel or vanadium or titanium or copper or compounds or alloys thereof in addition to or instead of silicon or silicon compound or alloy according to what resultant alloy it is desired to produce.

While the invention has been described as embodied in concrete form and as operating in a specific manner in accordance with the provisions of the patent statutes, it should be understood that the invention is not limited thereto, since various modifications will suggest themselves to those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. The method of producing low loss high permeability silicon steel which comprises the steps of charging an iron alloy into a furnace, reducing the carbon content in the furnace, tapping the furnace and causing a stream of molten metal to issue into a ladle to form a mass of molten steel in the ladle, and directing a stream of flux particles against the molten iron stream at its point of entry into the ladle at the molten metal level, said flux particles comprising silicon and a desulphurization agent which react with the steel to form a slag highly fluid at molten iron temperature.

2. The method of producing electrical steel which comprises the steps of introducing a stream of molten silicon steel into a ladle to form a bath of molten metal and simultaneously directing against the molten steel stream, at its point of entry into the bath at the molten metal level, a stream of desulphurization agent comprising a substance selected from the group consisting of cryolite and a mixture of sodium carbonate and calcium fluoride in the form of granules 10 millimeters in diameter or under.

3. The method of producing electrical steel which comprises the steps of melting a silicon steel having a nitrogen content below 0.003% in a furnace, tapping the

furnace to form a stream of molten metal directed into a ladle to form a molten steel bath and continuously directing against the stream of metal at its point of entry into the bath a flux stream composed of solid particles of silicon and a substance selected from the group consisting of cryolite and a mixture of sodium carbonate and calcium fluoride.

4. The method of producing silicon steel, which comprises the steps of melting the steel, pouring the steel in the form of a stream of molten metal into a ladle to form a bath of molten metal and continuously directing against the stream of molten metal, at its point of entry into the bath, a flux stream composed of desulphurizing and deoxidizing agents and silicon.

5. The method of producing silicon steel with a sulphur content as low as 0.006% and total content of oxidized inclusions not over 0.02% which comprises the steps of melting a steel having a composition including approximately 0.028% carbon, 0.04% manganese, a trace of silicon, 0.010% phosphorous and 0.011% sulphur and a nitrogen content of 0.003% or less, pouring the steel into a ladle as a stream of molten metal to form a bath of molten steel and directing a stream of flux particles against the molten metal stream at its point of entry into the bath, said flux particles comprising 2 to 10 kilograms each of soda ash and fluorspar per ton of molten metal.

6. The method of producing electrical steel with a loss between 1.55 and 1.61 watts per kilogram at 10,000 gausses and 50 cycles which comprises the steps of melting a steel having the composition of approximately 0.028% carbon, 0.04% manganese, a trace of silicon, 0.010% phosphorous, 0.011% sulphur, pouring the molten steel into a ladle in a stream to form a bath of molten steel and projecting against the stream of molten steel at its point of entry into the bath a stream of solid particles of silicon, desulphurizer and deoxidizer.

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