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METHOD OF ANNEALING SILICON-STEEL SHEETS.

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This invention relates to the annealing of silicon steel sheets such as used in the construction of certain parts of electrical apparatus.

Annealing of sheet steel is now practiced by two methods, one known as box annealing and the other as open annealing.

Box annealing consists in placing a pile of sheets in a closed box and raising the temperature of the box to the desired temperature, in maintaining the box at that temperature for a certain period of time in removing the box from the furnace, in allowing the same to cool and then in removing the sheets from the box.

In this method the use of the box prevents excessive scaling and in those cases where it is necessary to avoid any scaling the box is often tightly sealed. In some cases a reducing atmosphere is maintained in the box during the entire operation. Sometimes a reducing atmosphere is established and maintained in the box only after the annealing temperature has been attained so that any oxide formed during the initial heating will be reduced. This is known as a deoxidizing anneal.

In open annealing, the sheets are heated singly or in packs in an open furnace which is maintained at the temperature desired and the sheets are removed from the furnace as soon as they have reached this temperature. This process is most frequently operated continuously by conveying single sheets through a relatively long furnace, the rate of travel of the sheets being so regulated that they reach the desired temperature in passing through the furnace.

We have found that in annealing silicon steel sheets of relatively light gage such as used in the building up of laminated cores for transformers and other electrical devices neither of the above methods gives the results desired.

While it is possible to obtain commercial sheets having fairly good magnetic properties by the ordinary methods these do not yield sheets having the best electrical properties especially when the silicon content of the sheets is in excess of three percent.

These methods have the further disadvantage of frequently causing embrittlement of the sheets which renders them unfit for the purpose intended.

High grade silicon steel sheets having the best electrical properties are not commercially obtainable by open annealing as heretofore practiced. One reason for this is that the time required to obtain such properties can not be had in the cycle of operation of any of the open annealing processes as heretofore commercially practiced.

Aside from the question of time however open annealing is impracticable for the reason that light gage silicon steel sheets so annealed are bound to warp and as flatness is a most important requirement in sheets used in the building up of laminated structures of electrical apparatus, sheets so annealed are unsuitable. This is especially so when the sheets have a silicon content in excess of three percent because it is impracticable to flatten such sheets after they have been annealed.

Even if such sheets could be flattened commercially they still would be practically valueless because their electrical properties would be destroyed by the strain to which they would necessarily be subjected during the flattening step.

We have discovered that in order to anneal silicon steel sheets to obtain the best electrical properties and freedom from brittlement, it is necessary that the rate of heating of the sheets be as rapid as possible and that the heating be done in such a manner that all gases contained in the steel are released and dissipated.

In box annealing relatively large stacks of sheets, it is of course impossible to rapidly raise their temperature and since in such stacks the sheets are necessarily close together there is very little if any opportunity for the release and dissipation of the gases contained in the steel.

We have invented a method of annealing silicon steel sheets of light or of any gage which enables us to not only heat the sheets rapidly but which at the same time insures complete release and dissipation of the gases contained in the steel, at the same time avoiding any possible reabsorption of these gases during cooling down.

This method also results in commercially flat sheets that are free from brittleness which we believe is attributed to reabsorption of liberated gases.

Our method consists in charging one, two

or three sheets at a time into a furnace which is maintained at the temperature necessary to obtain the best electrical properties in the finished sheets, the furnace having a flat hearth upon which the sheets are stacked.

As soon as the sheet or sheets has or have reached the correct temperature, that is, the temperature of the furnace, we charge another sheet or two or three sheets on top of the first and so on successively until the stack is completed or the furnace filled.

In this way each sheet is rapidly heated and since its entire surface is exposed during such heating the gases are readily released and become dissipated in the furnace atmosphere which is replaced in whole or in part every time the furnace door is opened for the purpose of placing the sheets therein.

It may appear, when two or three sheets are charged into the furnace at a time, that the entire surface of each sheet is not exposed during the heating but the fact is that with sheets of the gauges here contemplated the gases contained in the sheet rapidly pass through two or even three sheets.

As soon as the stack is completed or the furnace filled and the last sheet or sheets has or have reached the proper temperature the entire stack or pack is maintained at this temperature for a definite period of time which time depends upon the total weight of the stack. We have found that three hours is a suitable period of time for a stack weighing approximately 2,000 pounds and that a temperature of 1,500 degrees F. gives the best results.

No particular type of furnace is essential for this method as long as it is equipped with a flat hearth. We have successfully used a muffle type furnace and also a type of furnace in which the products of combustion are allowed to remain in contact with the sheets during annealing.

If desirable, air or any other gas may be introduced in the furnace to facilitate the removal of the gases as they are released from the sheets.

The particular type of fuel used in heating the furnace is relatively unimportant but we prefer to use a fuel which is as free as possible from impurities that might be absorbed by the sheets. It is obvious that an electrically heated furnace is eminently suitable.

By our above described method, we have been able to obtain silicon steel sheets having uniformly better electric properties than can be obtained by any of the present methods of commercial annealing with which we are familiar and these sheets have been consistently free from condemnation due to brittleness.

We have also been able to obtain sheets that are as flat as it is obtainable by the best commercial processes of annealing.

Although the best results are obtained by charging one or two sheets at a time, it is not our intent to limit the process to a maximum charge of three sheets for the reason that fairly good results can be obtained by charging the sheets in relatively small piles or packs, and when practiced in packs consisting of eight or ten sheets the results will still be superior to those obtained by the ordinary methods of anneal.

Having thus described our invention, what we claim as new and useful and desire to secure by Letters Patent is:

1. The method of open annealing silicon steel sheets of relatively light gauge, which consists in carrying on the annealing upon a flat support within a furnace raised to and maintained at annealing temperature by substantially adhering to the following steps— by incrementally building up a stock of such sheets within the furnace and upon said support, each increment consisting of one, two or three sheets, the periods of time between the introduction of each increment being sufficient to permit the preceding increment to attain annealing temperature, in closing the furnace door between the introduction of each increment, then when the stack is complete and the furnace door closed thereafter, in allowing the stack to soak for from one to three hours, then in allowing the furnace to cool (to about 1200 degrees F.) and in then removing the support with its stack of sheets from the furnace and allowing the sheets to cool.

2. The method of annealing silicon steel sheets of relatively light gauge, which consists in carrying on the annealing upon a flat support within a furnace raised to and maintained at annealing temperature by substantially adhering to the following steps— by incrementally building up a stack of such sheets within the furnace and upon said support, each increment consisting of one, two or three sheets, the periods of time between the introduction of each increment being sufficient to permit the preceding increment to attain annealing temperature, in closing the furnace door between the introduction of each increment, then when the stack is complete and the furnace door closed thereafter, in allowing the stack to soak for from one to three hours and thereafter in removing the sheets therefrom.

3. The method of annealing silicon steel sheets, which consists in building up a stack of horizontally disposed sheets by periodically charging a batch of one, two or three sheets onto a flat support within a furnace raised to annealing temperature, in allowing each of such batches to reach annealing temperature before the succeeding batch is

charged and in causing the gases given off by the sheets during annealing to be dissipated thus preventing reabsorption of such gases by the sheets during their cooling down.

4. The method of annealing silicon steel sheets, which consists in incrementally building up upon a flat support within a furnace raised to annealing temperature, a stack of sheets and during such building up in ventilating the furnace so that the gases given off by the sheets during annealing are dissipated and reabsorption prevented.

5. The method of annealing silicon steel sheets upon a flat support within a furnace raised to and maintained at annealing temperature, which consists in periodically charging into said furnace and upon said support batches of one, two or three sheets of such silicon steel until a stack of such sheets is obtained; in so regulating the time of charging such batches that the sheets of the charged batch are raised to annealing temperature before the next batch is charged, in holding the completed stack (made up of such periodical batches) until annealing is accomplished, then in allowing the furnace to cool and then in removing the sheets therefrom.

In testimony whereof, we have hereu[illegible] set our names this 27th day of June, 1927.

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