UNITED STATES PATENT OFFICE.

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ELECTRICAL APPARATUS.

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To all whom it may concern:

Be it known that I, JOHN F. KELLY, a citizen of the United States, residing at Pittsfield, county of Berkshire, and State of Massachusetts, have invented and discovered a new and useful Improvement in Electrical Apparatus, of which the following is a specification.

My invention relates to electrical apparatus which has a magnetic circuit composed wholly or in part of iron, which is wholly or in part traversed by a varying magnetic flux when the apparatus is in operation.

This invention is applicable to parts of almost all dynamo-electric machinery, and particularly to what are known as secondary generators, transformers, or converters.

In all such apparatus there is in those parts of the iron core where the magnetic flux is varying—even where Foucault currents are suppressed by laminating it—a loss of energy due to hysteresis, which appears as heat in the iron and is called "core loss." It has been known for some years that this core loss in annealed iron cores, which become heated while the apparatus is in use, increases after such use has continued for some time, the increase being due to an increase in hysteresis. This increase in hysteresis accompanies long-continued heating, such as that produced by the reversal of the lines of force in uncooled transformers as now ordinarily constructed. If the heating of the iron could be prevented, the increase of the hysteresis and resulting increase of core loss could also be prevented, but the cost of prevention of heating is such as to make it commercially impossible. Hence the increase of core loss has up to the present time been submitted to as a necessary evil. This evil is marked in alternating-current dynamos and motors, but is probably greater in transformers than in other kinds of electrical apparatus. Its magnitude in transformers will be plain from the following figures: The average size of transformers at present is fifty lights, being such a transformer as would be used to light a large-sized dwelling-house of fifteen or twenty rooms. The average all-day load is quarter-load, making its average output about seven hundred watts. The core loss in such a transformer, when new, will at a frequency of one hundred and thirty-three alternations per second be about fifty-five (55) watts. After the transformer has been in use under ordinary conditions for some time there is, as above stated, an increase in the core loss due to hysteresis. This increased core loss in a comparatively short time amounts to at least forty per cent., (40%,) and later frequently rises to one hundred per cent. (100%) of the original core loss. Taking it at only forty-five per cent. (45%) it will in this case amount to about twenty-five (25) watts, or over three and one-half per cent. ($3\frac{1}{2}$%) of the average output; that is to say, the average efficiency of the transformer will be reduced about three and one-half per cent., ($3\frac{1}{2}$%,) or, to put it another way, the steady losses in a ten-thousand (10,000) light central plant installation would be increased by some five kilowatts, which, at the low rate of one cent per kilowatt hour, would cost the producer one dollar and twenty cents ($1.20) a day, or four hundred and thirty-eight dollars ($438) a year.

The object of my invention is to prevent the core loss increase above referred to.

Heretofore, although the increased core loss has been recognized, all attempts to prevent it by changing the composition or character of the iron have been attempts to make a purer iron to exclude as far as possible all foreign substances. I, however, have discovered that the hysteresis growth which gives rise to the increase of the core loss can be prevented by intentionally having the iron of the core contain one foreign substance (silicon) in suitable proportions. One proportion suitable for attaining the object of my invention is two hundred and thirty-five ten-thousandths per cent. (0.0235%) of silicon, the other parts being pure iron, so far as it can be conveniently made for commercial purposes. Such purity is, however, required rather for convenience and assistance in manufacturing than for the purposes of my invention. In that proportion the silicon alloy is a hysteresis-growth-preventing alloy under any ordinary conditions to which a core may be subjected. The iron of the particular core to which I now have reference upon analysis was found to have the following composition: iron, 99.5215 per cent.; silicon, 0.0235 per cent.; sulfur, 0.0316 per cent.; manganese, 0.1680 per cent.; phosphorus, 0.0830 per cent.;

graphite carbon, 0.0076 per cent.; combined carbon, 0.1138 per cent.; copper, 0.0510 per cent. It is the silicon which is the active agent in preventing the molecular change which results in an increase in core loss, and when the proportion of silicon is as that above specified such increase is prevented. The proportion of silicon admits of considerable variation. I have, however, given one which I have found to be satisfactory.

The iron heretofore used in laminated cores as now made is as free from all substances other than pure iron as is commercially practicable, the whole tendency being to attempt to prevent hysteresis growth by making the iron purer. Such purer iron has contained about one hundredth of one per cent. (0.0100%) of silicon, such an amount being usually present in iron as an incident of its manufacture. Such an alloy is not a hysteresis-growth-preventing alloy. The amount of silicon in the iron used by me, it will be noticed, is considerably larger than that present in the ordinary iron used for laminated cores. The abnormal amount of silicon in the iron does not increase the original core losses in perfectly-annealed iron, but prevents the hysteresis growth at the temperatures to which the transformers are subjected when in use. The iron with the hysteresis-growth-preventing silicon alloy is, I have observed, more springy than iron ordinarily used in cores, in addition to being more difficult to anneal. The alloy appears to resist molecular change of any sort.

Methods of making iron containing approximately any particular proportion of silicon or similar metals that may be desired are known to those skilled in the art of manufacturing iron and form no part of my invention; no more do the methods of annealing or of rolling, where rolling is desired, since these methods need be only the ordinary ones. The annealing requires, however, more care and attention than that of ordinary iron in order that it be perfectly done, as the increase of silicon makes the metal more difficult to anneal. I have found that such iron can be sufficiently annealed by subjecting it twice to the ordinary annealing process.

In making up the cores for the magnetic circuits in transformers and other dynamo-electric machines any usual methods of construction and lamination now used can be adopted.

What I claim as my invention is—

1. In an electrical apparatus having when in operation a varying magnetic flux, a laminated iron core traversed by said varying flux having in its composition an alloy preventing hysteresis growth, substantially as described.

2. In an electrical apparatus having when in operation a varying magnetic flux, a laminated iron core traversed by said varying flux having in its composition an abnormal proportion of silicon, substantially as described.

3. In electrical apparatus having when in operation a varying magnetic flux, an annealed laminated iron core traversed by said varying flux having in its composition sufficient silicon to prevent hysteresis growth at temperatures to which transformers are subjected when in use, substantially as described.

JOHN F. KELLY.

Witnesses:
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