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Easton

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[54] **LOW-OXYGEN, SILICON-BEARING LAMINATION STEEL**

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[58] **Field of Search** .... 148/120, 121, 31.55, 122, 148/112, 36; 75/123 B, 123 L

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

1,931,420 4/1971 Germany 148/121

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[57] **ABSTRACT**

A lamination steel of the carbon steel type for magnetic uses having a 60 hertz core loss of about 4 watts per pound at 15 kilogausses at a thickness of 0.025 in. if annealed after shearing or stamping and a core loss of about 4.5 watts per pound if used as sheared or stamped. The invention also relates to methods of making such steel. The steel contains from about 0.05% up to 0.60% silicon, from about 0.05% to 1.0% manganese, about 0.020% or less sulfur, from residual quantities up to about 0.15% phosphorus, about 0.008% or less nitrogen, about 0.02% or less oxygen, and a final carbon content of about 0.010% maximum. The final carbon content may be achieved in the melt, during processing or in an anneal performed by the customer. If the steel is fully-processed, it is preferred that the carbon be removed in the melt. The lamination steel may be processed by various routings, all including hot rolling, pickling and cold rolling to final gauge, to provide the customer with a fully-processed or semi-processed steel, as will be described hereinafter.

17 Claims, No Drawings

LOW-OXYGEN, SILICON-BEARING LAMINATION STEEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to lamination steel and methods of making it, and more particularly to such lamination steel killed with sufficient silicon to impart the desired magnetic, punching or casting properties. The steel can be processed by a number of routings to obtain the desired magnetic or mechanical properties and to provide a semi-processed or a fully-processed lamination steel.

2. Description of the Prior Art

The steel of the present invention has many uses. While not intended to be limiting, it is well suited for use in the manufacture of the magnetic parts of low horsepower electric motors.

Heretofore, various grades of non-oriented silicon steel were used in the manufacture of such magnetic parts. In recent years, however, many improvements have been made in the decarburization of motor laminations and in the design of the motors themselves enabling the manufacturers thereof to turn to ordinary plain carbon steels for the fabrication of the magnetic parts. While plain carbon steel is less expensive than non-oriented silicon steel, its magnetic properties are not as good. For example, greater heat losses are generated within the plain carbon steel when magnetized. Such heat losses are the result of hysteresis, eddy current and anomalous losses. Eddy current losses, in particular, are higher in carbon steel than in non-oriented silicon steel. Heretofore, a 60 hertz core loss of 5 to 5.5 watts per pound at 15 kilogausses in a 0.025 in. thick sample of ordinary carbon steel was considered normal for a sample given a proper anneal by the customer and 7 watts per pound was considered good for a sample not annealed after shearing or punching.

Prior art workers have expended much time and energy in an attempt to improve core losses in lamination steel of the carbon steel type. Numerous patents teach the benefit of processing with a critical amount of strain so that critical grain growth is obtained in the customer's anneal. Examples of this are U.S. Pat. No. 2,672,429; German Pat. DT 2,219,059; British Pat. No. 1,114,448; Canadian patent Nos. 642,689 and 707,731 and Japanese Pat. Nos. 4139/1965 and 8556/1963. Critical grain growth can reduce core loss by about 10%, but the process (including the customer's anneal) must be carefully controlled; the results can be variable; and the punched laminations must be annealed because of the high stress level necessary for critical grain growth.

In U.S. Pat. No. 3,180,767, Easton and Carpenter teach that core loss under 5 watts per pound can be obtained consistently in a carbon steel of normal melt composition by decarburizing the pickled hot band ahead of cold reduction but this process also is limited to production of a semi-processed grade because it must be cold rolled in order to provide sufficient hardness for good punchability. British Pat. No. 1,100,771 teaches the effects of manganese. The manganese level throughout the industry has ranged from about 0.15% to approaching 1%, but for motor laminations it is generally over about 0.4%.

Silicon-killed grades have been made for other types of applications but they normally have relatively high oxygen contents and contain many inclusions. They have not been very satisfactory in magnetic applications. It has been found that if motor lamination steel contained about 0.1% phosphorus and had a carbon content of about 0.06% or less, the requirements for a decarburizing anneal practiced by the customer were less stringent and a core loss of 4.5 to 5.0 watts per pound could be achieved, and much steel of this type has been produced by the industry, although not in combination with a low-oxygen, silicon-killed steel. German Pat. No. 1,931,420 teaches vacuum degassing, deoxidation with manganese and/or silicon, the use of 0.05% to 0.25% phosphorus, and decarburization in a process anneal. Deoxidation with manganese or silicon does not mean that a low total oxide or inclusion content has been achieved, even though such deoxidation can be used to avoid the rimming action. The remaining oxides and inclusions act as barriers for grain growth and for domain-wall movement.

The present invention is directed to a lamination steel characterized by the fact that a core loss of about 4 watts per pound can be consistently achieved in a semi-processed grade and about 4.5 watts per pound in a fully-processed grade. The lamination steel of the present invention is quite versatile in that it may be processed by a number of different routings to obtain the particular magnetic or mechanical properties desired and, as indicated above, can be provided to the customer in a fully-processed form or a semi-processed form. As used herein and in the claims, the term "fully processed" relates to a lamination steel which does not require an anneal to be practiced by the customer although a stress relief anneal would improve the magnetic properties and can be optionally practiced. The term "semi-processed," as used herein and in the claims, refers to a lamination steel which does require an anneal by the customer. The annealing of semi-processed grades may or may not involve decarburization depending upon the amount of carbon removal prior to receipt by the customer.

The lamination steel of the present invention is competitive with plain carbon steels used heretofore, but exhibits improved magnetic characteristics while being cheaper than non-oriented silicon steels. This is accomplished by reducing the number of inclusions and increasing the amount of silicon as compared to that found heretofore in plain carbon steel motor laminations. As will be explained hereinafter, the upper limit of the silicon content is based not on metallurgical reasons but on economic reasons to assure that the steel of the present invention is not classified as a silicon steel and subjected to the rates and standards applied by the industry to silicon steel.

SUMMARY OF THE INVENTION

The lamination steel of the present invention is intended for magnetic uses. It is characterized by a 60 hertz core loss of about 4 watts per pound at 15 kilogausses and a thickness of 0.025 inches if semi-processed and tested as annealed, and about 4.5 watts per pound if fully-processed and tested as sheared. In its most basic form, the lamination steel has the following analysis in weight percent:

C	from less than about .010% to about .1%
Mn	from about .05% to about 1.0%
S	.02% maximum
Si	from about .05% up to the greatest amount possible without classifying the steel as a silicon steel
N	as low as possible, i.e., .008% or less
O	as low as possible, i.e. .02% or less
P	residual to about .15%

The remainder being iron and impurities incident to the mode of manufacture.

When the product of the present invention has a carbon content greater than about 0.010%, it will be necessary for the customer to perform a decarburizing anneal. The lamination steel can be produced by a number of different routings as will be described hereinafter. All of the routings include the steps of hot rolling, pickling and cold rolling to or near final gauge. The choice of routing will depend on a number of factors including the magnetic or mechanical properties desired in the lamination steel, the use to which the lamination steel is to be put and the various processing steps to be practiced on the lamination steel by the customer.

Certain of the routings will provide a fully-processed lamination steel requiring no further annealing by the customer. In these routings, decarburization is achieved in the melt or during processing. Others of the routings produce a semi-processed lamination steel requiring further annealing by the customer which may or may not involve decarburization.

When it is desired to provide the lamination steel of the present invention in fully-processed form, it is preferred that the melt be vacuum degassed to remove oxygen to as low a level as possible and to decarburize to about 0.010% carbon or less. After the vacuum degassing step, silicon in an amount from about 0.05% to the maximum permissible without classifying the steel as a silicon steel is added to the melt together with from about 0.05% to about 0.15% phosphorus and from about 0.05% to about 1.0% manganese. It is desired that the sulfur level be maintained at about 0.010% or less and that the nitrogen and oxygen content be as low as possible (under about 0.005% each). The melt is ingot cast or strand cast, hot rolled to hot band, pickled, cold rolled to final thickness and subjected to an anneal to develop the magnetic properties, but leaving the strip with sufficient hardness to permit punching into laminations.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Ordinary carbon steel, heretofore used for magnetic purposes, is well known in the art. Such ordinary carbon steel generally has the following analysis in weight percent:

C	.06% to .08%
Mn	.30% to .50%
P	less than about .005%
S	.025% maximum
Si	under .005%
N	.008% or less
O	from about .03% to about .05%.

The present invention is based upon the discovery that if the above chemistry is modified, a lamination steel can be achieved consistently having a 60 hertz core loss of about 4 watts per pound at 15 kilogausses and at a thickness of 0.025 in. if semi-processed and tested as annealed and about 4.5 watts per pound if fully-processed and tested as sheared. The core loss values given above and hereinafter are based on tests using equal numbers of samples cut parallel to and transversely of the rolling direction, a common testing technique in the industry.

In accordance with the present teachings, the amount of manganese may be raised; oxygen is removed to as low a value as possible; and the lamination steel is killed with sufficient silicon to impart desired magnetic, punching or casting properties but not in an amount such as to class the steel as a silicon steel. In its simplest form, the present invention contemplates a steel having from less than 0.010% to about 0.1% carbon as desired, from about 0.05% to about 1.0% (and preferably about .45%) manganese, about 0.020% maximum (and preferably under 0.010%) sulfur, from about 0.05% up to 0.60% (and preferably about 0.10% to about 0.15%) silicon, nitrogen as low as possible (about 0.008% or less and preferably under about 0.005%), oxygen as low as possible (about 0.02% or less and preferably under about 0.005%) and from residual to 0.15% phosphorus as desired, the balance being iron and those impurities incident to the mode of manufacture.

In its final form, the steel should contain about 0.010% maximum carbon, and preferably less. The above noted range of 0.010% to 0.1% is given because the carbon may be reduced to the desired 0.010% or less value in the melt, during processing (before or after cold rolling) or in an anneal practiced by the customer. In some applications, the economics are such that the customer does not wish to practice a decarburizing anneal. In other applications, better magnetics are achieved if at least some decarburization is practiced by the customer to achieve the desired final carbon content of 0.010% or less.

If some or all of the decarburizing is to be achieved in the melt, it can be accomplished by vacuum degassing, as is well known in the art. If some or all of the decarburizing is to be achieved during the steel manufacturer's processing of the steel, a decarburizing anneal may be performed on the hot band after pickling or after cold rolling. If performed after cold rolling, the decarburizing anneal may constitute a part of an anneal to achieve the desired magnetic characteristics of the steel. Decarburizing anneals are well known in the art. An exemplary technique taught by Carpenter et al. in U.S. Pat. No. 2,287,467 may be used before or after cold rolling, subjecting the steel to an anneal at a temperature of about 1350°F in a 20–40% hydrogen atmosphere, the balance being nitrogen, at a dewpoint of 120°F. Other atmospheres containing more or less hydrogen can be used with higher or lower dewpoints, or the decarburizing atmosphere can be produced by partially combusting fuel gases. The decarburization can be carried out over a range of temperatures. Hot bands can be decarburized by annealing with the hot mill scale on the strip, as taught by Carpenter in U.S. Pat. Nos. 2,236,519 and 2,242,234 and by British Pat. No. 1,037,396. However, the carbon may not be as low or as uniform as desired and the reduced scale is difficult to remove by pickling.

The silicon, added to the melt as high purity ferrosilicon, iron-manganese-silicon alloy, or metallic silicon, is used to kill the steel and to raise its volume resistivity, thereby improving the magnetics. The silicon addition also reduces segregation generally obtained with rimmed or capped steel.

By present standards recognized in the industry and outlined in the *AISI Flat Rolled Electrical Sheet Manual*, 1972 Edition (pp. 6 and 7), steels with a silicon content greater than 0.60% are classed as Silicon Alloy Steels; those having 0.60% or less are classed as Nonoriented Carbon Steels; and those containing 0.15% or less are classed as Cold Rolled Carbon Sheet (or Motor Lamination Steel). Each of the above classifications has its own pricing structure. The teachings of this patent apply to any of the above classifications. The upper limit of the silicon content of the steel of the present invention is the highest possible silicon content without causing the steel to be classified as a silicon steel and to be subject to silicon steel standards and rates (i.e. 0.60%), with the preferred upper limit being the 0.15% of the cold rolled carbon steel sheet.

The upper silicon limit, and the preferred upper silicon limit, are based strictly on commercial reasons. If classified as a silicon steel the steel of the present invention could not be competitive pricewise with motor lamination steels currently in use. There is no metallurgical reason why more silicon could not be added and some magnetic properties might be improved through further reduction in the eddy current and hysteresis components of core loss.

The desired low oxygen content may be obtained in the melt by argon stirring or vacuum degassing, by providing the proper balance of carbon and oxygen in the melt before degassing or stirring, and by proper additions of aluminum or other deoxidizing agents to the ladle, all as is well known in the art. Depending upon whether the carbon content is to be reduced to the final desired level or some higher level in the melt, the melt should be provided with an appropriate carbon-oxygen ratio to reduce the carbon content as desired and the oxygen level to as low a value as possible. In addition, other elements can be added or substituted to improve the magnetic properties. For example, manganese, aluminum, chromium and the like can be added for the purpose of increasing the volume resistivity and phorphorus may be added to increase both the volume resistivity and the hardness.

The manganese in the above given composition (as does silicon) increases volume resistivity — i.e., reduces eddy currents and thus diminishes core loss. Within the above given range the quantity of manganese used depends upon the desired magnetic characteristics of the final product. If it is desired to have a lower silicon content within the above given range, volume resistivy can be increased by adding more manganese within the above given range and vice versa.

As indicated above, phosphorus also increases the volume resistivity and contributes to the hardness of the material. Again, within the above given range the quantity of phosphorus added will depend upon the magnetic and physical characteristics desired in the final product.

The melt can be ingot cast or strand cast. In all instances, the steel is hot rolled to hot band and pickled in the conventional manner. From this point on, however, variations may be made in the routing depending upon the type of product desired to be received by the customer, the additional processing steps practiced by the customer and the ultimate application for the steel.

The following is a list of 11 exemplary routings following hot rolling and pickling which may be practiced:

1. The steel may be decarburized in the hot band after pickling, cold rolled and shipped to the customer in the full hard condition.
2. The steel may be decarburized in the hot band after pickling, cold rolled, box annealed (to achieve recrystallization, relieve stresses and soften the steel) and temper rolled.
3. The steel may be decarburized in the hot band after pickling, cold rolled, strip normalized and temper rolled.
4. The steel may be decarburized in the hot band after pickling, cold rolled, strip normalized and shipped for use as stamped.
5. The steel may be cold rolled, box annealed and temper rolled without decarburization.
6. The steel may be cold rolled, strip normalized and temper rolled without decarburization.
7. The steel may be cold rolled, strip normalized and shipped for use as stamped, the desired low carbon content having been achieved in the melt.
8. The steel may be cold rolled, strip annealed and temper rolled with no decarburization step.
9. The steel may simply be cold rolled, strip annealed and shipped for use as stamped. The desired low carbon content can be achieved in the melt or additional carbon can be removed in the strip anneal.
10. The steel may simply be cold rolled and shipped.
11. The steel may be cold rolled, decarburized (by strand anneal or open coil anneal) and temper rolled.

In routings 1, 2, 3, 5, 6, 8, 10 and 11 the customer should subject the steel to an anneal after shearing or punching to develop the magnetic properties and to decarburize to 0.010% or less if not achieved in the routing or the melt.

Routings 4, 7 and 9 provide the customer with a fully-processed product. While not required, a stress relief anneal after shearing or punching will improve the magnetic properties.

In routings 7 and 9 low carbon is achieved in the melt. Additional carbon can be removed in the process anneals, if desired.

In routings 5, 6, 8, and 10 decarburization may be complete in the melt or partially achieved in the melt to reduce the decarburizing required of the customer. Otherwise the customer must perform the entire decarburization.

In routings 1 through 3 and 11 decarburization in the melt may reduce the amount of decarburization required in the routing and if the product received by the customer has a carbon content of 0.010% or less, no decarburizing is required of the customer.

It will be understood that in the above listed routings the steps of hot rolling, pickling, cold rolling, box annealing, strip normalizing, strip annealing and temper rolling are individually conventional and well known in the art. When strip annealing best results have been achieved at a temperature of about 1600°F. As between routings 7 and 9, routing 9 is preferred, having been found to yield better all around properties due to the lower temperature used and additional decarburization.

In any of the above routings ending with a temper roll pass, the amount of reduction may be such as to produce critical grain growth in the customer's anneal if desired, thereby improving the magnetic properties.

It will be understood by one skilled in the art that not all of the above listed routings give equal results. In general, however, if the final carbon content is 0.010% or less, the resultant steel will be characterized by a core loss of about 4 watts per pound in a semi-processed grade and about 4.5 watts per pound in a full-processed grade. A steel is produced which has an inclusion content sufficiently low to permit it to act as a member of the silicon steel family, although the silicon content is such that it cannot properly be classified as a silicon steel.

If the steel of the present invention is to be provided to the customer in fully-processed form, i.e., if the customer desires not to have to perform an anneal, there is a preferred chemistry for the steel. Under these circumstances the steel should contain about 0.010% maximum carbon (and preferably about 0.006% or lower); from about 0.05% to about 1.0% manganese (and preferably about 0.45%), from about 0.05% to about 0.15% phosphorus (and preferably about 0.10%), about 0.010% maximum sulfur (and preferably as low a sulfur content as possible), up to the largest silicon content achievable without causing the steel to be classified as a silicon steel (and preferably from about 0.10% to about 0.15%); about 0.008% or less nitrogen (and preferably under about 0.005%) and about 0.01% or less oxygen (and preferably under about 0.005%); the balance being iron and those impurities incident to the mode of manufacture.

The low carbon and low oxygen indicated above are achieved in the melt by vacuum degassing and by making the proper aluminum additions to the ladle. To this end, the carbon and oxygen content of the melt is adjusted so that these elements combine for the maximum removal of both by the vacuum degassing. Manganese, silicon and phosphorus are added to the melt after the decarburization in the liquid state. The silicon is added for the same purposes given above, i.e., primarily to improve the magnetics. Normally, if ordinary carbon steel is decarburized during plant processing to a point where the magnetic properties can be fully developed, the steel is so soft as to be difficult to punch. If hardness is increased by mechanical working, the magnetic properties are severely impaired. The above noted phosphorus additions, along with the silicon, enable the magnetic properties of the steel of the present invention to be developed while at the same time maintaining sufficient hardness for good punchability. Again the manganese serves to increase the volume resistivity.

If the steel of the present invention is to be provided to the customer in the fully-processed form, it can be supplied with either an organic or an inorganic insulative coating, if desired. Such coatings may be applied by either the manufacturer or the customer.

The melt can be ingot cast or strand cast as desired. The steel is hot rolled to hot band, pickled, cold rolled to final gauge and finished with an anneal to develop the magnetic properties. The anneal is conducted in a protective atmosphere at a temperature of from about 1400°F to about 2000°F (and preferably about 1600°F) for a period of about 3½ minutes. Such an anneal will permit the development of the desired magnetic properties, but will leave the strip with sufficient hardness to permit punching into laminations or the like. The finished product possesses good punching characteristics and may be used as stamped without a customer's stress relief anneal, although a stress relief anneal may optionally be performed. It is further characterized by a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses measured at a thickness of 0.025 in. and has good permeability and exciting current.

EXAMPLES

Five steels designed A, B, C, D and E were produced with the chemistries given in Table I below. In this table "Routing" refers to those listed above and "F-P" and "S-P" refer to "fully-processed" and "semi-processed", respectively.

TABLE I

Material	Routing	CHEMISTRY IN WEIGHT-PERCENT								Grade	Hardness Rb
		C		Mn	P	S	Si	N	O		
		Melt	Sample								
A	9	.009	.002	.48	.12	.011	.15	.0046	.014	F-P	55–60
B	7	.009	.009	.48	.12	.011	.15	.0046	.014	F-P	55–60
C	1	.079	.001	.55	.11	.017	.12	.0034	.0032	S-P	90–95
D	1	.050	.001	.35	.007	.014	.12	.0026	.0097	S-P	90–95
E	11	.040	.0024	.36	.003	.015	.14	.006	.011	S-P	60

Steel A was hot rolled to 0.090 inch, pickled, cold rolled to 0.024 inch, strip annealed for 3½ minutes at 1600°F in a dissociated ammonia atmosphere with +130°F dewpoint and tested as sheared (Routing 9 above). Steel B was the same as Steel A except it was normalized at 1850° instead of 1600°F.

Steel C was hot rolled to 0.090 inch, pickled, decarburized at 1300°F in an atmosphere of 15% hydrogen, 85% nitrogen with a dewpoint of 120°F for several hours, cold rolled to 0.025 inch and given a simulated customer anneal at 1550°F in a partially-combusted natural gas atmosphere for 30 minutes (Routing 1). Steel D received the same processing and simulated customer anneal as Steel C but differed in chemistry, including higher oxygen (see Table I).

Steel E was hot rolled to 0.080 inch, pickled, cold rolled to a nominal thickness of 0.025 inch, and opened-coil annealed at 1100°F in a dry atmosphere of 8% hydrogen and 92% nitrogen, the furnace power having been shut off when the charge reached 1100°F. Steel E was then temper rolled 0.7% and given a simulated decarburizing customer anneal at 1450°F in a wet, partially-combusted natural gas atmosphere for 1½ hours (Routing 11).

Table II below gives the magnetic properties of steels A, B, C, D and E. The values given in Table II are average values for several samples, each sample consisting of equal numbers of strips of each steel cut parallel to and transversely of the rolling direction.

TABLE II

MAGNETIC PROPERTIES

Material	Thickness (Inches)	Core Loss 2/lb, 15 KGa)	Exciting Current (AT/inch, 15 KGa)	Permeability 15 KGa	10 Oersteds
A	.0239	4.40	8.0	1900	1530
B	.0239	4.95	15.6	955	1370
C	.025	4.05	5.54	3345	1595
D	.025	4.60	6.60	2845	1570
E	.0255	3.95	6.73	2060	1525

Modifications may be made in the invention without departing from the spirit of it.

What is claimed is:

1. A steel of the carbon steel type for magnetic uses and producible by the manufacturer in fully-processed and semi-processed grades, said steel consisting essentially of from less than about 0.010% to about 0.1% carbon, from about 0.05% to about 1.0% manganese, about 0.02% maximum sulfur, from about 0.05% to 0.6% silicon, about 0.008% maximum nitrogen, about 0.02% maximum oxygen, about 0.15% maximum phosphorus the balance being iron and those impurities incident to the mode of manufacture, said steel having a 60 hertz core loss of about 4 watts per pound at 15 kilogausses at a thickness of 0.025 inch in said semi-processed grade and a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses at a thickness of 0.025 inch in said fully-processed grade.

2. A steel of the carbon steel type for magnetic uses and producible by the manufacturer in fully-processed and semi-processed grades, said steel consisting essentially of from less than about 0.010% to about 0.1% carbon, from about 0.05% to about 1.0% manganese, about 0.01% maximum sulfur, from about 0.05% to about 0.60% silicon, about 0.005% maximum nitrogen, about 0.005% maximum oxygen, from about 0.05% to about 0.15% phosphorus, the balance being iron and those impurities incident to the mode of manufacture, said steel having a 60 hertz core loss of about 4 watts per pound at 15 kilogausses at a thickness of 0.025 inch in said semi-processed grade and a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses at a thickness of 0.025 inch in said fully-processed grade.

3. The steel claimed in claim 2 wherein said manganese content is about 0.45%.

4. The steel claimed in claim 2 wherein said silicon content is from about 0.10% to about 0.15%.

5. A fully-processed grade steel of the carbon steel type for magnetic uses consisting essentially of about 0.010% maximum carbon, about 0.05% to about 1.0% manganese, about 0.01% maximum sulfur, up to 0.6% maximum silicon, about 0.008% maximum nitrogen, about 0.01% maximum oxygen, from about 0.05% to about 0.15% phosphorus, the balance being iron and those impurities incident to the mode of manufacture, said steel having a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses at a thickness of 0.025 inch.

6. A fully-processed grade steel of the carbon steel type for magnetic uses consisting essentially of about 0.006% maximum carbon, about 0.45% manganese, 0.01% maximum sulfur, from about 0.10% to about 0.15% silicon, about 0.005% maximum nitrogen, about 0.005% maximum oxygen, about 0.10% phosphorus, the balance being iron and those impurities incident to the mode of manufacture, said steel having a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses at a thickness of 0.025 inch.

7. A process of making a fully-processed grade steel of the carbon steel type comprising the steps of providing a carbon steel melt having a carbon content up to 0.1% maximum, reducing the nitrogen content of said melt to 0.008% maximum and reducing the oxygen content of said melt to 0.01% maximum, adding to said melt from about 0.05% to about 1.0% manganese and from about 0.05% to about 0.15% phosphorus and up to 0.6% silicon, casting said steel melt, hot rolling said steel to hot band, pickling said steel, cold rolling said steel to cold band, subjecting said steel to a heat treatment and reducing said carbon content to 0.010% maximum in at least one of said melt, said hot band and said cold band during said process thereby providing said fully-processed grade steel with a 60 hertz core loss of about 4.5 watts per pound at 15 kilogausses at a thickness of 0.025 inch.

8. The process claimed in claim 7 wherein said reduction of said carbon content is accomplished in said melt.

9. The process claimed in claim 7 wherein said reduction in carbon content is accomplished by decarburizing said hot band after said pickling thereof, said heat treatment comprising a strip normalizing treatment.

10. The process claimed in claim 8 wherein said heat treatment comprises an anneal to develop the magnetic properties of said steel, said anneal being conducted at a temperature of from about 1400°F to about 2000°F for a period of about 3½ minutes.

11. The process claimed in claim 8 wherein said heat treatment comprises a strip normalizing treatment.

12. The process claimed in claim 10 wherein said carbon content is reduced to 0.006% maximum and said nitrogen and oxygen contents are both reduced to 0.005% maximum.

13. The process claimed in claim 10 wherein said silicon addition is from about 0.10% to about 0.15%.

14. The process claimed in claim 12 wherein said silicon addition is from about 0.10% to about 0.15%.

15. The process claimed in claim 14 wherein said mangahese addition is about 0.45% and said phosphorus addition is about 0.10%.

16. A process of making a semi-processed grade steel of the carbon steel type comprising the steps of providing a melt having up to about 0.1% carbon, reducing the nitrogen content to about 0.008% maximum and reducing the oxygen content to about 0.02% maximum, adding to said melt from about 0.05% to about 1.0% manganese and up to 0.6% maximum silicon, hot rolling said steel to hot band, pickling said steel and cold rolling said steel to final gauge thereby providing said semi-processed grade steel with a 60 hertz core loss of about 4 watts per pound at 15 kilogausses at a thickness of 0.025 inch.

17. The process claimed in claim 7 wherein said reduction in carbon content is accomplished in said cold band.

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