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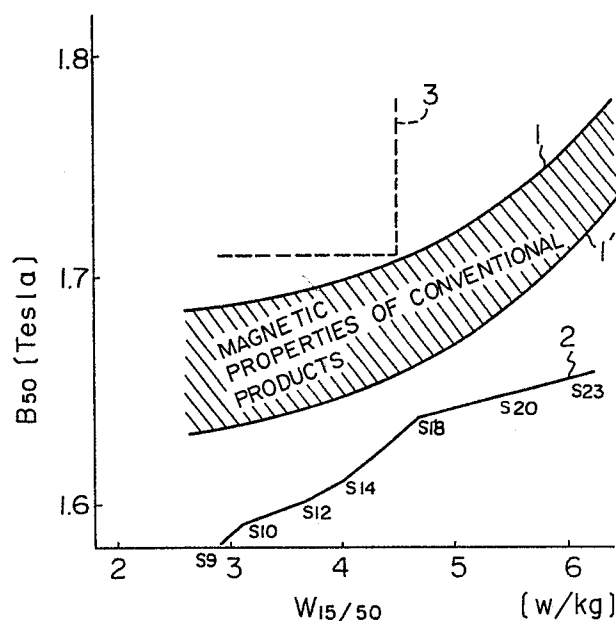
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Non-oriented electrical steel sheet having a low watt loss and a high magnetic flux density and a process for producing the same.

In the production of non-oriented electrical steel sheets, it has been attempted to decrease the watt loss, e.g. by adding Sn into silicon steels, but in such a case the relationship between the watt loss and magnetic flux density falls within the curves 1 and 1' in Fig. 1. The addition of boron is therefore unsatisfactory for meeting the recent demands, for improving the magnetic properties of a non-oriented electrical steel sheet over those indicated by the curve 3.

In the present invention, the combined addition Sn with B and/or sol. Al results in development of (110) and (100) textures which are desirable for the magnetic properties.

A non-oriented electrical steel sheet according to the present invention, contains 0.015% of C at the highest, from 0.3 to 2.0% of Si, from 0.005 to 0.10% of sol. Al, from 0.02% to 0.20% of Sn, 0.007% of N at the highest, and 0.005% of B at the highest, the weight ratio of B content/N content being from 0.5 to 1.5, said non-oriented electrical sheet being produced by a process comprising an annealing of a hot-rolled steel strip. Instead of B, an appreciable amount of sol. Al may be contained in said sheet, when Mn content is from more than 1.0% to 1.5%.



NON-ORIENTED ELECTRICAL STEEL
SHEET HAVING A LOW WATT LOSS AND A HIGH
MAGNETIC FLUX DENSITY AND A PROCESS FOR
PRODUCING THE SAME

5 The present invention relates to a non-oriented
electrical steel material having a low watt loss and a
high magnetic flux density, and to a process for
producing the same. Although throughout this specifica-
tion and claims specific reference is made to the steel
10 material being in sheet form, other geometric forms of
the material may, of course, be used according to
requirements.

A non-oriented electrical steel sheet is used as
core material for electrical machinery and apparatuses,
15 such as motors and transformers.

Recently, the demands for electrical machinery and apparatuses having enhanced characteristics have been increasing since, internationally, industry has been attempting to reduce electric power consumption and energy consumption in general. In respect to this, a low watt loss and a high magnetic flux density of the core material are indispensable for reducing electric power and energy consumption in electrical machinery and apparatuses.

Also, recently, there have been very strong demands for the development core material which can be used especially for medium and small sized electrical machinery and apparatuses and by which a low watt loss is attained, while at the same time maintaining the meritoriously a high magnetic flux density, and a low cost of a non-oriented electrical steel sheet. In order to meet such demands, the magnetic properties of a non-oriented electrical steel sheet must be improved so that the watt loss in terms of $W_{15/50}$ is 4.5 w/kg or less, while the magnetic flux density in terms of B_{50} is 1.71 Tesla or more

As is well known, non-oriented electrical steel sheets are graded in accordance with the watt loss and magnetic flux density from S60- to S9-grades according to a JIS standard. In conventional high-grade non-oriented electrical steel sheets, the content of silicon which appreciably

increases resistivity, is high so as to decrease the watt loss. For instance, the silicon content of a grade S60 is virtually 0%, and the silicon contents of S23, S18, and S9 grades are approximately 1.5%, approximately 2.0%, and approximately 3.0%, respectively. However, a high silicon content results in a decrease in the magnetic flux density.

The prior art is further described with reference to Figure 1 which illustrates relationships between the watt loss in terms of $W_{15/50}$ and the magnetic flux density B_{50} with regard to conventional non-oriented electrical steel sheets as well as a non-oriented electrical steel sheet according to the present invention.

The curves 1, and 1' in Fig. 1 represent the upper and lower limits of the B_{50} and $W_{15/50}$ of conventional non-oriented electrical steel sheets which are explained hereinafter, and illustrate that the watt loss is decreased in accordance with an increase in the magnetic flux density. Symbol 2 in Fig. 2 is the lines connecting the magnetic properties of non-oriented electrical steel sheets stipulated in JIS Standard C2552.

Attempts to improve the magnetic properties of a non-oriented electrical steel sheet, which does not rely on increasing the content of silicon have been made previously. That is, these attempts include devising a steel chemistry, e.g., the addition of aluminum or boron to silicon steel, or decreasing the carbon or sulfur content, as well as improving production conditions, i.e. employing a high-temperature annealing or a high reduction degree of cold rolling which is carried out before the final annealing. For instance, Japanese Unexamined Patent Publication No. 54-163720/79 of the present applicant (Nippon Steel Corporation) discloses the addition boron into silicon steel in such an amount that the weight ratio of the boron content/nitrogen content is maintained within a predetermined range. The growth of crystal grains during annealing is promoted due to the addition of boron, resulting in the economic production of economically a non-oriented

electrical steel sheet having a low watt loss. Although the addition of boron disclosed in Japanese Unexamined Patent Publication No. 54163720/79 results in decrease in watt loss the relationship between the watt loss and the magnetic flux density falls within the curves 1 and 1' in Fig. 1. The addition of boron is therefore unsatisfactory for meeting the recent demands for improving the magnetic properties of non-oriented electrical steel sheet as compared that indicated by the curve 3. USP No. 4,293,336 discloses the addition of tin into silicon steel so as to decrease the watt loss. However, in order for tin to effectively decrease the watt loss, it is necessary to carry out slow cooling during the annealing of a hot-rolled steel strip or employ a slow heating rate during the final annealing, which procedure disadvantageously limits to the process for producing a non-oriented electrical steel sheet. Although the addition of tin disclosed in USP No. 4,293,364 results in decrease in a watt loss, the relationship between the watt loss and magnetic flux density falls within the curves 1 and 1' of Fig. 1. Thus, the addition of tin is unsatisfactory for meeting the above-mentioned recent demands for improving the magnetic properties of a non-oriented electrical steel sheet.

It is an object of the present invention to provide a non-oriented electrical steel sheet, in which in the production thereof the watt loss in terms of $W_{15/50}$ is 4.5 w/kg at the highest and the magnetic flux density in terms of B_{50} is 1.71 Tesla at the lowest, that is, the relationship between $W_{15/50}$ and B_{50} is at least equal to the line 3 in Fig. 1.

It is another object of the present invention to provide a process for producing a non-oriented electrical steel sheet having the watt loss and magnetic flux density as specified above.

According to a discovery made by the present inventors, an increase in the magnetic flux density in non-oriented electrical steel sheets as compared with conventional

non-oriented electrical steel sheets containing either tin or boron can be achieved by: adding boron into silicon steel in such an amount that the weight ratio of the boron content/nitrogen content be maintained within a predetermined range; adding tin into silicon steel in a small amount; and, subjecting a hot-rolled steel strip to an annealing or carrying out a self-annealing by means of coiling a hot-rolled steel strip at a high temperature. That is, although the known addition of either boron or tin alone does not provides the magnetic flux density increased but only provides the watt loss to be decreased, the combined addition of boron and tin can simultaneously attain both low watt loss and high magnetic flux density.

According to another discovery made by the present inventors, the boron can be totaly or partially replaced with aluminum when content of manganese in a silicon steel is appreciably high.

According to another discovery made by the present inventors, when silicon steel contains both boron and tin, the annealing mentioned above of a hot-rolled steel strip as well as a finishing annealing of a cold rolled steel strip can be carried out consinuously in a short period of time.

The present invention was completed based on this discovery.

A non-oriented electrical steel sheet, according to the present invention having a low watt loss and a high magneistic flux density consists of 0.015% of carbon at the highest, from 0.3% to 2.0% of silicon, from 0.005% to 0.10% of acid-soluble aluminum (hereinafter referred to as sol. Al), from 0.02% to 0.20% of tin, 0.007% of nitrogen at the highest, and 0.005% of boron at the highest, the weight ratio of boron content/nitrogen content being from 0.5 to 1.5, the balance being iron and unavoidable impurities, said nonoriented electrical sheet being produced by a process comprising an annealing of a hot-rolled steel strip. This non-oriented electrical steel sheet of the

present invention is hereinafter referred to as the Sn-B non-oriented electrical steel sheet.

Another non-oriented electrical steel sheet, according to the present invention, having a low watt loss and a high magnetic flux density consists of 0.015% of carbon at the highest, from 0.3% to 2.0% of silicon, from more than 1.0% to 1.5% of manganese, from 0.02% to 0.20% of tin, and either (a) or (b): (a) from 0.005% to 0.10% of sol. Al and 0.007% of nitrogen at the highest, and 0.005% of boron at the highest, the weight ratio of boron content/nitrogen content being from 0.5 to 1.5; or, (b) from more than 0.1% to 0.2% of sol. Al, the balance being iron and unavoidable impurities, said sheet being produced by a process comprising the steps comprising an annealing of a hot-rolled steel strip. This sheet is hereinafter referred to as the Sn-Al(B) nonoriented electrical steel sheet.

A process for producing the SnB non-oriented electrical steel sheet or the Sn-Al(B) non-oriented electrical steel sheet according to the present invention successively comprises the steps of: hot-rolling a silicon steel which having the composition as specified above; annealing the hot-rolled steel strip; cold rolling the hot-rolled steel strip once, or twice or more with an intermediate annealing; and, continuously annealing the cold-rolled steel strip. The annealing of the hot-rolled steel strip may be carried out by means of coiling a hot-rolled steel strip at a temperature of 700°C at the lowest and then self-annealing the coiled hot-rolled steel strip. That is, instead of carrying out usual annealing, such as hotcoil annealing, after the steel is hot-rolled, annealing of the hot-rolled strip may be completed in the hot-rolling step. When the annealing of a hot-rolled strip is carried out after the hot-rolling step, the annealing temperature is 850°C at the lowest.

First, the Sn-B non-oriented electrical steel sheet is described with regard to how tin and boron synergistically improve the magnetic properties thereof. When a nonoriented

electrical steel sheet contains boron only, the boron fixes nitrogen which is detrimental to the magnetic properties and boron nitrides precepitate in the crystal grains. When a non-oriented electrical steel sheet contains tin only,
5 the tin segregates at the grain boundaries and suppresses during recrystallization the generation of a [111] orientation which orientation is detrimental to the magnetic properties thereof.

10 In the Sn-B non-oriented electrical steel sheet, the segregated tin suppresses the recrystallization to initiate at the grain boundaries and promotes recrystallization to initiates in the crystal grains. In addition, the boron nitrides which are precipitated in the crystal grains behave as nuclei during recrystallization and promotes the
15 generation of [110] and [100] textures which are advantageous for the magnetic properties thereof. Therefore, the magnetic properties of the Sn-B non-oriented electrical steel sheet are considerably improved over the magnetic properties of a non-oriented electrical steel sheet
20 containing either boron or tin alone.

Second, the Sn-Al(B) non-oriented electrical steel sheet is described with regard to how manganese, tin and aluminum or boron synergistically improve the magnetic properties thereof. Manganese lowers the recrystallization
25 temperature and substantially facilitates the recrystallization. When the Sn-Al(B) non-oriented electrical steel sheet contains boron, the synergistic effect of tin and boron is explained with reference to the Sn-B non-oriented electrical steel sheet is also attained and promoted since
30 manganese substantially promotes recrystallization.

When the Sn-Al(B) non-oriented electrical steel sheet contains an appreciable amount of sol. Al, i.e. from more than 0.1% to 0.2%, the improvement in magnetic properties is attained by even partially or totally replacing boron
35 with sol. Al. Aluminum added to a silicon steel and alloyed in the silicon steel as sol. Al in an appreciable amount prevents the precipitation of AlN, which is

detrimental to the magnetic properties thereof. In addition, aluminum increases the resistivity and decreases the watt loss of silicon steels. Tin segregates at the grain boundaries and suppresses during recrystallization the generation of [111] orientation which is detrimental to the magnetic properties of a silicon steel. Manganese, sol. Al, and tin which are advantageous for the magnetic properties as understood from the above description synergistically promotes the generation of [110] and [100] orientations so that the Sn-Al(B) non-oriented electrical steel sheet has predominantly [110] and [100] textures.

It is to be noted with regard to nitrogen and sol. Al that: nitrogen does not form compounds or precipitates which behave as nuclei during recrystallization; AlN which is detrimental to the magnetic properties of a silicon steel is not formed due to an appreciable Sol. Al content of; and, sol. Al not only removes the detrimental effects of nitrogen but also increases resistivity, thereby decreasing the watt loss.

As will have been understood from the descriptions hereinabove, the concept which are common to both the Sn-B nonoriented electrical steel sheet and the Sn-Al(B) non-oriented electrical steel sheet is to controlling the recrystallization so that it is advantageous with regard to the magnetic properties thereof. When this concept is explained in more metallurgical terms, it can be said that the combined addition of tin together with boron and or sol. Al renders recrystallization liable to occur predominantly in the crystal grains, and [110] and [100] textures which are desirable for the magnetic are formed during recrystallization. On the other hand, conventional addition of tin only and addition of boron and/or sol. Al only are not very effective for suppressing the formation of [111] texture which is detrimental to the magnetic properties of a non-oriented electrical steel sheet.

The compositions of the Sn-B nonoriented electrical steel sheet and the SnB(Al) non-oriented electrical steel

sheet are now described.

Carbon is a harmful element which increases the watt loss. Therefore, a low carbon content, i.e. 0.015% or less, is desirable so as to reduce the watt loss and prevent deterioration of the magnetic properties due to aging or the so-called magnetic aging. A carbon content of not more than 0.005% is desirable for promoting the synergistic effects which are attained by combined addition of tin with boron and/or sol. Al.

Silicon increases the resistivity and decreases the watt loss of a steel as is well known. Silicon content which is effective for decreasing the watt loss is 0.3% at the lowest. However, when the silicon content is more than 2.0%, the rolling workability of silicon steel is impaired and the nonoriented electrical steel sheet becomes expensive.

Aluminum is necessary for deoxidizing steels. A sol. Al content of 0.005% is necessary for effectively deoxidizing silicon steels.

In the case of the Sn-B non-oriented electrical steel sheet and the Sn-Al(B) non-oriented silicon steel sheet containing boron, the maximum content of sol. Al should be so controlled that sol. Al does not excessively fix the nitrogen. If the sol. Al content is more than 0.1%, the sol. Al fixes the nitrogen excessively, and thus the amount of solute boron is increased with the result that the watt loss is increased and the magnetic flux density is decreased. In other words, when the sol. Al content is more than 0.1%, sol. Al renders the boron ineffective for improving the magnetic properties of the non-oriented electrical steel sheet.

In the case of the Sn-Al(B) non-oriented electrical steel sheet, boron can be partially or totally replaced with sol. Al as described above. If boron is totally replaced with sol. Al, the sol. Al content must be more than 0.1% so as to prevent the precipitation of AlN. If boron is partially replaced with sol. Al and if the content

of sol. Al is 0.1% at the highest, the weight ratio of the boron content/nitrogen content should be from 0.5 to 1.5 ($0.5 \leq B/N \leq 1.5$). When the content of sol. Al is more than 0.20%, the magnetic flux density is low.

5 Boron together with tin or together with both manganese and tin synergistically improves the magnetic properties of a non-oriented electrical steel sheet. In order for boron to have a synergistic effect, the weight ratio of the boron content/nitrogen content must be from 0.5 to 1.5. If the
10 weight ratio is less than 0.5, it is difficult to eliminate the detrimental effect of nitrogen. On the other hand, when such ratio is more than 1.5, an amount of solute boron is so increased that the magnetic properties of the non-oriented electrical steel sheet cannot be improved. The
15 boron content must be 0.005% at the highest so as to prevent that cracks are formed on slabs during hot rolling.

 Tin together with boron, or together with both manganese and sol. Al synergistically improve the magnetic properties of the non-oriented electrical steel sheet. In
20 order for tin to have a synergistic effect, the content of tin must be 0.02% at the lowest. However, when the tin content is more than 0.20%, the effect of tin is saturated and the production cost is increased.

 Manganese is not conventionally used to enhance the
25 magnetic properties of a non-oriented electrical steel sheet because manganese is liable to form nonmetallic inclusions, such as sulfides and oxides. However, it is possible to use manganese to enhance the magnetic properties of an electrical steel sheet since the steelmaking technique
30 is advanced enough so that high-purity steels can be produced. According to a discovery made by the present inventors manganese is effective for developing [100] and [110] textures, which textures result in desirable magnetic properties, and for suppressing a [111]
35 texture, which texture is detrimental to the magnetic properties thereof. In the Sn-Al(B) nonoriented electrical steel sheet the manganese content is more than 1.0%

so as to promote development of [100] and [110] textures. And, since manganese lowers the ferrite-austenite transformation temperature, if the manganese content is more than 1.5%, ferrite-austenite transformation is likely
 5 to occur during the annealing of a hot-rolled strip, thereby rendering the manganese ineffective for improving the texture and the magnetic properties. The manganese content in the Sn-B non-oriented electrical steel sheet is not specified and may be less than 1.0%, e.g. approxi-
 10 mately 0.3%.

The elements other than those described above are iron and unavoidable impurities.

The Sn-B nonelectrical steel sheet and a process for producing such a sheet are further described with reference
 15 to experiments carried out by the present inventions.

In the experiments, four hot-rolled steel strips having the compositions as given in Table 1-1, below, were subjected to each of the production steps given in Table 1-2, below. The magnetic properties obtained are
 20 given in Table 1-3, below.

Table 1-1

Composition of Steels (%)

<u>No.</u>	<u>C</u>	<u>Si</u>	<u>S</u>	<u>Sol.Al</u>	<u>B</u>	<u>N</u>	<u>Sn</u>
1	0.003	1.50	0.005	0.023	0.0021	0.0018	0.065
2	0.003	1.51	0.004	0.022	0.0022	0.0017	-
3	0.003	1.38	0.004	0.260	-	0.0018	-
4	0.003	1.40	0.005	0.255	-	0.0018	0.070

Table 1-2

Process A	Hot-rolled Strip	Annealing 900°Cx2 min.	Cold-rolling 0.5 mm	Continuous Annealing 900°Cx20"
Process B	Hot-rolled Strip	Annealing 900°Cx2 min.	Cold-rolling 0.5 mm	Continuous Annealing 900°Cx20"

Table 1-3

Magnetic Properties

Composition & Process	$W_{15/50}$ W/kg	B_{50} Tesla	Composition & Process	$W_{15/50}$ W/kg	B_{50} Tesla
1A	3.58	1.754	1B	4.01	1.701
2A	3.84	1.684	2B	4.32	1.663
3A	3.98	1.686	3B	4.36	1.673
4A	3.67	1.704	4B	4.25	1.686

As can be seen from Table 1-3, only the Sn-B non-oriented electrical steel sheet, i.e. the symbol 1A, had a low watt loss and a high magnetic flux density. Other symbols, i.e., non-oriented electrical steel sheets, in which at least either the combined addition of tin and boron, or annealing of a hot-rolled strip, had a high watt loss and a low magnetic flux density is not satisfied.

The process for producing the Sn-B non-oriented electrical steel sheet and the Sn-Al(B) non-oriented electrical steel sheet is now described.

Steels having the composition as described above are melted in a converter, an electric furnace, or the like,

and are continuously cast or cast as an ingot, followed by rough rolling to obtain a slab.

5 The slab is hot-rolled at a predetermined temperature so as to produce a hot-rolled steel strip. Annealing of a hot-rolled steel strip can improve the texture of the strip, thereby enhancing the magnetic properties thereof as compared with those without annealing of a hot-rolled strip. If the hot-rolled strip is annealed at a temperature less than 850°C, the annealing is not very effective for
10 improving the texture of the strip.

Annealing of the hot-rolled steel strip may be carried out by means of self-annealing, in which the strip is annealed by the heat retained therein. The self-annealing can be attained by coiling a hot-rolled steel strip at a
15 temperature of 700°C at the lowest. If the coiling temperature is less than 700°C, fine precipitates form during a subsequent annealing, i.e. the annealing of a hot-rolled steel strip, and suppress the growth of crystal grains.

20 A coiled hot-rolled strip is advantageously covered with a heat-insulation cover which reduces the amount of heat which radiates from the strip. Evidently, if the coiling temperature is less than 700°C, the hot-rolled steel strip is subsequently annealed, e.g. by means of the
25 batch annealing or continuous annealing. Since the magnetic properties obtained by both rapid heating- and cooling-rates of annealing are excellent, the continuous annealing is advisable for annealing a hot-rolled steel strip.

30 A hot-rolled steel strip is then cold-rolled once or twice or more with an intermediate annealing, thereby obtaining a final thickness. The intermediate annealing is carried out between successive cold-
-rollings.

35 Finishing annealing of a cold-rolled steel strip is then carried out. Slow heating during the finishing annealing is not very advantageous for the magnetic

properties, since the combined addition of tin with boron and/or sol. Al changes the influences of the heating rate upon the magnetic properties in such a manner that a rapid heating is rather desirable for the magnetic properties.

5 The annealing temperature is varied in accordance with the magnetic properties to be attained. Since the continuous finishing annealing is more advisable than the batch finishing annealing, the production efficiency of the Sn-B non-oriented electrical steel sheet and Sn-Al(B) non-
10 -oriented electrical steel sheet is high, which is one of the synergistic effects attained by the combined addition of tin with boron and/or sol. Al.

Although the process for producing the Sn-B non-oriented electrical steel sheet and the Sn-Al(B)
15 non-oriented electrical steel sheet is completed at the finishing annealing, such sheets may be further subjected to stress-relief annealing or skin pass rolling. The reduction rate (draft) at skin pass rolling depends on the intermediate annealing temperature. Preferably, reduction
20 rate at skin-pass rolling is from 2% to 10%. A skin-pass rolled steel strip is then subjected to blanking to obtain a predetermined sheet section and is then stress-relief annealed. In this case, the so-called semi-processed non-oriented electrical steel sheet is produced. When the
25 reduction rate at skin pass rolling, is less than 2%, stress-relief annealing is ineffective for improving the watt loss. On the other hand, a reduction rate at skin pass rolling of more than 10% results in deterioration the magnetic properties.

30 The present invention is described now by way of examples.

Example 1

Non-oriented electrical steel sheets were produced under the conditions of process for treating steels given
35 in Table 2.

Table 2

Steel Nos.	Composition of Slobs							Process Conditions					Magnetic Properties				Remarks		
	C	Si	Mn	S	Sol Al	B	Sn	N	B/N	CT	SA	ICA	T	FA		SRA			
														W 15/50 (W/kg)	B50 (Tesla)	W 15/50 (W/kg)		B50 (Tesla)	
5	0.003	0.46	0.26	0.006	0.022	0.0022	0.07	0.0019	1.2	780°C	Effectcd	-	0.5mm	875°C x20sec.	4.41	1.79	4.19	1.79	In- vention
6	0.003	0.47	0.24	0.007	0.023	0.0023	0.07	0.0020	1.2	650°C	-	-	0.5mm	875°C x20sec.	6.88	1.75	6.47	1.74	Control
7	0.003	0.52	0.31	0.006	0.031	0.0024	-	0.0021	1.1	790°C	Effectcd	-	0.5mm	900°C x60sec.	5.03	1.76	4.78	1.76	Control
8	0.003	1.13	0.28	0.006	0.025	0.0024	0.06	0.0020	1.2	800°C	Effectcd	-	0.5mm	900°C x20sec.	3.98	1.77	3.27	1.77	In- vention
9	0.003	1.12	0.22	0.005	0.023	0.0023	0.06	0.0021	1.1	650°C	-	-	0.5mm	900°C x20sec.	4.72	1.69	4.02	1.69	Control
10	0.003	1.09	0.26	0.006	0.270	-	0.05	0.0019	-	650°C	-	900°C x2min.	0.5mm	900°C x30sec.	4.52	1.70	3.88	1.69	Control
11	0.003	1.67	0.27	0.004	0.023	0.0024	0.07	0.0021	1.1	670°C	-	925°C x2min.	0.5mm	900°C x20sec.	3.38	1.75	2.86	1.75	In- vention
12	0.002	1.69	0.30	0.004	0.022	0.0025	0.07	0.0023	1.1	660°C	-	-	0.5mm	900°C x20sec.	3.98	1.70	3.51	1.69	Control
13	0.003	1.72	0.22	0.005	0.025	0.0021	-	0.0019	1.1	660°C	-	925°C x2min.	0.5mm	900°C x20sec.	3.76	1.68	3.34	1.68	Control
14	0.003	0.51	1.31	0.004	0.022	0.0024	0.07	0.0023	1.0	780°C	Effectcd	-	0.5mm	875°C x20sec.	3.95	1.81	3.48	1.80	In- vention
15	0.003	0.50	1.30	0.004	0.18	-	0.06	0.0023	-	780°C	Effectcd	-	0.5mm	875°C x20sec.	3.89	1.81	3.41	1.80	In- vention

CT ... Coiling temperature SA ... Self-annealing ICA ... Hot-coil annealing FA ... Finishing annealing SRA ... Stress-relief annealing

As can be understood from Table 2, both a low watt loss and a high magnetic flux density are attained when steels: contain both boron and tin or has high manganese and sol. Al contents and contains tin, and at the same time
5 these steels are self-annealed or annealed after the hot-rolling step.

Example 2

Steel Nos. 5, 6, 7, 14, and 15, were subjected to the same production procedure as in Example 1, except that
10 virtually 0.5 mm thick cold-rolled steel strips were continuously annealed at 750°C for the period of 60 seconds (1 minute) and then skin-passes rolled at the reduction rate of 4%. An Epstein specimen was cut from the skin-pass rolled strip and the magnetic properties were measured
15 after carrying out a stress-relief annealing at 790°C for the period of 1 hour (60 minutes).

The magnetic properties are given in Table 3.

Table 3

Magnetic Properties of Semi-Processed
Non-oriented Electrical Sheets

Steel Nos.	$W_{15/50}$ (W/kg)	B_{50} (Tesla)
5	3.95	1.75
6	6.23	1.73
7	4.53	1.73
14	2.92	1.79
15	2.89	1.78

Example 3

Steels having the composition as given in Table 3, below were subjected to continuously annealing hot-rolling, coiling at 750°C, annealing at 900°C for the period of 2 5 minutes, cold-rolling, to obtain 0.50 mm thick strips, finishing annealing at 850°C for the period of 1 minutes, skinpass rolling with reduction degree of 6%; and, stress-relief annealing at 790°C for the period of 1 hour in 100% N₂ atmosphere.

Table 4
Composition of Steels (%)

No.	C	Si	Mn	S	Sol.Al	Sn	N	B	B/N
16	0.004	0.49	0.26	0.003	0.026	-	0.0023	0.0024	1.0
17	0.004	0.51	0.50	0.002	0.022	-	0.0022	0.0022	1.0
18	0.003	0.46	0.77	0.002	0.028	-	0.0024	0.0023	1.0
19	0.004	0.47	1.03	0.003	0.024	-	0.0021	0.0025	1.2
20	0.003	0.53	1.27	0.002	0.022	-	0.0019	0.0023	1.2
21	0.004	0.50	0.28	0.003	0.027	0.09	0.0022	0.0020	0.9
22	0.003	0.49	0.52	0.003	0.030	0.10	0.0024	0.0025	1.0
23	0.003	0.49	0.79	0.003	0.021	0.09	0.0019	0.0022	1.2
24	0.003	0.51	1.04	0.002	0.024	0.11	0.0022	0.0022	1.0
25	0.004	0.47	1.27	0.002	0.027	0.10	0.0023	0.0026	1.1

The dependence of the magnetic properties upon the manganese content is illustrated in Figure 2. As will be understood from Fig. 2 a manganese content of more than 1% is effective for improving the magnetic properties of
5 non-oriented electrical steel sheets containing tin and boron at such contents as providing $0.5 \leq B/N \leq 1.5$ and a decrease in the watt-loss and an increase in magnetic flux density are simultaneously attained.

CLAIMS:

1. A non-oriented electrical steel material having a low watt loss and a high magnetic flux density consisting of 0.015% of carbon at the highest, from 0.3
5 to 2.0% of silicon, from 0.005 to 0.10% of acid-soluble aluminium, from 0.02% to 0.20% of tin, 0.007% of nitrogen at the highest, and 0.005% of boron at the highest, the weight ratio of boron content/nitrogen content being from 0.5 to 1.5, the balance being iron and unavoidable
10 impurities, said non-oriented electrical material being produced by a process comprising annealing after hot-rolling the steel material.

2. A non-oriented electrical steel sheet having a low watt loss and a high magnetic flux density
15 according to the present invention, contains 0.015% of carbon at the highest, from 0.3% to 2.0% of silicon, from more than 1.0% to 1.5% of manganese, from 0.02% to 0.20% of tin, and either (a) or (b): (a) from 0.005% to 0.10% of acid-soluble aluminium and 0.005% of boron
20 at the highest, 0.007% of nitrogen at the highest, the weight ration of boron content/nitrogen content being from 0.5 to 1.5, or, (b) from more than 0.1% to 0.2% of acid-soluble aluminium, the balance being iron and

unavoidable impurities, said sheet being produced by the steps comprising annealing after hot-rolling the steel material.

3. A process for producing a non-oriented
5 electrical steel sheet according to claim 1 or 2 successively comprises the steps of: hot-rolling a silicon steel which has the composition as specified above; annealing after hot-rolling the steel material; cold rolling said hot-rolled steel material once or twice or
10 more with an intermediate annealing; and, continuously annealing cold-rolled steel material.

4. A process according to claim 3, wherein the material is in strip form.

5. A process according to claim 3 or claim 4,
15 wherein said annealing of the hot-rolled steel strip is carried out by means of coiling a hot-rolled steel strip at a temperature of 700°C at the lowest and self annealing the coiled hot-rolled steel strip.

6. A process according to claim 3 or claim 4,
20 wherein said annealing of the hot-rolled strip is carried out after the hot-rolling step at a temperature of 850°C at the lowest.

7. A process according to claim 3 or claim 4, wherein said continuously annealed cold rolled steel strip is further subjected to a skin-pass rolling at a reduction rate of from 2 to 10%.

Fig. 1

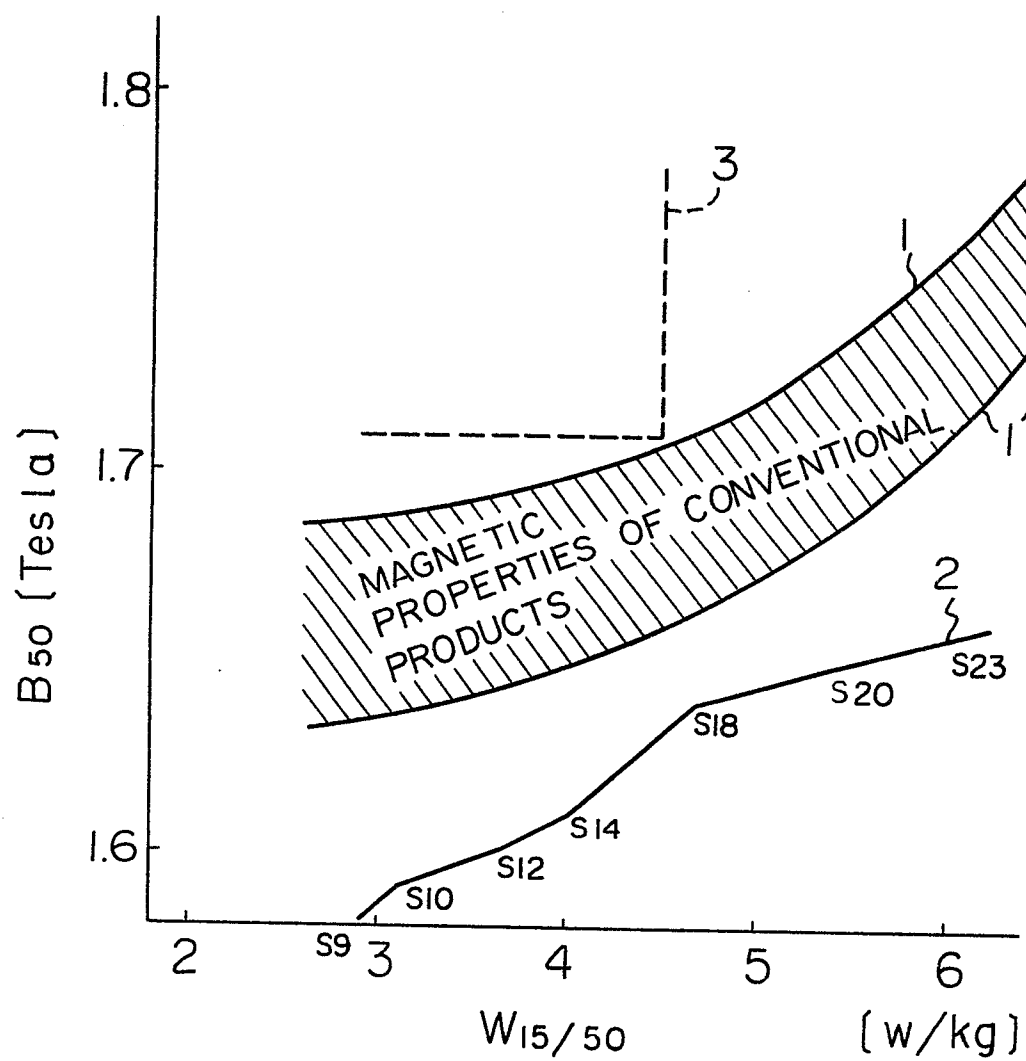


Fig. 2