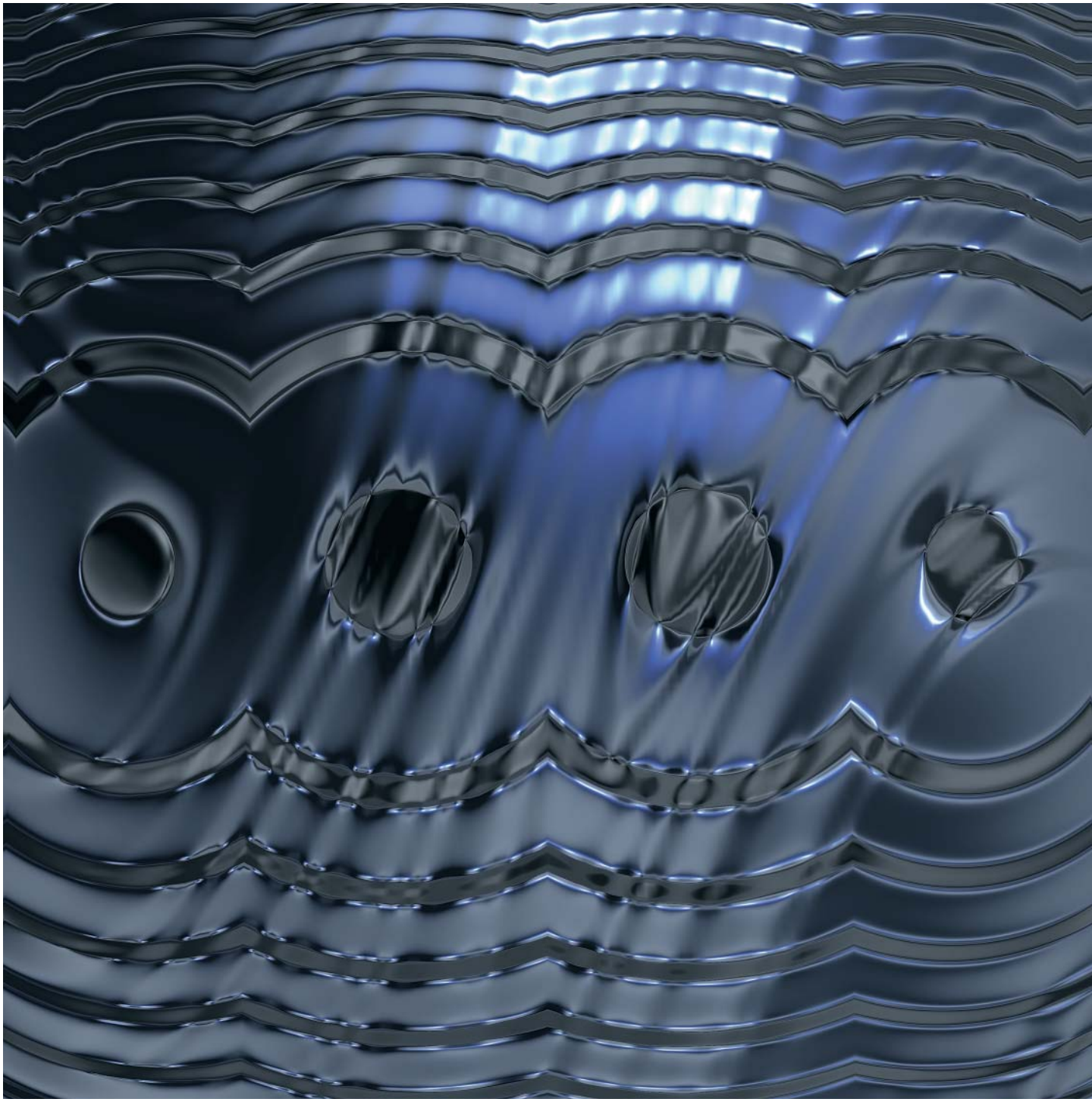
Super Core™

Electrical steel sheets for high-frequency application



JFE Steel Corporation

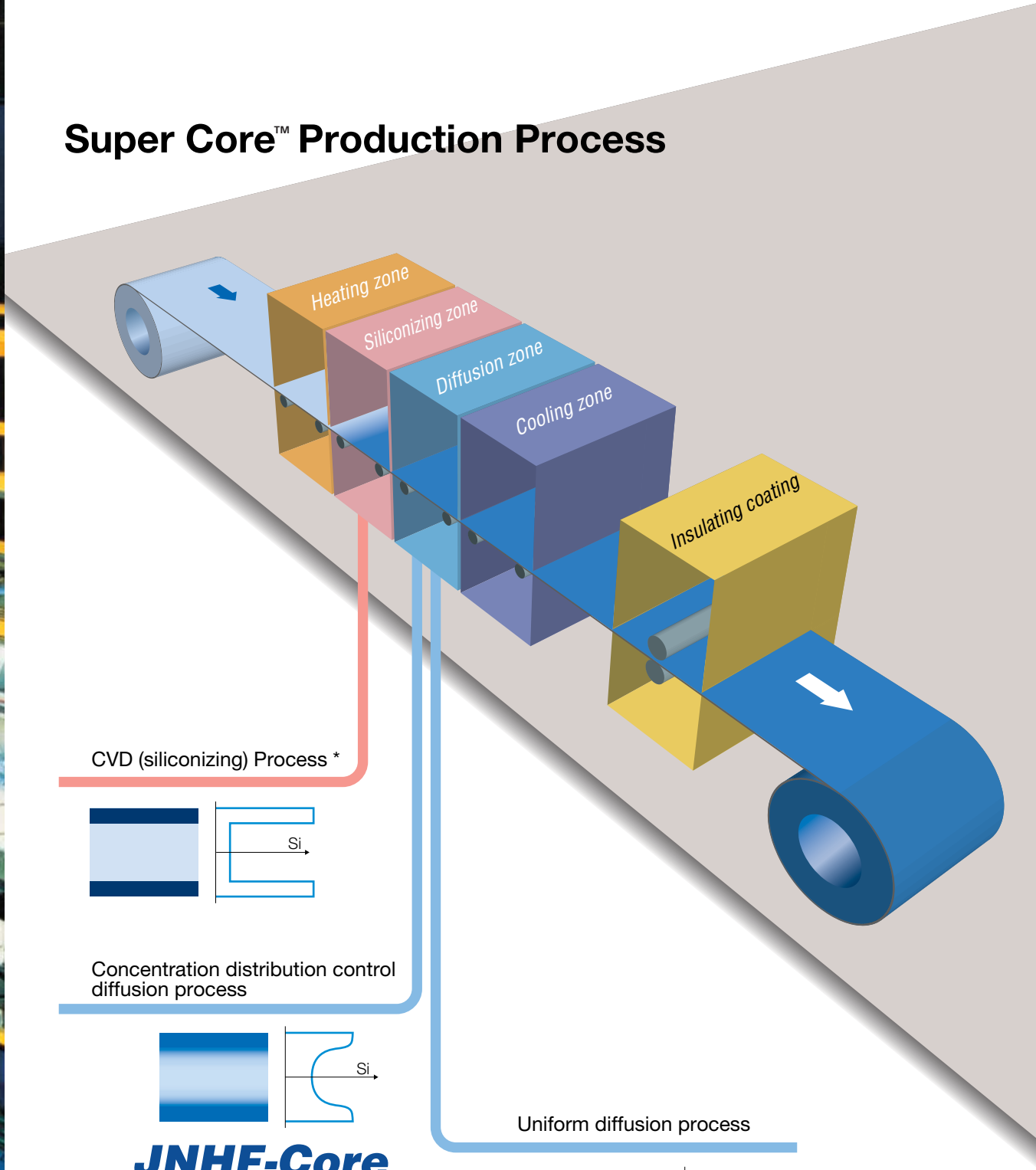
Super Core™

Super Core™ is manufactured using an innovative process that is completely different from that for conventional silicon steel sheets. These are the highest grade, non-oriented magnetic steel sheets available.

Conventional silicon steel sheets have a Si (silicon) content of 3.5% or less. It has long been known that the magnetic characteristics of a silicon steel sheet improve as the Si content increases, peaking at 6.5%. However, it has been impractical to produce thin steel sheets with a Si content of over 3.5% because the steel tends to harden and become brittle. In 1993 JFE Steel solved this production problem through the adoption of a process called the CVD process, and successfully introduced the first 6.5% Si steel sheets (JNEX-Core) to the world.

In order to meet new demands, this technology has continued to be developed, leading to the commercial production of gradient high-silicon steel sheets with superior high-frequency characteristics (JNHF-Core).

Super Core™ Production Process



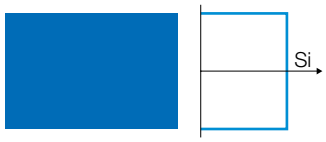
CVD (siliconizing) Process *

Concentration distribution control diffusion process

JNHF-Core

Gradient high-silicon steel sheet with low silicon content at the center portion and 6.5% silicon near the outer surface areas

Uniform diffusion process



JNEX-Core

6.5% silicon steel sheet. (A high-silicon steel sheet with a uniform silicon content of 6.5% throughout the sheet)

* CVD Chemical Vapor Deposition

JNEX-Core

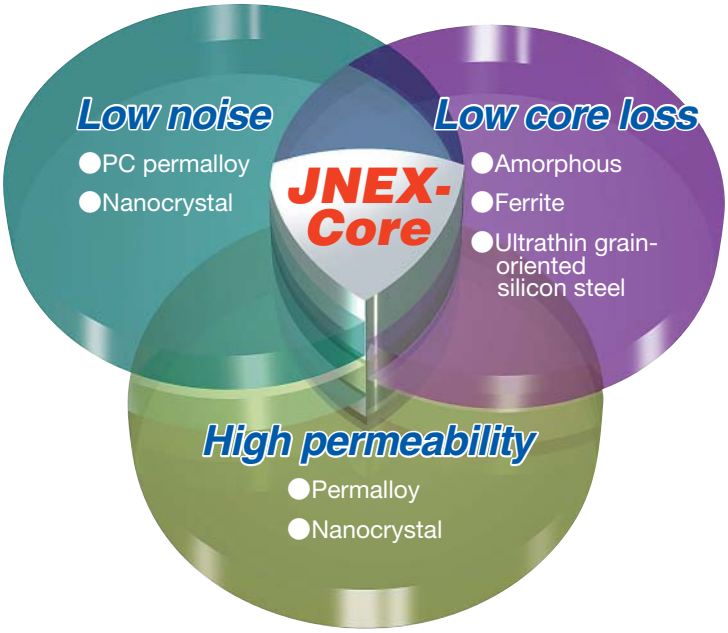
JNEX-Core is the highest-grade non-oriented magnetic steel sheets manufactured with a production method (CVD process) that is completely different from that for conventional silicon steel sheets, allowing a previously impossible Si content of 6.5%.

Low Core Loss

Core loss in high-frequency ranges is extremely low. This allows for low heat generation and size reductions for magnetic components such as high-frequency reactors and transformers.

Low Magnetostriction

Magnetostriction which causes noise and vibration is nearly zero. This enables significant noise reductions for magnetic components such as reactors and transformers.



High Permeability

The permeability is extremely high across a wide range of frequencies, making it highly suitable for use in shield applications and CT.

Stable Quality

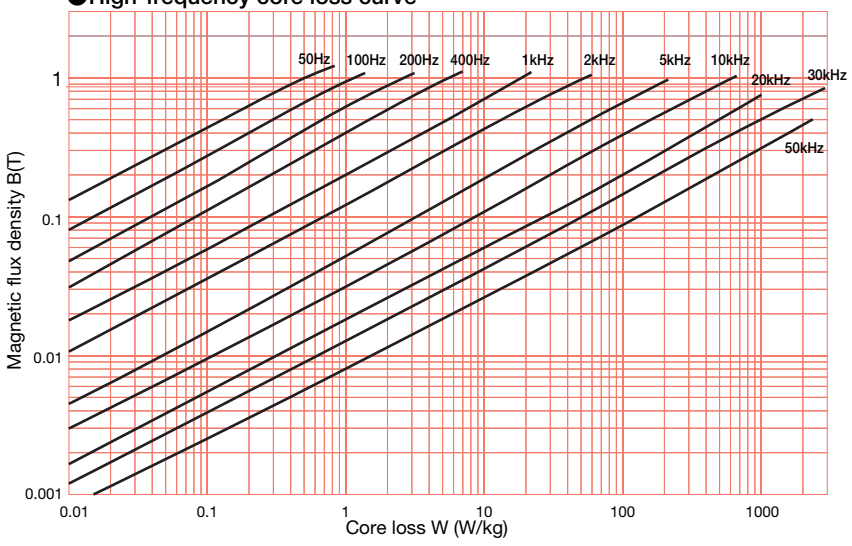
The high-temperature processing provides thermal stability. Since there is minimal deterioration of the properties due to machining, so stress-relieving anneals are not required.

Non-oriented

There is virtually no difference in the characteristics between the rolling direction (L-direction) and the transverse (C-direction). Therefore, this can be used in a wide range of applications, from stationary machines to rolling machines.

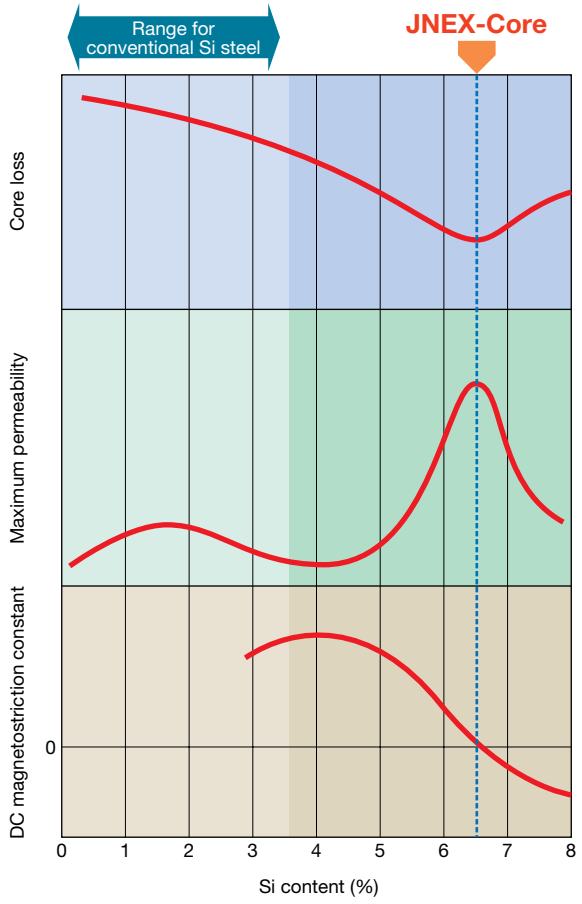
10JNEX900

●High-frequency core loss curve



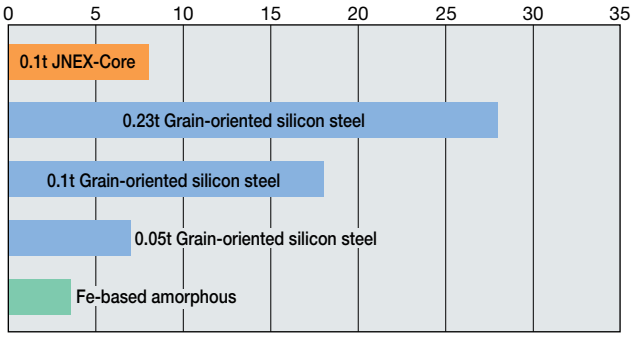
Measurement : 25 cm Epstein test
Rolling direction, shear cross-section

Variation in magnetic properties of silicon steel by Si content

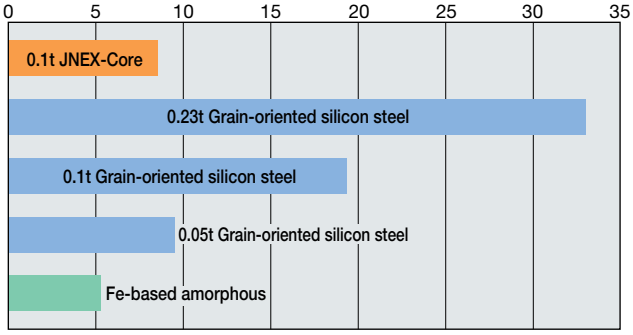


Characteristics

■Material core loss W1/10k (W/kg)* (in-house data)



■Cut core (CS500 core loss W1/10k (W/kg)* (in-house data)



* W1/10k is the core loss at 10kHz, 0.1T(=1kG) when the magnetic flux sine wave is excited.

Sample Characteristics Table

■Comparison of magnetic characteristics (JFE in-house data) : Rolling direction, shear cross-section

Material	Thickness (mm)	Specific resistance ($\mu\Omega$·m)	DC max relative permeability	Saturation magnetization (T)	Magnetic flux density B_8(T)	Magnetic flux density B_{25}(T)	Magnetostriction λ10/400 ($\times10^{-6}$)	Core loss (W/kg)						
								W10/50	W10/400	W10/1k	W5/2k	W2/5k	W1/10k	W0.5/20k
JNEX-Core	0.10	0.82	23,000	1.80	1.29	1.40	0.1	0.5	5.7	18.7	13.7	11.3	8.3	6.9
Grain-oriented silicon steel	0.05 0.10 0.23 0.35	0.48	— 24,000 92,000 94,000	2.03	1.75 1.84 1.92 1.92	— 1.91 1.96 1.96	−0.8	0.8 0.7 0.3 0.4	6.4 6.0 7.8 12.2	17.2 22.7 35.0 55.0	13.5 22.0 33.0 49.5	9.2 20.0 33.0 49.5	7.1 18.0 30.0 47.0	5.2 14.0 32.0 49.0
Non-oriented silicon steel	0.10 0.20 0.35	0.57	12,500 15,000 18,000	2.05 2.03 1.96	1.58 1.44 1.45	— 1.53 1.56	7.8	0.8 0.7 0.7	8.5 11.0 14.4	27.1 38.5 62.0	22.4 33.2 50.2	16.5 26.2 38.0	13.3 23.0 33.0	— — —
Fe-based amorphous	0.025	1.30	300,000	1.50	1.38	—	27.0	0.1	1.5	5.5	8.1	4.0	3.6	3.3
Ferrite	Bulk	—	3,500	—	0.37	—	21.0	—	—	—	—	2.2	2.0	1.8

* W10/50 is the core loss at 50Hz, 1T(=10kG) when the magnetic flux sine wave is excited.
* B_8 is the magnetic flux density at 800A/m.
* λ10/400 is the magnetostviction at 400Hz, 1T when the magentic flux sine wave is excited.

JNHF-Core

For the JNHF-Core, the siliconization technology (CVD process) used for JNEX-Core has been further developed, leading to even greater lower core loss in the high-frequency ranges.

Low Core Loss

For high-frequencies in excess of 5 kHz, outshines even JNEX-Core for low core loss.

Highly Workable

Excellent workability for pressing, bending, stamping, etc.

Non-oriented

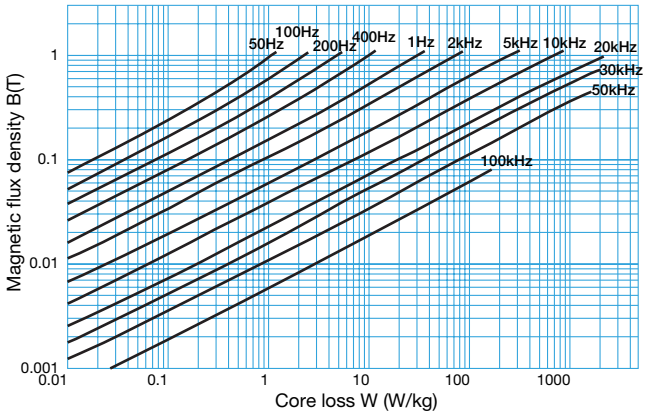
There is virtually no difference in the characteristics between the rolling direction (L-direction) and the transverse direction (C direction).
Therefore, this can be used in a wide range of applications, from stationary machines to rolling machines.

High-saturation magnetic flux density

Has a high saturation magnetic flux density of 1.85 ~ 1.94 T Using this material in a reactor takes full advantage of the superior DC superimposition characteristics.

10JNHF600

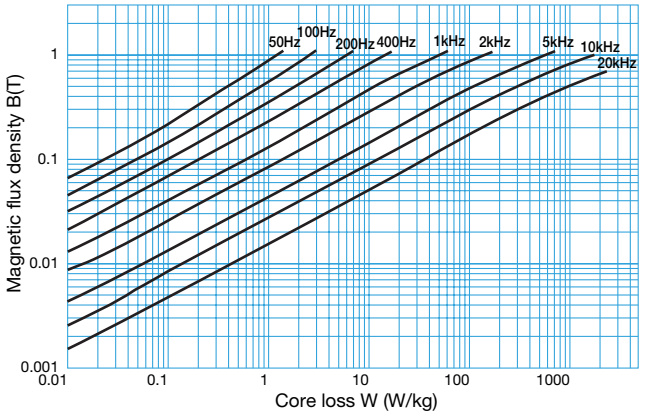
●High-frequency core loss curve



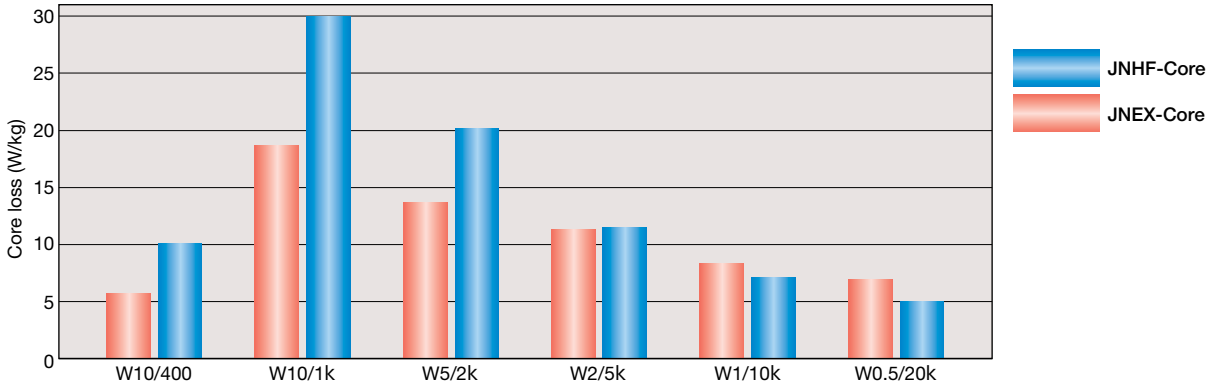
Measurement: 25 cm Epstein test
Rolling direction, shear cross-section

20JNHF1300

●High-frequency core loss curve

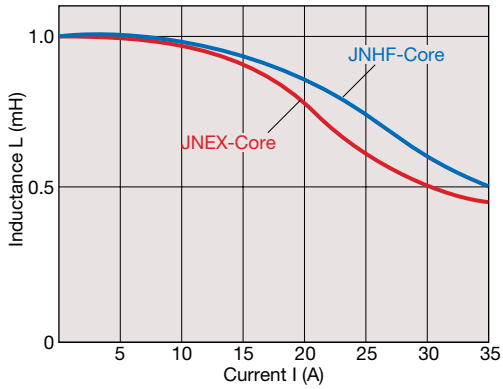


Core Loss Comparison between JNHF-Core and JNEX-Core (0.10 mm thick)



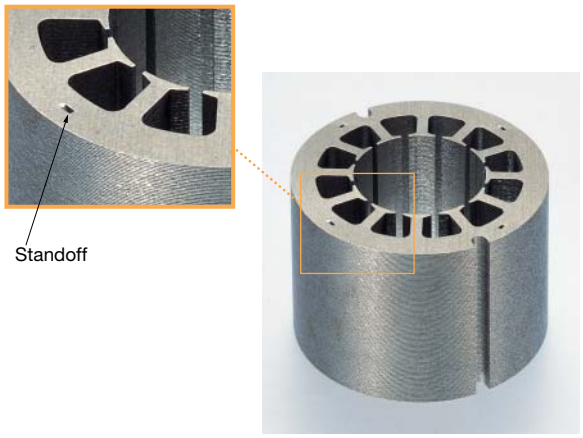
* W10/400 is the core loss at 400Hz, 1T(=10kG) when the magnetic flux sine wave is excited.

Comparison of reactor DC superimposition characteristics



* Using a multi-layer block core (sheet thickness 0.1 mm)
* 20 kHz, 0.05 T equivalent ripple current applied

Press machined sample (0.2 mm thick)



Sample Characteristics Table

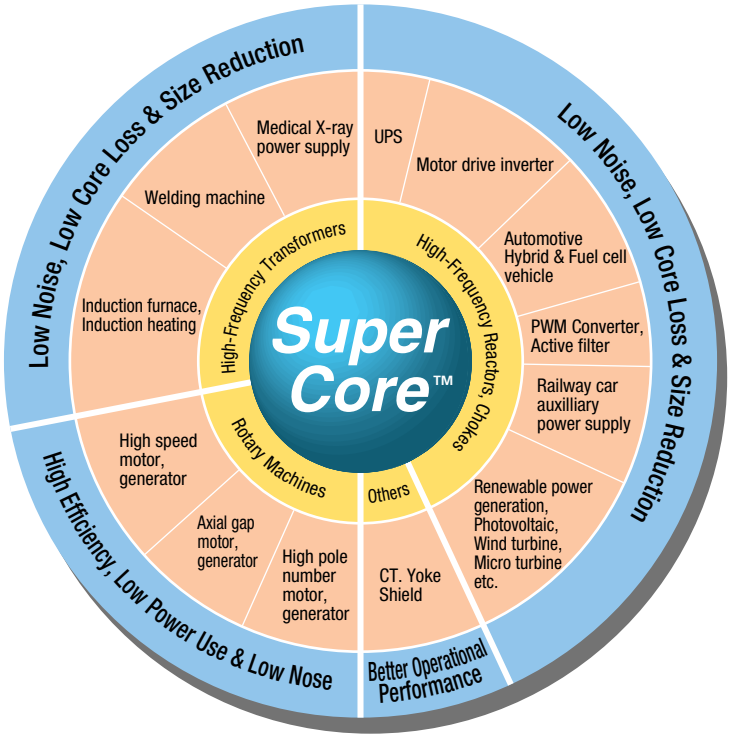
■Comparison of magnetic characteristics (JFE in-house data) : Rolling direction, shear cross-section

Material	Thickness (mm)	DC max relative permeability	Saturation magnetiza-tion (T)	Magnetic flux density B_8(T)	Magnetic flux density B_{25}(T)	Core loss (W/kg)						
						W10/50	W10/400	W10/1k	W5/2k	W2/5k	W1/10k	W0.5/20k
JNHF-Core	0.10 0.20	4,100 3,900	1.88 1.94	1.15 1.09	1.44 1.47	1.1 1.2	10.1 14.5	30.0 51.6	20.2 29.1	11.5 17.9	7.1 12.7	5.0 9.5
JNEX-Core	0.10	23,000	1.80	1.29	1.40	0.5	5.7	18.7	13.7	11.3	8.3	6.9
Grain-oriented silicon steel	0.10	24,000	2.03	1.84	1.91	0.7	6.0	22.7	22.0	20.0	18.0	14.0
Non-oriented silicon steel	0.35	18,000	1.96	1.45	1.56	0.7	14.4	62.0	50.2	38.0	33.0	—
Amorphous	0.025	300,000	1.50	—	—	0.1	1.5	5.5	8.1	4.0	3.6	3.3

* W10/50 is the core loss at 50 Hz, 1 T (=10kG) when the magnetic flux sine wave is excited
* B_8 is the magnetic flux density at 800A/m.

Uses for Super Core™

Super Core™ Applications



JNEX-Core

Reduced noise and low core loss for high-frequency magnetic components

JNHF-Core

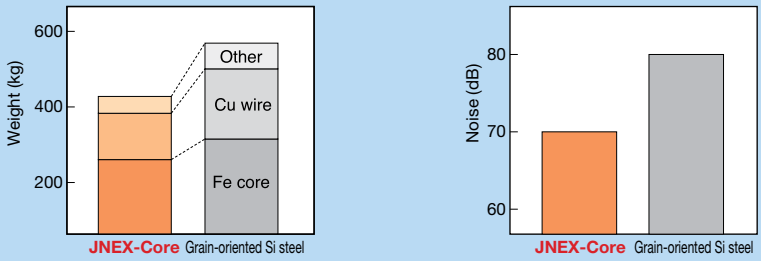
Further core loss reduction in high frequency ranges beyond 5 kHz

High-frequency transformer

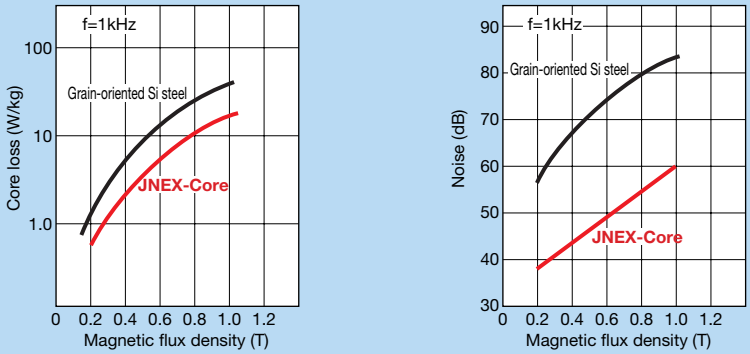
Transformers

The low core loss characteristics at high-frequency of Super Core™ allow it to be effectively used for a wide range of transformers, driven from several hundred Hz to several tens of kHz.
Super Core™ allow the transformer to generate less heat, and provide higher design induction than conventional silicon steel sheets, enabling transformer size to be reduced. This then reduces the quantities of other required transformer materials, such as the copper wire, leading to overall cost reductions.
By taking full advantage of the low magnetostriction characteristics of JNEX-Core, it is also possible to reduce transformer noise dramatically.

●Examples of noise and size reduction for high-frequency transformers (for fixed core loss)



●High-frequency transformer noise and core loss comparison



Reactors (Chokes, Inductors)

Due to the high saturation magnetic flux density, the low core loss at high-frequency and the high-permeability of Super Core™, it is ideal for applications in high-frequency reactors with high-frequency current superimposition over a broad range of frequencies.
Because Super Core™ meets all high frequency wave regulations and power factor improvements, demand is on the increase for its use in not only inverter output reactors but also in active filters and in PWM converter reactors in the market sectors from consumer electronics to industrial, renewable power generation and automotives.
Diagram below shows the characteristics of general magnetic cores and Super Core™ (JNHF-Core and JNEX-Core) from the perspective of the magnetic characteristics required for a high-frequency reactor, i.e., core loss and saturation flux density. In this diagram, the iron loss is compared under a ripple frequency of 20 kHz. The data shows that JNHF-Core and JNEX-Core both have the necessary characteristics for a high-frequency reactor, and indicate superior total balance compared to the other magnetic cores.

●Typical magnetic properties of soft magnetic core materials applied for switched mode power supplies using IGBT, MOS-FET

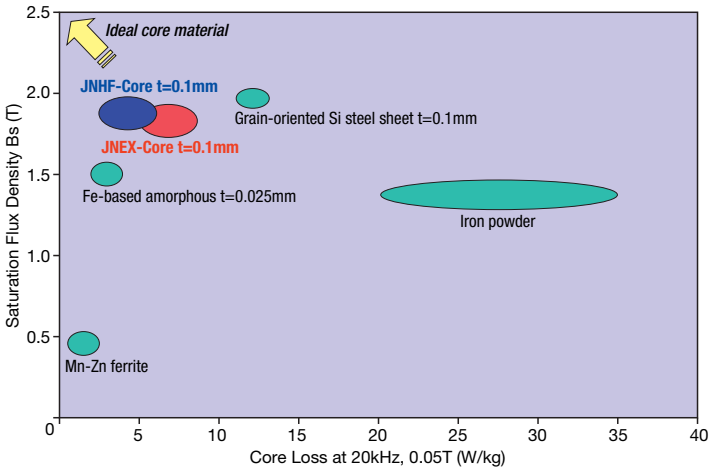
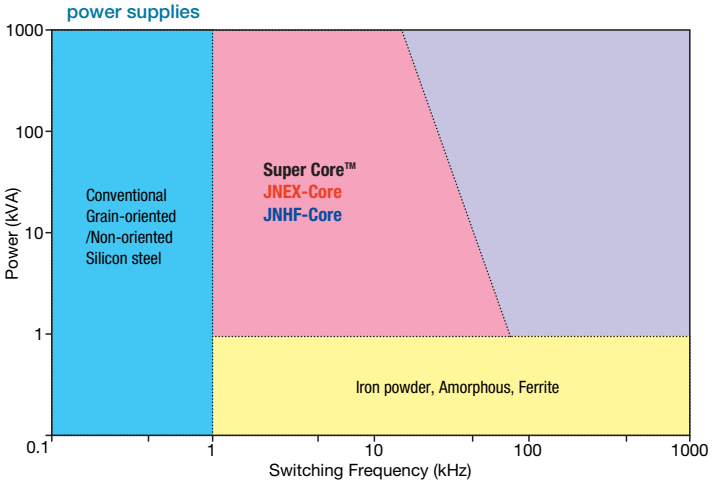
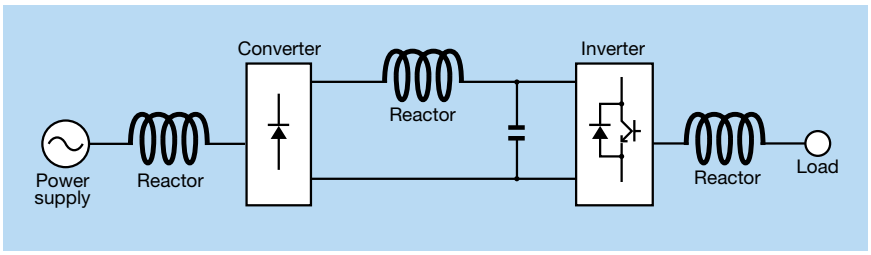


Diagram below indicates the power supply and the switching frequency (ripple frequency) that are suitable for Super Core™. As the data shows, Super Core™ is suitable for medium-capacity inverter and converter reactors of 3 kHz, 1 kVA or 10A or higher. Particularly with this power supply, Super Core™ effectively brings such benefits as high efficiency, compact size, and low noise.

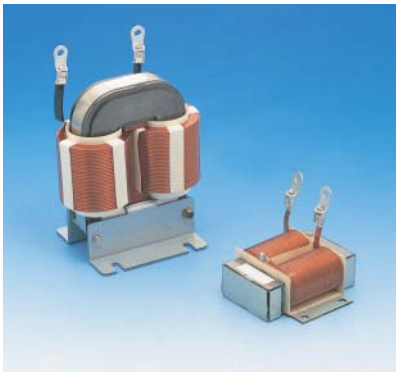
●Suitable core materials for transformers and reactors in switched mode power supplies



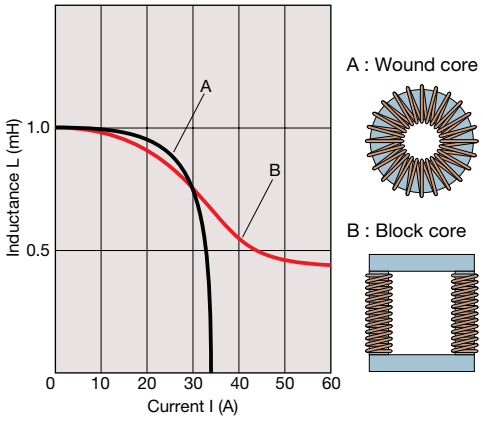
Super Core™ meets a diverse range of customers needs since it can be formed into wound cores, such as C-cores and toroidal cores, as well as into lamination cores and glued block cores of various shapes by cutting or pressing.
For example, as illustrated in the figure on the bottom right, a reactor with 4-point gaps, consisting of a combination of glued-lamination core and a flat, vertically wound coil, with excellent impedance-frequency characteristics, shows DC superimposition characteristics that are far superior to conventional wound core with one or two gaps.
Furthermore, the low magnetostriction characteristics of JNEX-Core reduce high frequency noise in the audible ranges of 20kHz or less, and therefore provide quiet power sources for inverters and converters.



●Comparison of DC superimposition characteristics



High-frequency reactors



Motors & Generators

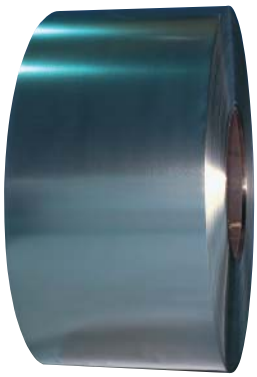
Because of its superior low core loss characteristics, Super Core™ has many advantages in high-speed motors and power generator applications -- stator, rotor, and yoke -- and contributes greatly to efficiency.
It is also effective in reducing noise that is caused in part by magnetostriction.
Super Core™ has attracted the attention for its use in electric and hybrid car motors, power generators, as well as the motors for OA devices.

Other applications

Applications are diverse, including magnetic shields, which take advantage of the excellent permeability into high-frequency ranges, magnetic yokes used at high-frequencies, heating equipment inductors, and CT(Current Transformer). Other applications include inductors and filters that reduce high-frequency noise.

PRODUCTS

■Base Coil



*The base coil is made on a continuous production line with a siliconizing process.

■Slit Coil

*The base coil goes through a slitter line, slits are cut and the coil is hooped.
*After a paper sleeve is put around its inner circumference, the slit coil is wound with rust-preventing paper used for packaging. It is then placed on skids for shipment.

Product Dimensions and Specifications

Product name	Thickness (mm)	Code number	Core loss (W/kg)	Dimensions (mm)	Space factor (%)	Density (g/cm³)
JNEX-Core	0.10	10JNEX900	W10/400 9.0 or less	Sheet width 20~600	90 or more	7.49
JNHF-Core	0.10	10JNHF600	W0.5/20k 6.0 or less	Core outer diameter Max 900	90 or more	7.53
	0.20	20JNHF1300	W0.5/20k 13.0 or less	Core inner diameter Std. 508	92 or more	7.57

* W10/50 indicates the core loss at 50 Hz, 1 T (=10kG) when the magnetic flux sine wave is excited. Similarly, W10/400 indicates for 400 Hz, 1 T (=10kG), and W0.5/20k indicates the core loss for 20 kHz, 0.05 T (=500G).

Insulating Coating

A mixture of organic and inorganic type of coating is available.

Substances of Environmental Concern Data

In JFE's Electrical Steel Sheet products, substances of environmental concern listed below are not detected in the results of analyses conducted by following methods.

●Analytical method

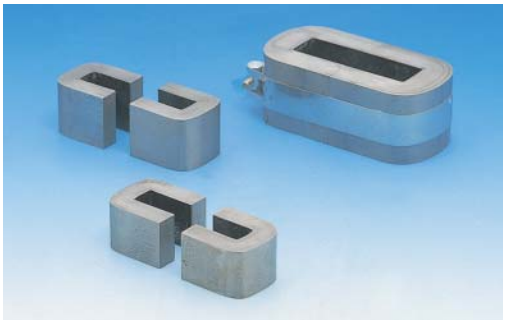
Substance	Preparation	Analytical method	Minimum limit of determination
Hg	Wet digestion	Atomic absorption spctrometric method after reduction-generation as Mercury gas	1ppm
Cd	Wet digestion (dissolved completely)	Atomic absorption spectrometric method	10ppm
Pb	Wet digestion (dissolved completely)	Atomic absorption spectrometric method	10ppm
Cr^{6+}	Extraction in boiling water	Diphenylcarbazide spectrophotometric method	0.01μg/cm²

Note:1.Insulation coating contains Cr^{3+}
Please pay attention when heating in the oxidizing atmosphere or using in the high temperature conditions.
2.Chemical substances such as PBB and PBDE are neither intentionally added nor used in our production processes.

Processed Goods

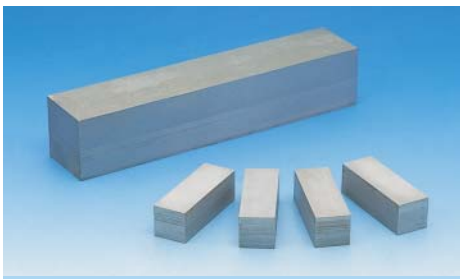
●Wound Cores (C-core and Toroidal core)

- After the steel coil is formed and annealed, it is soaked in varnish and fixed.
- The sheet thickness is 0.05 mm or 0.1 mm.
- Please contact us regarding the available size.



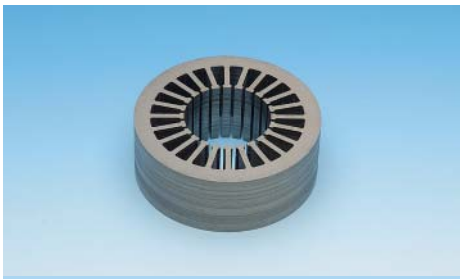
●Laminated Cores

- A core produced with a stamping-lamination process to take full advantage of the features of non-oriented Super Core™.
- Unlike products using conventional 3% Si electrical steel sheets, these can be used up to high-frequency ranges.
- Please contact us regarding the available size.



■Block Core

●Block cores are small and medium sized cores for reactors and transformers. They are highly effective for reducing costs when mass-producing such equipment.
●The standard lamination fixing method is adhesive fixation.



■Adhesive-Laminated Core for Motors

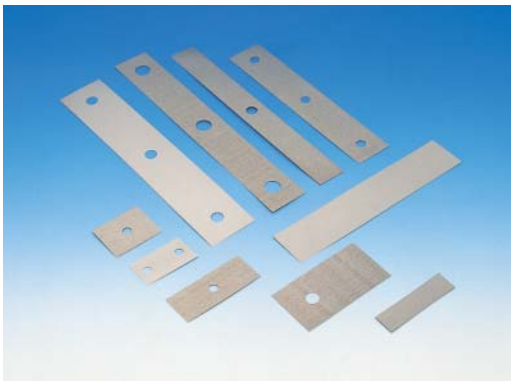
●A core that has been adhesive-laminated and solidified
●Provide significant reduction in high-frequency core loss due to high-speed rotation

■Block Core with Rounded Corners

●A laminated core made in virtually the same shape as a cut core, so that it is possible to use the same washers and clamp bands

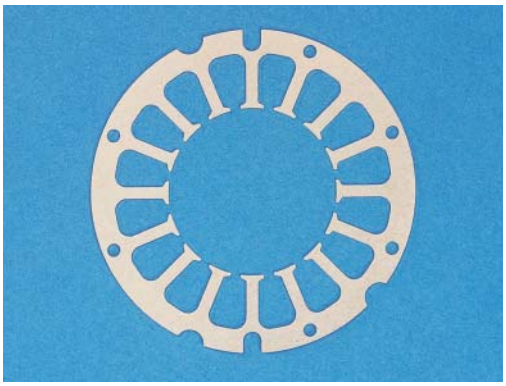
●Stacked Cores

- These cores are used mainly with medium- and large-sized transformers and reactors. The user stacks the strips and affixes them using bolts.
- The possible range of production varies somewhat depending on the processing maker, so check before proceeding.
- Please contact us regarding the available size.



●Cores for Motors and Power Generators

- Motors and power generators using Super Core™, the best non-oriented magnetic steel sheets available, demonstrate superior performance.
- The core manufacture is determined separately in consultation with each customer according to their design plans.



■For inquiries or orders, contact the office listed below or your nearest JFE Steel Corporation office.

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Cat.No.F1E-002-02

JFE

JFE Steel Corporation

http://www.jfe-steel.co.jp/en/

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