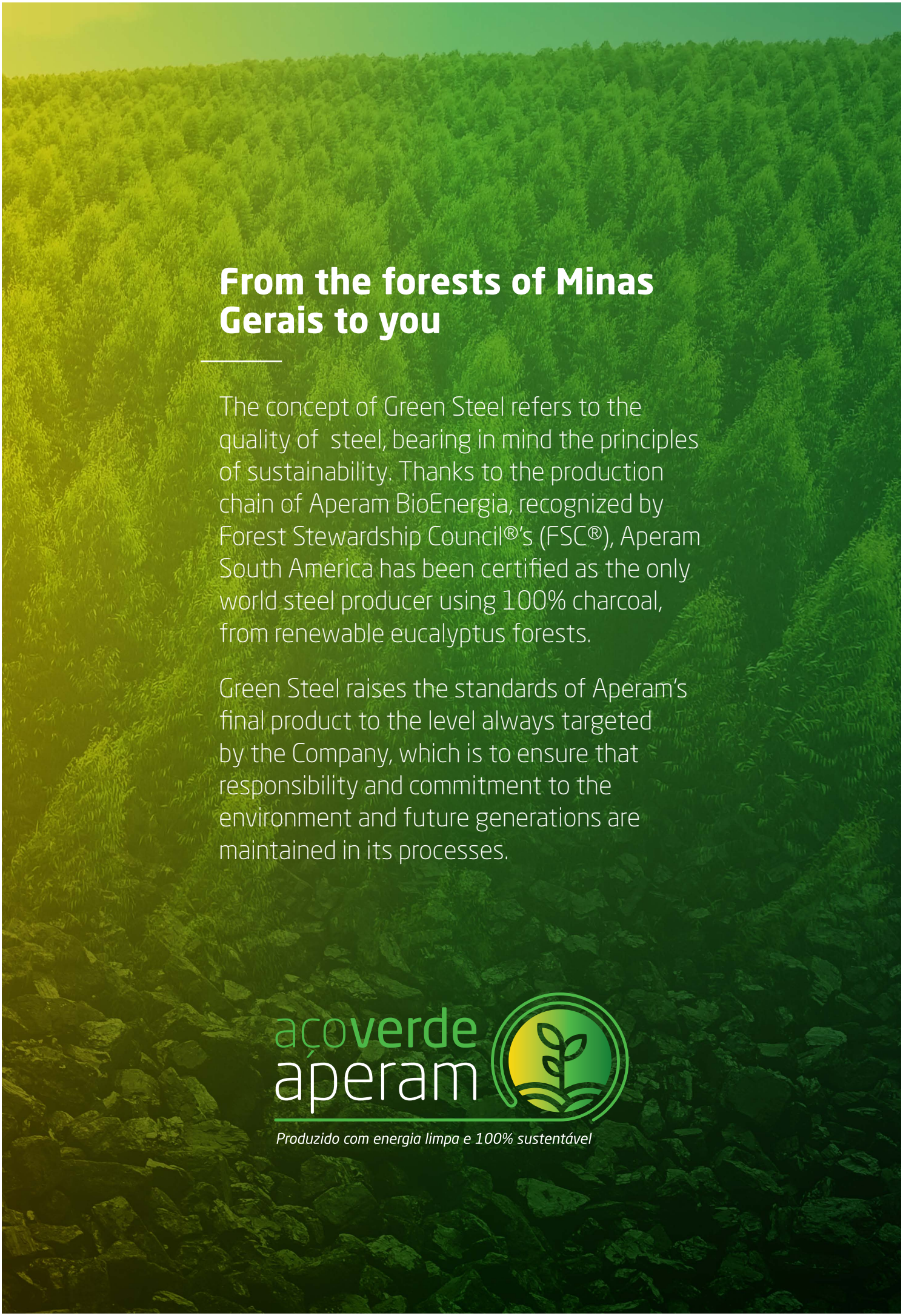
aperam

Electrical Steels

Sustainability and efficiency

Aperam is Latin America's exclusive producer of non-oriented electrical steels (NOES) and high permeability grain oriented electrical steels (GOES).

The combination of silicon in the chemical composition of these steels and the strict process control at all stages of production result in optimized magnetic properties, which ensures higher electrical equipment efficiency and energy savings.



From the forests of Minas Gerais to you

The concept of Green Steel refers to the quality of steel, bearing in mind the principles of sustainability. Thanks to the production chain of Aperam BioEnergia, recognized by Forest Stewardship Council®'s (FSC®), Aperam South America has been certified as the only world steel producer using 100% charcoal, from renewable eucalyptus forests.

Green Steel raises the standards of Aperam's final product to the level always targeted by the Company, which is to ensure that responsibility and commitment to the environment and future generations are maintained in its processes.

aço verde aperam

Produzido com energia limpa e 100% sustentável

The different types of Aperam's electrical steels

Non-oriented electrical Steel (NOES)

Thanks to its versatility, Non-oriented electrical Steel (NOES) can be found in generators and electric motors cores, ballasts, electricity meters, motors for hermetic compressors used in refrigerators, freezers and air conditioning units.

Aperam's NOES electrical steel offers excellent permeability and low magnetic losses. All of our Non-oriented electrical steel products are fully processed and cover the most varied classes as required by the market.

This steel has guaranteed values of magnetic permeability higher than those from International Standards. Thus, to reach a certain level of magnetic induction, it requires a lower magnetizing current. This means that copper or aluminum windings can be decreased, reducing the total cost of the electrical equipment.

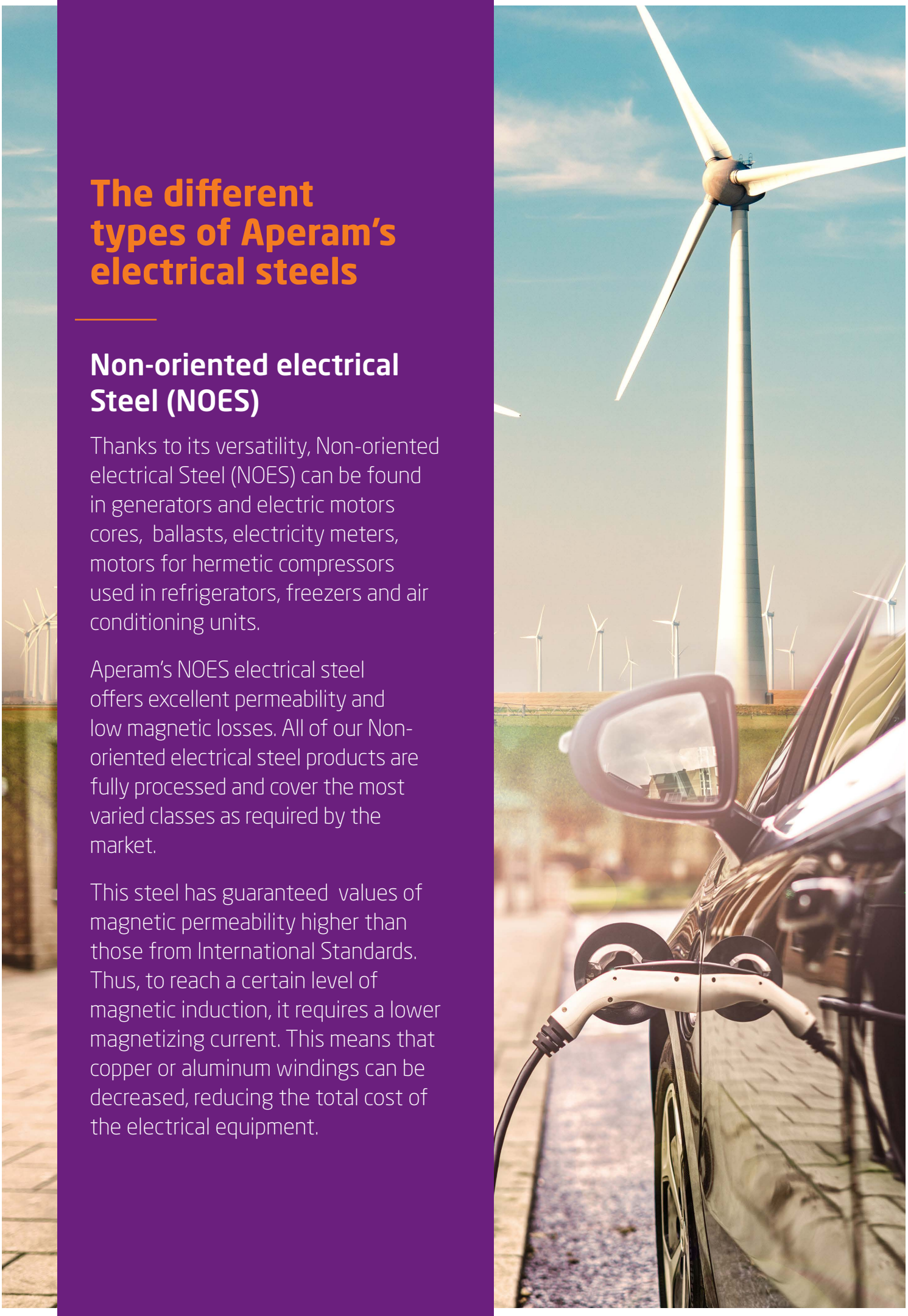


Table 1 - Guaranteed characteristics of standard NOES steels

Guaranteed Characteristics													
Product		Thickness (mm)	Maximum Core Loss at* (W/kg)				Minimum Magnetic Induction at (T)			Assumed Density (g/cm³)	Silicon Content (%)	Minimum Stacking Factor (%)	Minimum Bending Index
Reference	Aperam		1.0 T		1.5 T		2500 A/m	5000 A/m	10000 A/m				
			50 Hz	60 Hz	50 Hz	60 Hz							
M600-65A	E230-8	0.65	2.60	3.25	6.00	7.71	1.60	1.70	1.80	7.75	2.0	97.0	10
M530-65A	E185-4		2.30	3.00	5.30	6.84							5
M470-65A	E170-6		2.00	2.50	4.70	6.13							
M400-65A	E157-3		1.70	2.21	4.00	5.20							2
M530-50A	E230-8	0.50	2.30	2.91	5.30	6.66	1.59	1.69	1.79	7.75	2.0	96.0	10
M470-50A	E185-4		2.00	2.30	4.70	5.90							
M400-50A	E170-6		1.70	2.15	4.00	5.10							5
M370-50A	E157-3		1.60	2.10	3.70	4.70							
M350-50A	E145-8		1.50	2.05	3.50	4.45							
M330-50A	E137-5		1.35	1.80	3.30	4.20	1.56	1.65	1.76	7.65	3.0 to 3.3		3
M310-50A	E125-0		1.25	1.60	3.10	3.95							
M290-50A	E115-1		1.15	1.45	2.90	3.71							2
M270-50A	E110-2		1.10	1.40	2.70	3.47							
M250-50A	E105-2		1.05	1.35	2.50	3.21							
M230-50A	E100-3		1.00	1.30	2.30	2.95							
M330-35A	E170-6	0.35	1.30	1.70	3.30	4.12	1.56	1.66	1.76	7.75	2.0	95.0	3
M300-35A	E157-3		1.20	1.50	3.00	3.74							
M270-35A	E137-5		1.10	1.40	2.70	3.36				7.65	3.0 to 3.3		2
M250-35A	E125-0		1.00	1.25	2.50	3.14							
M235-35A	E115-1		0.95	1.20	2.35	2.97							
M210-35A	E110-2		0.90	1.15	2.10	2.65							

* APERAM guarantees only one test condition and it must be specified by the customer.

Note: » Magnetic properties measured in Epstein test specimens (50% in the rolling direction and 50% in the transverse direction), without stress-relief annealing, according to IEC 60404-2.

» Bending carried out on a specimen cut in transverse direction.

High Permeability Non-oriented electrical Steel

Aperam's high permeability steels reach higher values of magnetic induction with less magnetizing current, allowing reduced copper windings or aluminum windings, thus minimizing the total cost of the electrical equipment.

Table 2 - Guaranteed characteristics of high permeability NOES

Guaranteed Characteristics													
Product		Thickness (mm)	Maximum Core Loss at (W/kg)				Minimum Magnetic Induction at (T)			Assumed Density (g/cm³)	Silicon Content (%)	Minimum Stacking Factor (%)	Minimum Bending Index
Reference	Aperam		1.0 T		1.5 T		2500 A/m	5000 A/m	10000 A/m				
			50 Hz	60 Hz	50 Hz	60 Hz							
P800-100A	E233-2	1.00	3.60	4.55	8.00	10.70	1.64	1.73	1.83	7.75	2.0	98.0	5
P470-65A	E233-2	0.65	2.00	2.50	4.70	6.13	1.64	1.73	1.83		2.0	97.0	
P400-50A	E233-2	0.50	1.70	2.15	4.00	5.10	1.64	1.73	1.83		2.0	96.0	

Note: Magnetic properties measured in Epstein test samples (50% in the rolling direction and 50% in the transverse direction), without stress-relief annealing.

NOES Steels - Dimensional

Aperam's Non-Oriented Electrical Steels can be supplied in coils or strips.

All coils are supplied with a standard internal diameter of 610 mm, with the possibility of being supplied also with internal diameter of 508 mm, upon previous request. The standard internal diameter for strips is 508 mm. In both cases, the diameter tolerance is (-10/+ 20 mm).

Other dimensional characteristics can be found below:

Table 3 - Typical widths of finished product coils

Silicon Content	Thicknesses	Standard Widths Mill Edge (mm)	Standard Widths Trimmed Edge (mm)
2%Si (d = 7,75 g/cm3)	0.35 to 1.00mm	1015	995
		1045	1025
	0.35 to 0.54mm	1085	1065
3 a 3,3%Si (d = 7,65 g/cm3)	0.35 to 0.50mm	1025	1005
		1065	1045
		1080	1060

Table 4 - Thickness Tolerance

Thickness (mm)	Tolerance (mm)
1.00	+/- 0.05
0.65	+/- 0.05
0.50 / 0.54	+/- 0.04
0.35	+/- 0.03

Table 5 - Width Tolerance

Edge	Width (mm)	Tolerance (mm)
Trimmed	25 ≤ L ≤ 150	- 0 / + 0.3
	150 < L ≤ 500	- 0 / + 0.5
	500 < L ≤ 1060	-0 / + 1.5
Mill edge	1010 ≤ L ≤ 1080	+/- 10

Table 6 - Trimmed edge burr

Steel Thickness (mm)	Maximum Burr Values (mm)
1.00	0.06
0.65	0.04
0.35 to 0.54	0.03

NOES - Coating

Table 7 - General characteristics of NOES coatings

Coating		Characteristics
Aperam	ASTM A976	
N0	C-0	Uncoated steel, however a thin stable oxide film may be found on the surface. Surface electrical resistivity is not guaranteed. This coating withstands burn-off treatment (up to 0.5h at approximately 540°C in air) and stress relief annealing (up to approximately 840°C under a protective atmosphere).
T5	C-5	Inorganic-organic hybrid coating applied to steel surface. It is used in applications that require good electrical insulation and good punchability. This coating withstands burn-off treatment (up to 0.5h at approximately 540°C in air) and stress relief annealing (up to approximately 840°C under a protective atmosphere). Lower thickness compared to Aperam N5 coating.
N5	C-5	Inorganic-organic hybrid coating applied to steel surface. It is used in applications that require good electrical insulation and good punchability. This coating withstands burn-off treatment (up to 0.5h at approximately 540°C in air) and stress relief annealing (up to approximately 840°C under a protective atmosphere).
N6	C-6	Organic based coating with addition of inorganic pigments to improve its insulating ability. It is used in applications that require excellent surface electrical resistivity and good punchability. It withstands burn-off treatment (up to 0.5h at approximately 540°C in air), but does not withstand stress relief annealing.

Table 8 - Insulation resistance and average thickness of NOES coatings

Coating		Guaranteed Value - Franklin Test	Average Thickness*	
Aperam	ASTM A976	Maximum Average* (A)	Typical (µm)	Tolerance (µm)
T5	C-5	0.563	1.00	+/- 0.50
N5	C-5	0.400	2.25	+/- 1.25
N6	C-6	0.300	3.25	+/- 1.25

*Average of ten measurements (five on the upper side and five on the lower side).

Coating composition determines most of its properties. The organic composition favors resistivity and punchability, and the inorganic composition favors thermal resistance and weldability.

Coating color may vary depending on processing conditions.

All Aperam NOES use chrome-free coatings.

Alkaline emulsions (containing amide solutions, for example) interact with T5 and N5 coatings and may cause adverse reactions.

Table 9 - Performance of NOES coatings according to their composition

Type of Coating	Composition	Temperature Resistance	Electrical Resistivity	Punchability	Weldability
N0	Natural oxide	Withstands stress relief annealing	Low	Low	High
N5	Inorganic-organic varnish	Withstands burn-off and stress-relief annealing	High	Average	Low
T5	Inorganic-organic varnish	Withstands burn-off and stress-relief annealing	Average	Average	Average
N6	Organic varnish with inorganic pigments	Withstands burn-off, but not stress-relief annealing	High	High	Low

High Frequency Non-oriented electrical Steel

Aperam's High Frequency NOES are materials that have low magnetic loss at high frequencies (>400Hz), high magnetic induction (B50) and high mechanical strength. They are the ideal steels for applications in the electric mobility market, in which motors must be efficient, compact, light and have high torque. In addition, Aperam's High Frequency NOES can be used in applications that require high efficiency through rotational speed variation (through frequency variation), such as variable speed motors and compressors, among others.

Table 10 - Guaranteed characteristics of EV NOES steels

Conventional		Guaranteed Features			
Thickness (mm)	Aperam	Maximum Loss at 1.0T/400Hz	Minimum Magnetic Induction B_{50} (T)	Minimum Yield Strength 0.2% (MPa)*	Minimum Tensile Strength (MPa)*
0.25	NO25-14	14.0	1.62	400	500
0.30	NO30-16	16.0	1.64	400	500
0.35	NO35-18	18.0	1.66	400	500

High permeability		Guaranteed Features			
Thickness (mm)	Aperam	Maximum Loss at 1.0T/400Hz	Minimum Magnetic Induction B_{50} (T)	Minimum Yield Strength 0.2% (MPa)*	Minimum Tensile Strength (MPa)*
0.25	NO25-14HP	14.0	1.65	400	500
0.30	NO30-16HP	16.0	1.66	400	500
0.35	NO35-18HP	18.0	1.70	400	500

High mechanical strength		Guaranteed Features			
Thickness (mm)	Aperam	Maximum Loss at 1.0T/400Hz	Minimum Magnetic Induction B_{50} (T)	Minimum Yield Strength 0.2% (MPa)*	Minimum Tensile Strength (MPa)*
0.30	NO30-22HS	22.0	1.65	470	560

*Mechanical properties measured on rolling direction specimens.

Note: Magnetic properties measured on Epstein samples (50% - rolling direction and 50% - transverse direction), without stress relief annealing.

GoCore Family (RGO, HGO and HGO DR)

GoCore is the name given to Aperam South America's line of high-permeability grain-oriented (HGO) steel produced using low-temperature technology.

There are three different lines: Regular Grain Oriented Electrical Steel (RGO), High Permeability Grain Oriented Electrical Steel (HGO) and High Permeability Grain Oriented Electrical Steel with Domain Refinement (HGO DR).

Regular Grain Oriented Electrical Steel (RGO)

Its main applications are manufacturing of power and distribution transformer cores, power reactors, hydrogenerators and turbogenerators. Aperam's RGO electrical steel contributes significantly to the global reduction towards energy consumption and greenhouse gas emissions.

Developed to achieve low losses and high magnetic permeability, RGO has excellent magnetic properties in the rolling direction.

Table 11 - Guaranteed characteristics of RGO steels

Guaranteed Features								
Product		Thickness (mm)	Maximum Magnetic Loss at 1.7 T (W/kg)		Minimum Magnetic Induction at 800A/m (T)	Assumed Density (g/cm³)	Minimum Stacking Factor (%)	Minimum Bending Index
Type	Aperam		50 Hz	60 Hz				
RGO	R120-27	0.27	1.20	1.58	1.80	7.65	95.0	2
	R130-27	0.27	1.30	1.68				
	R130-30	0.30	1.30	1.71			95.5	
	R140-30	0.30	1.40	1.83				

Note: Magnetic properties measured on Epstein samples (100% in the rolling direction) and subject to stress relief annealing, according to IEC 60404-2.

High Permeability Grain Oriented Electrical Steel (HGO)

GoCore HGO electrical steel is the material of choice for high efficiency transformers because it offers higher permeability and better energy efficiency, in line with the trend of greater demand for products that achieve lower electricity consumption. For the power generation and distribution sectors, this means smaller and more efficient transformers.

Table 12 - Guaranteed characteristics of HGO steels

Guaranteed Features								
Product		Thickness (mm)	Maximum Magnetic Loss at 1.7 T (W/kg)		Minimum Magnetic Induction at 800A/m (T)	Assumed Density (g/cm³)	Minimum Stacking Factor (%)	Minimum Bending Index
Type	Aperam		50 Hz	60 Hz				
HGO	H100-27 *	0.27	1.00	1.32	1.88	7.65	95.0	2
	H110-27	0.27	1.10	1.45				
	H100-30	0.30	1.00	1.32			95.5	
	H105-30	0.30	1.05	1.38				
	H110-30	0.30	1.10	1.46				
	H120-30	0.30	1.20	1.58	1.85			

*This grade may eventually be supplied with laser scribing (HGO DR), if not previously agreed. In this case, all other characteristics shall be maintained.

Note: » For HGO - magnetic properties measured in Epstein samples (100% in the rolling direction), and subject to stress relief annealing, according to IEC 60404-2.

» For HGO DR - magnetic loss measured by means of a Single Sheet Tester, multiplied by the Fc conversion factor of 0.925, according to IEC 60404-8-7 (2020).

High Permeability Grain Oriented Electrical Steel with Domain Refinement (HGO DR)

GoCore HGO DR steels are the evolution of HGO steels. The HGO DR products are treated by means of laser scribing method which generate microstress in the steel matrix, thus leading to magnetic domains refinement. This new structure of refined magnetic domains produces lower magnetic losses in this type of product, without changing the magnetic permeability and preserving the surface quality.

Table 13 - Guaranteed characteristics of HGO DR steels

Guaranteed Features								
Product		Thickness (mm)	Maximum Magnetic Loss at 1.7 T (W/kg)		Minimum Magnetic Induction at 800A/m (T)	Assumed Density (g/cm³)	Minimum Stacking Factor (%)	Minimum Bending Index
Type	Aperam		50 Hz	60 Hz				
HGO DR	L085-27	0.27	0.85	1.12	1.85	7.65	95.0	2
	L090-27	0.27	0.90	1.18				
	L095-27	0.27	0.95	1.25				
	L100-27*	0.27	1.00	1.32				
	L080-23	0.23	0.80	1.05			94.5	
	L085-23	0.23	0.85	1.12				
	L090-23	0.23	0.90	1.18				

*This grade may eventually be supplied without laser scribing (HGO DR), if not previously agreed. In this case, all other characteristics shall be maintained.

Note: » For HGO - magnetic properties measured in Epstein samples (100% in the rolling direction), and subject to stress relief annealing, according to IEC 60404-2.

» For HGO DR - magnetic loss measured by means of a Single Sheet Tester, multiplied by the Fc conversion factor of 0.925, according to IEC 60404-8-7 (2020).

» **HGO DR steels should not be subjected to heat treatment (>600°C) under risk of loss of magnetic domains refinement, returning to typical losses prior to laser scratching.**

To check the performance curves of each material, access:

GO Steels - Dimensional

Aperam's GO electric steel is supplied in coils or strips. The standard internal diameter of all coils are 508 mm. In both cases the diameter tolerance is -10 / +20 mm. For all these steels the maximum burr is 0.02 mm.

Table 14 - Thickness Tolerance

Thickness (mm)	Tolerance (mm)
0.27	+/- 0.030
0.30	+/- 0.030

Table 15 - Width Tolerance

Width (mm)	Tolerance (mm)
30 ≤ L ≤ 150	- 0 / + 0.3
150 < L ≤ 500	- 0 / + 0.5
500 < L ≤ 1020	-0 / + 1.0

GO Steels - Coating

Aperam GO steels are supplied with ASTM-C5 coating over ASTM-C2. They are called Aperam R5 (for RGO steels), H5 (for HGO steels) and L5 (for HGO DR steels) coatings. Despite the difference of nomenclature, R5, H5 and L5 are exactly the same coatings.

Table 16 - Insulation resistance of GO coatings

Steel	Aperam nomenclature	Coating	Guaranteed Value	Typical Value
			Maximum Average (A)*	Average (A)
RGO	R5	ASTM C5	0.200	0.108
HGO	H5			
HGO DR	L5			

*Average of ten measurements (five on the upper side and five on the lower side).

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