Electrical Steel

powercore® grain oriented electrical steel

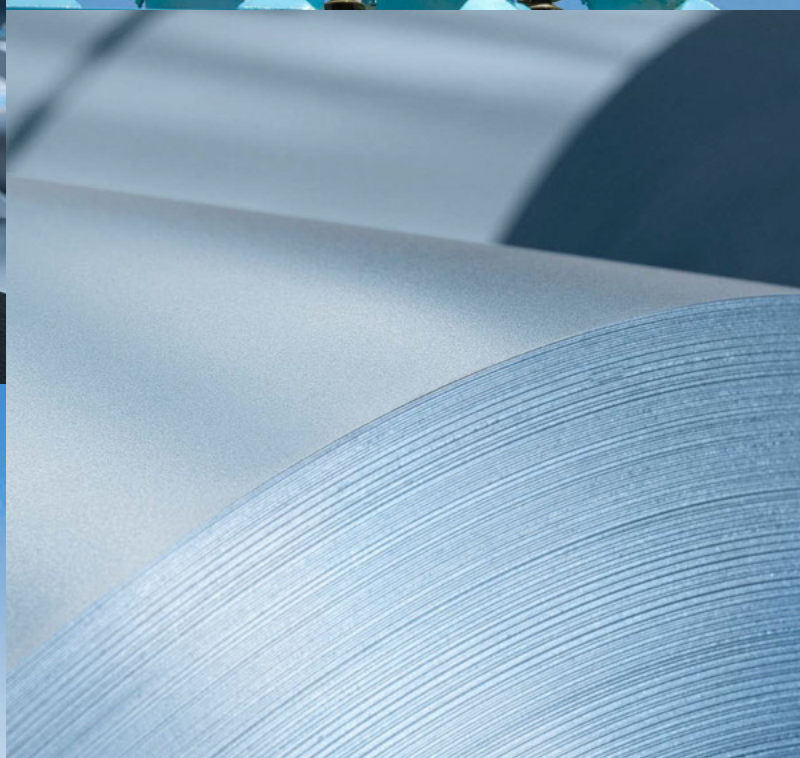
Product range

thyssenkrupp





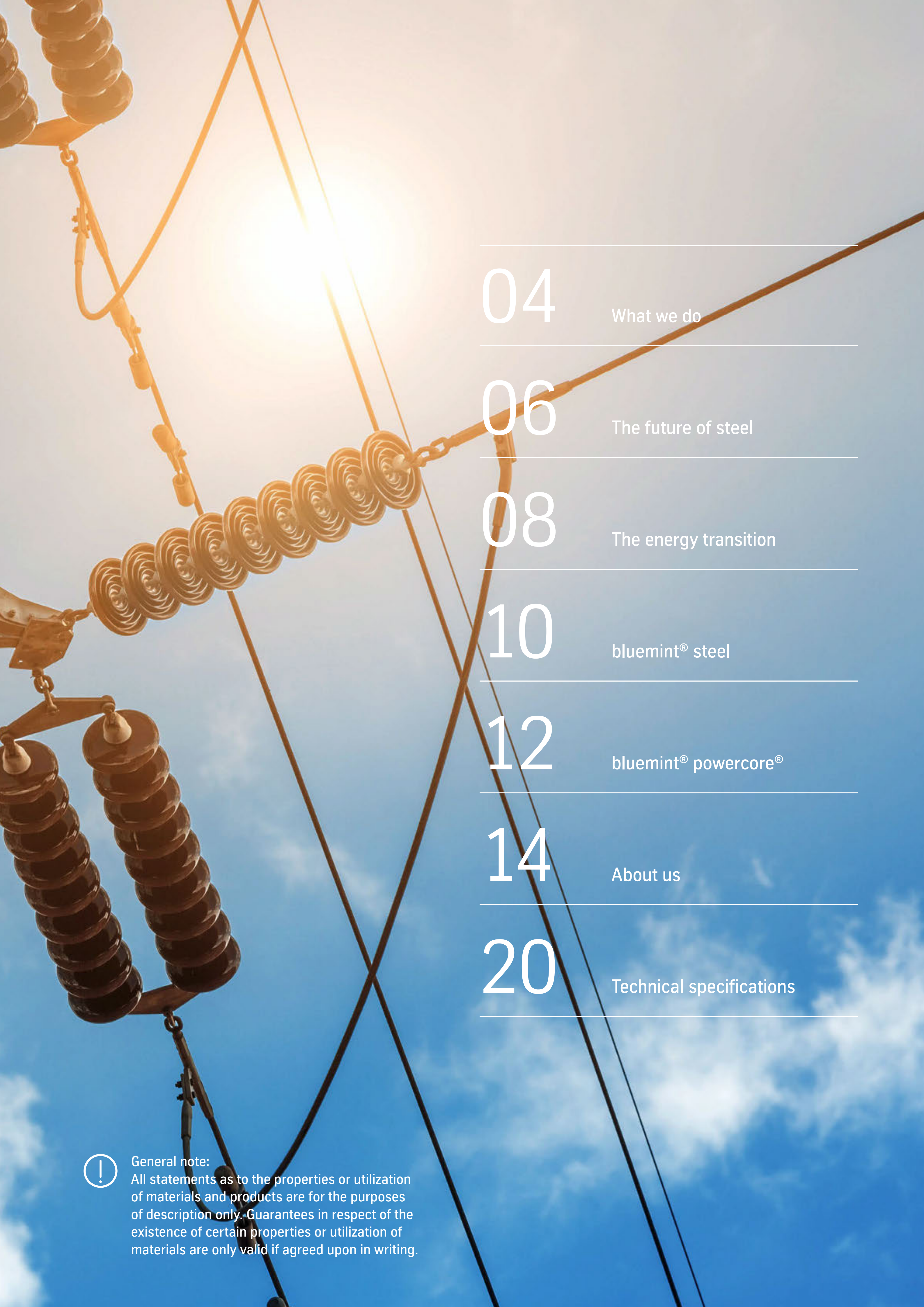


powercore® – enabling the future of energy

Grain oriented electrical steel is a sophisticated, high-tech material used to produce transformers and large, high-performance generators. As energy demand continues to grow, so does the demand for greater efficiency. powercore® from thyssenkrupp Electrical Steel is exceptionally energy efficient, making it a core material for the future of electricity and the coming green energy transition.

From smaller, higher performance transformers to lower noise emissions in urban areas, powercore® enables new and innovative technology that contributes to environmental protection and improved standards of living for everyone.



General note:
All statements as to the properties or utilization of materials and products are for the purposes of description only. Guarantees in respect of the existence of certain properties or utilization of materials are only valid if agreed upon in writing.

Enabling electric transformation

The world would not work without transformers. They are the key components to transfer electricity from one circuit to another and are essential when it comes to distributing electricity. Transformers need grain oriented electrical steel to function. In short: they need powercore®.

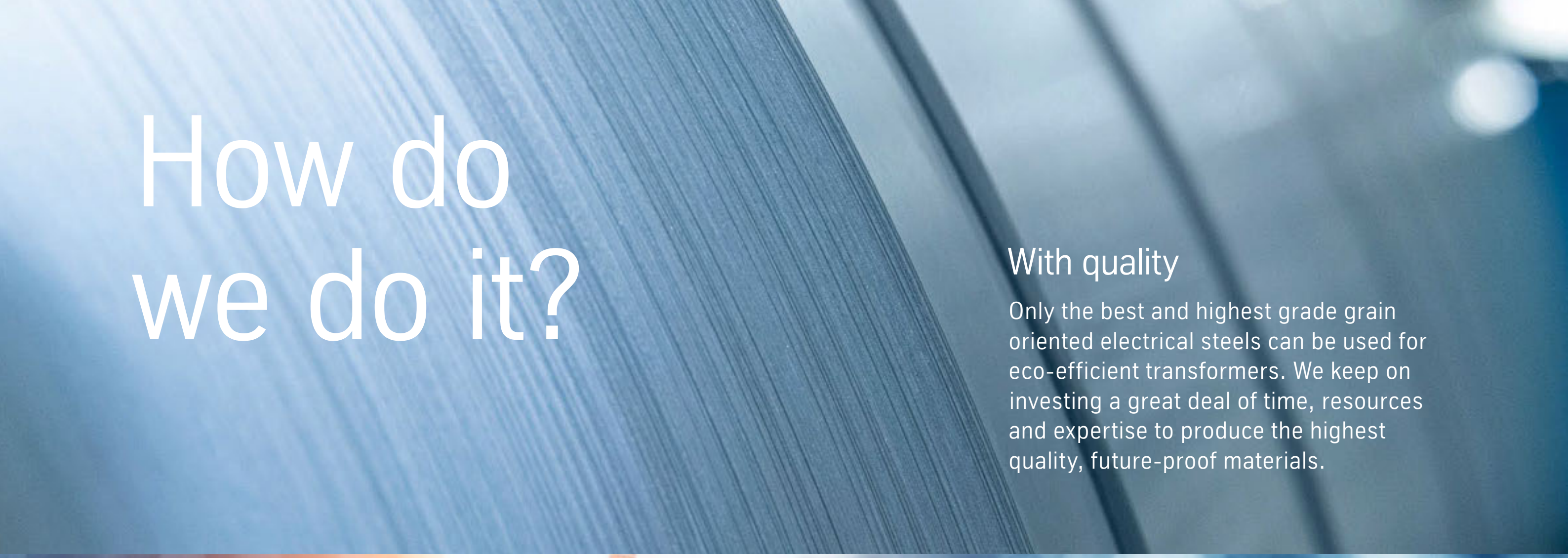
Elaborately manufactured, high-quality powercore® enables transformers to operate with a high level of efficiency, transforming electric energy with as little loss as possible. The lower the iron losses of the electrical steel, the higher the efficiency. This is key when it comes to meeting increasing demands for electricity and the need to generate more power from renewable sources.

powercore® grain oriented electrical steel is also used in charging stations for electric cars and innovative electric motors, making even more of a difference to the way we use energy in future.

Created at two locations in Europe, Germany and France, thyssenkrupp Electrical Steel supplies powercore® to our clients directly, contributing to further energy savings thanks to shorter transport distances and more efficient, high-grade technology.

With powercore®, our goal is to enable the transition to the energy of the future.

How do we do it?

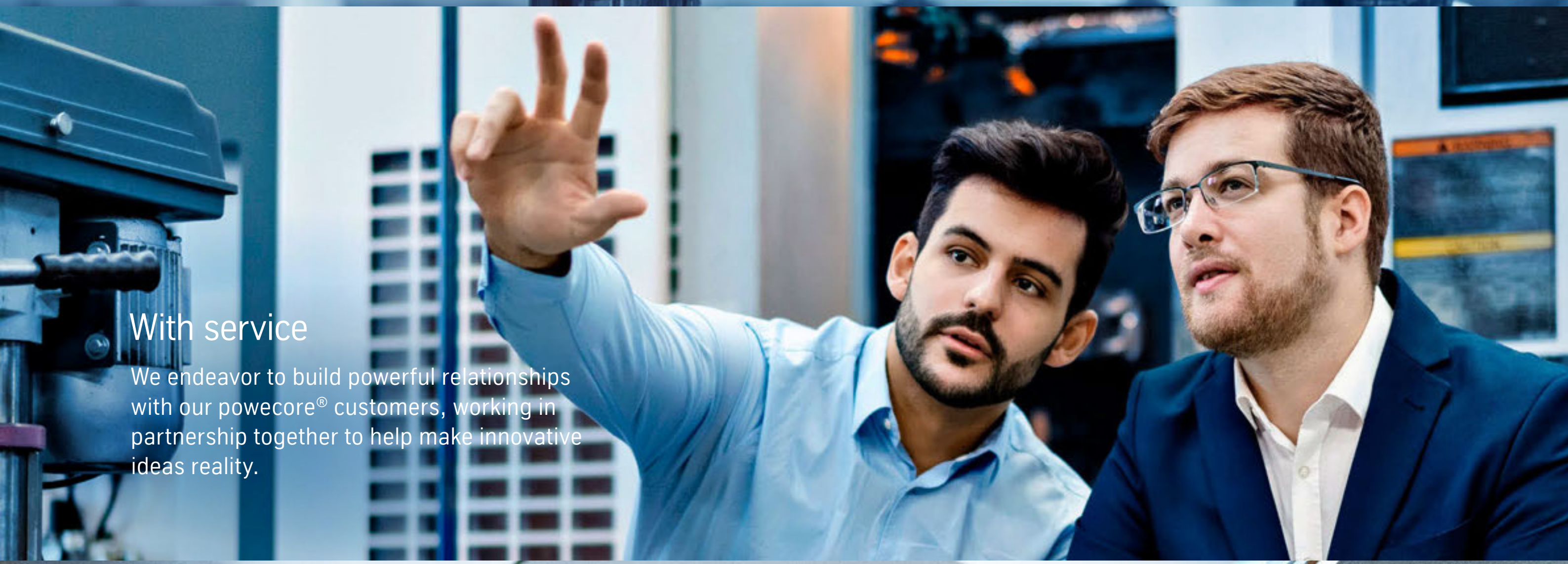


With quality

Only the best and highest grade grain oriented electrical steels can be used for eco-efficient transformers. We keep on investing a great deal of time, resources and expertise to produce the highest quality, future-proof materials.

With performance

powercore® enables transformers that are much smaller, while providing the same power output. This means transformer designs can be more compact and preserve further resources.



With service

We endeavor to build powerful relationships with our powecore® customers, working in partnership together to help make innovative ideas reality.

With sustainability

Our bluemint® steel is made with less CO_2. Our powercore® electrical steel is more efficient. Our products contribute towards environmental protection and a more sustainable future.

Our future – climate-neutral steel production

As one of Europe's leading industrial enterprises, we at thyssenkrupp Steel are committed to our social responsibility and pay particular attention to environmental compatibility and sustainability – from the conservation of all natural resources to the efficient recyclability of our products.

And there's more: we are committed to our decision to significantly reduce greenhouse gas emissions and thus make our contribution to the goals of the Paris Climate Accords. And since 2022, we offer our customers continuously increasing quantities of CO_2-reduced steel. As part of our climate strategy, we are stepping up current activities and will reduce emissions from our own production and processes as well as from external energy consumption by 38 % by 2030. We intend to be completely climate-neutral by 2045 at the latest.

Time for major changes

The path to climate neutrality means one thing above all: we need to move away from coal-fired blast furnaces to direct reduction plants running on hydrogen. This change in production represents a significant technology shift and requires the establishment of reliable logistics for the continuous procurement and supply of hydrogen.

First hydrogen blast furnace tests

It is a world premiere and a project supported by the IN4climate initiative of the state government of North Rhine-Westphalia: in blast furnace number 9 at our Duisburg location, we used hydrogen instead of pulverized coal for injection in one of the 28 tuyeres in an initial test phase. This reduces CO_2 emissions, because the use of hydrogen produces water vapor instead of CO_2.

The green dream team: the direct reduction plant

A direct reduction plant operates virtually emission-free using hydrogen, or with low emissions using natural gas. The plant does not produce liquid pig iron like a blast furnace, but rather solid sponge iron. This must first be melted before it can be processed into high-quality steel. We are developing an innovative installation for this purpose: a melting furnace powered by green electricity. In combination with the direct reduction plant, it will supply the liquid precursor product for steel production. The plan is to commission the first industrial-scale direct reduction plant in 2026. Until then, the existing production operation will of course continue.

What is particularly important for our customers: with our blast furnaces 2.0, we are producing pig iron that can be further processed into all the products in our steel mills as before – without any loss of quality, but in a climate-neutral way.

Our climate targets were approved by the Science Based Targets Initiative (SBTi) on May 16, 2024 as compliant with the Corporate Net Zero standard/in line with a 1.5-degree-pathway.

2030

(outside SBTi validation)
> 30 % CO2 savings

2032

(SBTi-compliant)
- 38 % CO2 savings

2045

(SBTi-compliant)
Net-Zero

powercore® – empowering the green energy transition

Electrical steel plays a key role everywhere electricity is generated, distributed and used. That is because transformers rely on electrical steel to function not just effectively, but efficiently. This is a major issue to contend with for the future, as the International Energy Agency has projected that electricity demand will increase by 120 % over the next 25 years. Greater efficiency in transformers will reduce losses when feeding power into the grid, thus contributing to a further reduction in emissions.

powercore® is the core material in high-performance transformers and can make a big difference in terms of efficiency, noise emissions and production. With minimal losses at full load, improved insulation, an optimized domain structure and lower weight, powercore® is the ideal material for the efficient transformers of tomorrow – available today.

Addressing the energy challenges of the future is no easy task, especially given the logistics needed to connect new sources of power with homes and industry. Thousands of kilometers of power lines will be needed, as well as smart grids that intelligently link generation and consumption. Given its efficiency and versatility, powercore® is certain to play a decisive role in these changes and transitions.

bluemint® Steel

High quality. Less CO_2.

With bluemint® Steel we are launching our first certified steels with reduced CO_2 intensity. The CO_2-reduced products are produced at our Duisburg site and give our customers the certainty to use high-quality steel with an improved ecobalance. bluemint® Steel is the beginning of the transformation to green steel.

A portfolio that lasts

bluemint® Steel is another important step towards a climate-neutral steel industry. The special feature: The material properties do not differ from the existing steel grades – except in their reduced specific CO_2 emissions.

This is our first transformation success within the scope of our climate strategy and reflects our ambitious goal of a sustainable and customer-oriented steel production. In the coming years, we will intensively invest in innovations and technologies which will gradually move our customers further towards our common goal of climate-neutrality and a green steel product.

bluemint® is our promise

In view of the challenges associated with climate change and the opportunities in future markets, the concept of low carbon dioxide steels is attracting the attention of many processing and end user industries.

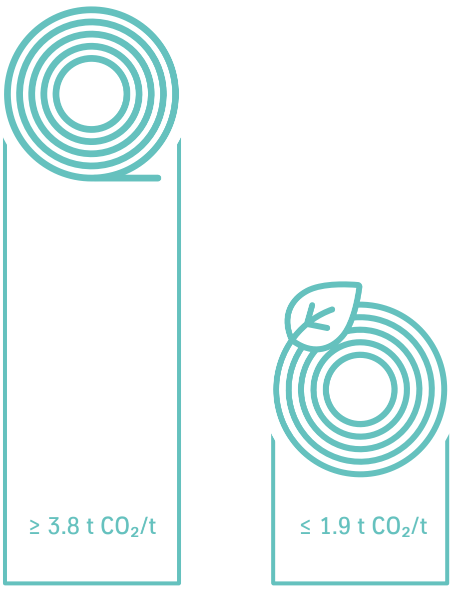
Certified quality

bluemint® Steel stands for the diversity of our portfolio of grades. This means that you can rely on the continued availability of the familiar materials. In terms of material and processing properties, our two bluemint® Steel products by no means fall short of our existing grades. On the contrary: The high premium quality is complemented by a significant CO_2 reduction.


bluemint® Steel
bluemint® Steel

Green to the power of blue

Our bluemint® powercore® is made with 50 % less CO_2. That means it can now contribute even more towards changing the course of climate change by reducing global energy demand and the associated CO_2 emissions: transformers made with bluemint® powercore® meet the demanding efficiency requirements under the EU Ecodesign directive.



Conventional powercore®

bluemint® powercore®

By allocating CO_2 savings to specific products

Advantages at a glance

Produced using bluemint® Steel.

- 1 t of bluemint® powercore®: CO_2 emissions reduced by more than 1.9 metric tonnes (> 50 %)
- Directly applicable to your Scope-3 emission reduction
- Certificates available
- CO_2 savings achieved in the primary steel route, all qualities available
- No specific technical qualification necessary

Transformer specialist SGB-SMIT purchases the first 50 tons of bluemint® powercore®

The first customer to use bluemint® powercore® with 50 % less CO_2 is SGB-SMIT. The transformer manufacturer uses our CO_2 reduced steel for transformers in new digital stations operated by energy specialist E.ON. SGB-SMIT supports the development of a decentralized supply network in which the share of wind power, photovoltaic and biogas plants is steadily increasing.

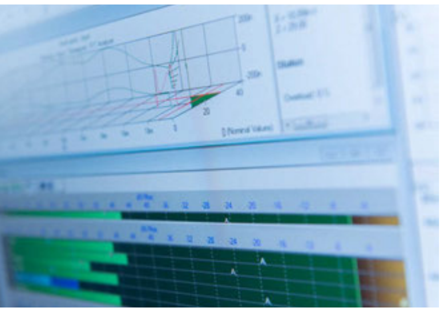
> "For us, it represents a great added value that the top grades of thyssenkrupp Steel are now also CO_2-reduced. This is an important step towards further decarbonization of the energy process chain,"
>
> says Managing Director Holger Ketterer

To effectively reduce CO_2, the company has set itself two goals: to continuously reduce energy losses in the utilization phase of the transformers and to cut the carbon footprint of the transformers themselves. "With our first goal, the energy transition has dealt us a good hand," Ketterer adds. "The more renewable energy we use, the lower the CO_2 emissions from energy losses. That is why our focus is on the climate impact of the materials we use."

According to Achim Hübner, International Category Lead for transformers at E.ON, "It makes a big difference in the overall assessment of a plant if a substation or green power station also has transformers made with CO_2-reduced electric steel." This makes these components key to a more sustainable future, as they ensure the conversion and transmission of green electricity. powercore® is high-tech, highly efficient and up to the job.

Who we are: the enablers

For us at thyssenkrupp Electrical Steel, enabling means more than just making something possible. It is an active mindset that allows us to empower, to facilitate, to inspire, to improve. This does not happen in isolation. It is a collaborative process in which thyssenkrupp Electrical Steel works in concert with partners to develop new, innovative and efficient solutions.



Enabling innovation, thyssenkrupp Electrical Steel is a proactive partner that gets involved in transforming the future together with frontrunners in the electricity value chain – from generation over transmission and distribution to usage.

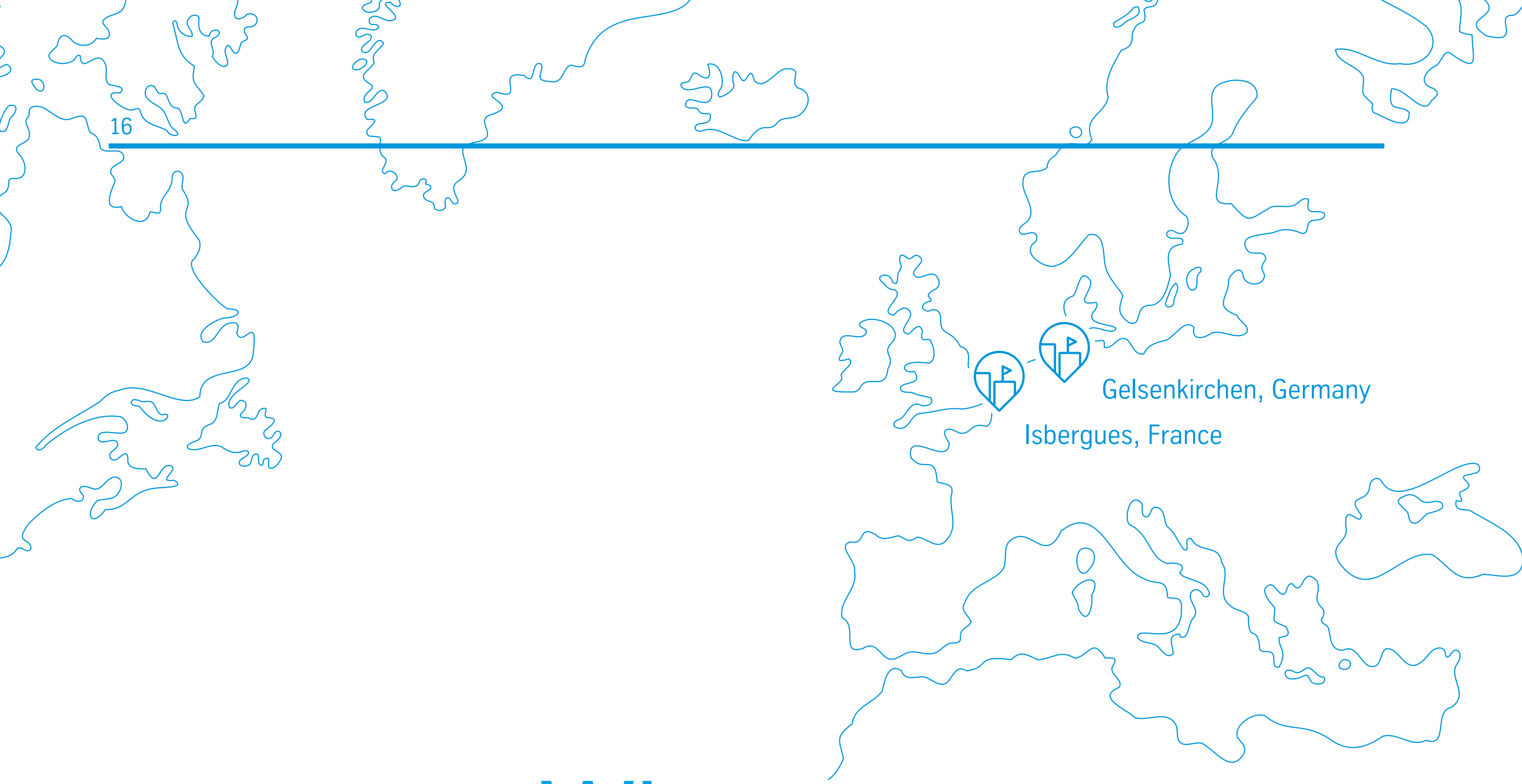
Enabling transformation, thyssenkrupp Electrical Steel provides products that make transformers more efficient, which supports the green energy transition.

Enabling performance and energy savings, thyssenkrupp Electrical Steel is literally at the core of large and medium power, oil immersed and dry type distribution, instrument and current transformers, as well as high-voltage direct current (HVDC) transmission systems.

At thyssenkrupp Electrical Steel, we see beyond our high-quality grain oriented electrical steel. We see the possibilities that our materials can make into reality. From new power lines that bring energy into our homes from renewable sources to quieter and more efficient, smaller-scale transformers, these technological innovations have real and measurable benefits for our lives.

Our customers, our engineering know-how and material and every one of our 1,200 people are a vital part of the energy transition. This is a responsibility which makes us proud, humble and drives our passion every day.

Because when it comes to the future of our energy, it is thyssenkrupp Electrical Steel that enables it.



Where we are: where our clients are

The primary steel comes from Duisburg; the applications go around the world. And because geography matters, we have chosen to be close to our clients. With facilities in Germany and France, we can strengthen our partnerships and build upon our relationships – locally.

Our global parent organization enables us to provide the same levels of quality and service across the globe. Which means that our clients benefit from the passion and expertise of our skilled team from Germany and France.

Success is best when it is shared.
A selection of who we work with:

SGB-SMIT Group SIEMENS energy

ORMAZABAL velatia · LTC GROUP · Shihlin Electric · LAGOR PT CORES · ROMAGNOLE · transformers & rectifiers (india) ltd

What we are doing: transforming the future – together

Partnership drives us forward. As electrical energy will play an ever-increasing role in our future, transformers are the main actors in increasing the efficient use of electricity. Working together with our customers, suppliers and many stakeholders like universities, we constantly develop, discover, evaluate and test new ideas to move our industry and our understanding further.

We never stop learning. For example, we developed transformer core design software which enables us to better understand and work with our customers to select the optimum grain oriented steel grade. In another example of our close partnership with industry, we supplied top grade grain oriented electrical steel to Siemens Energy for state-of-the-art HVDC transformers. These transformers are used in Amprion's Ultranet – bringing green electricity from the northern shores of Germany to the south.

We are who we work with

We would not be anywhere without our dedicated and dynamic team. And they are the best advertisement for our approach to collaborative innovation and technological enablement.

Customers, Markets & Technology is the name of the team that stays in touch with our customers – day in, day out. The name itself says it all: we focus on our customers, their markets and our technology to provide the highest levels of product quality and customer service.

Staying current

The field of electricity is fascinating. And grain oriented electrical steel is one of the most complex products in the steel world. Our dedicated team works constantly to stay ahead of the curve and we invest a great deal of time and effort into research in our fields.

The requirements for grain oriented electrical steel as a core material have changed considerably in recent years and will continue to do so in the future. That is why our research and development team in Duisburg, Gelsenkirchen and Isbergues is permanently researching how our product can be optimized and how our production process to make our premium powercore® electrical steel can be improved.

Our research and development efforts also ensure that the needs of new regulations, such as the European Union's Ecodesign, can be fulfilled and that future eco-regulations can be considered with all of our products.

Grain oriented electrical steel

Our high-tech core material powercore® has been largely responsible for increasing the efficiency of transformers.

powercore® grades have an extremely sharp crystallographic texture. This, combined with a high-performance insulation coating, improves magnetic domain structure for a reduction of core loss and noise, making the powercore® grades the material of choice for Ecodesign power transformers.

The use of powercore® can also significantly reduce total manufacturing costs for transformers, a major advantage in the face of rising raw material costs.

powercore® is the core material for the future!

powercore®

also available as bluemint® Steel

Magnetic properties

powercore grade	Compatible with grade as defined in IEC 60404-8-7	Thickness [mm]	Thickness [inch]	Maximum specific loss at 1.7 T 50 Hz W/kg	Maximum specific loss at 1.7 T 60 Hz W/kg	Minimum polarization at 800 A/m T
H 070-20	M70-20R5	0.20	0.008	0.70	0.92	1.88
H 075-20	M75-20R5	0.20	0.008	0.75	0.99	1.88
H 070-23		0.23	0.009	0.70	0.92	1.88
H 075-23	M75-23R5	0.23	0.009	0.75	0.99	1.88
H 078-23		0.23	0.009	0.78	1.03	1.88
H 080-23	M80-23R5	0.23	0.009	0.80	1.05	1.88
H 085-23	M85-23R5	0.23	0.009	0.85	1.12	1.88
H 090-23	M90-23R5	0.23	0.009	0.90	1.18	1.88
H 100-23	M100-23P5	0.23	0.009	1.00	1.32	1.85
H 085-27	M85-27R5	0.27	0.011	0.85	1.12	1.88
H 090-27	M90-27R5	0.27	0.011	0.90	1.18	1.88
H 095-27	M95-27R5	0.27	0.011	0.95	1.25	1.88
H 100-27	M100-27P5	0.27	0.011	1.00	1.32	1.88
H 110-27	M110-27P5	0.27	0.011	1.10	1.45	1.88
H 100-30	M100-30P5	0.30	0.012	1.00	1.32	1.88
H 105-30	M105-30P5	0.30	0.012	1.05	1.38	1.88
H 110-30	M110-30P5	0.30	0.012	1.10	1.45	1.88
H 125-35	M125-35P5	0.35	0.014	1.25	1.64	1.88

All grades are delivered with laser domain refinement if not specifically agreed otherwise. This domain refinement is not heatproof. If no annealing is applied to these materials, they are compatible to the high permeability “P” grades of IEC 60404-8-7, table 2.
Magnetic properties measured by SST according to IEC 60404-3. Obtained losses at 1.7 T are converted by applying a factor of 0.925 as defined by IEC 60404-8-7. For the magnetic polarization at 800 A/m a conversion of 1.01 is applied.

powercore® according to BIS standard 3024

also available as bluemint® Steel

Magnetic properties

	Thickness		Maximum specific loss at		Minimum polarization at
	[mm]	[inch]	1.7 T	1.7 T	
			50 Hz	60 Hz	800 A/m
			W/kg	W/kg	T
Grade					
23HP80d	0.23	0.009	0.80	1.04	1.85
23HP85d	0.23	0.009	0.85	1.12	1.85
23HP90d	0.23	0.009	0.90	1.19	1.85
23HP95d	0.23	0.009	0.95	1.25	1.85
23HP100d	0.23	0.009	1.00	1.32	1.85
27HP90d	0.27	0.011	0.90	1.19	1.85
27HP95d	0.27	0.011	0.95	1.25	1.85
27HP100	0.27	0.011	1.00	1.32	1.88
27HP110	0.27	0.011	1.10	1.45	1.88
30HP105	0.30	0.012	1.05	1.38	1.88
30HP110	0.30	0.012	1.10	1.46	1.88
30HP120	0.30	0.012	1.20	1.58	1.88
35HP115	0.35	0.014	1.15	1.51	1.88
35HP125	0.35	0.014	1.25	1.64	1.88
35HP135	0.35	0.014	1.35	1.77	1.88

(d) = Magnetic domain refined by laser scribing.
All the grades may be delivered with laser domain refinement if not agreed otherwise.
Magnetic properties measured by Epstein frame or by SST as defined in IS 649.

Insulation

Grain oriented electrical steel strip is supplied with a thin inorganic coating on the glass film layer formed during annealing. A film thickness of 2 to 5 µm provides good electrical resistance and a high stacking factor.

The coating, which is annealing resistant up to 840 °C, enables wound cores and sheet blanks to be stress relief annealed.

The coating is chemically resistant to liquids to which it is typically exposed during the production process and has no effect on the various types of transformer oils.

We offer two types of insulation coatings: the chromium-containing coating and the chromium-free coating. Both coatings are similar from a technological point of view.

Insulation types

Coloration	
Color deviations are possible, but they have no influence on the properties	Phosphate layer on glass film: gray

Coated sides
both sides

Coating thickness
2 µm – 5 µm

Surface insulation resistance	
at room temperature according to IEC 60404-11	> 10 Ω cm^2

Annealing resistance	
Under inert gas according to IEC 60404-12	840 °C/2 h

Comparison with the designations IEC 60404-1-1
EC-5-G on EC-2

Comparison with the designations ASTM A976
C-5 over C-2

Chemical resistance	
w.r.t. transformer oil	very good

Dimensions and geometrical tolerances

Dimensions

Full widths	
Internal diameter	508 mm
Nominal widths	900 – 1,020 mm
Nominal thicknesses	0.20 mm
	0.23 mm
	0.27 mm
	0.30 mm
	0.35 mm

Slit widths	
Internal diameter	508 mm
Nominal widths	> 6 mm
Nominal thicknesses	0.20 mm
	0.23 mm
	0.27 mm
	0.30 mm
	0.35 mm

Geometrical tolerances

Thickness tolerances	
Max. deviation from the nominal thickness	±0.020 mm
Max. thickness difference parallel to the rolling direction within a strip section of 1,000 mm length	0.025 mm
Max. thickness difference perpendicular to the rolling direction, measured at least 40 mm from the edge	0.020 mm

Width tolerances	
Full widths	±1 mm
Slit widths * < 150 mm	0 / - 0.2 mm
> 150 – 400 mm	0 / - 0.3 mm
> 400 – 750 mm	0 / - 0.5 mm
> 750 – 1,000 mm	0 / - 0.6 mm

* Plus tolerances must be specially agreed when ordering.

Typical properties and tolerances

Residual curvature (horizontal method)

Max. curvature for a strip section of 500 mm length for application widths > 150 mm	17.5 mm

Deviation from the shearing line (internal stresses)

From 1,000 mm length for application widths > 500 mm	1 mm

Burr height (for slit width)

Max. burr height	0.025 mm

Edge camber

Max. edge curvature within a strip section of 1,000 mm length for application widths > 150 mm	0.5 mm

Edge wave (wave factor)

Max. flatness for cut widths > 150 mm	1.5 %

All test methods for thickness and width according to EN 10107 and IEC 60404-8-7.
All other test methods and definitions according to EN 10251 and IEC 60404-9.

Tensile strength R_m

Longitudinal to rolling direction	330 – 370 MPa
Transverse to rolling direction	390 – 420 MPa

Ultimate yield strength $R_{p0,2}$

Longitudinal to rolling direction	300 – 340 MPa
Transverse to rolling direction	330 – 360 MPa

Saturation polarization J_S	2.03 T
Coercive field strength H_S	5 A/m
Curie temperature T_C	745 °C / 1,345 °F
Specific resistance p_e	0.48 µΩm

Elongation at break $A_{l=80}$

Longitudinal to rolling direction	6 – 14 %
Transverse to rolling direction	24 – 48 %

Hardness

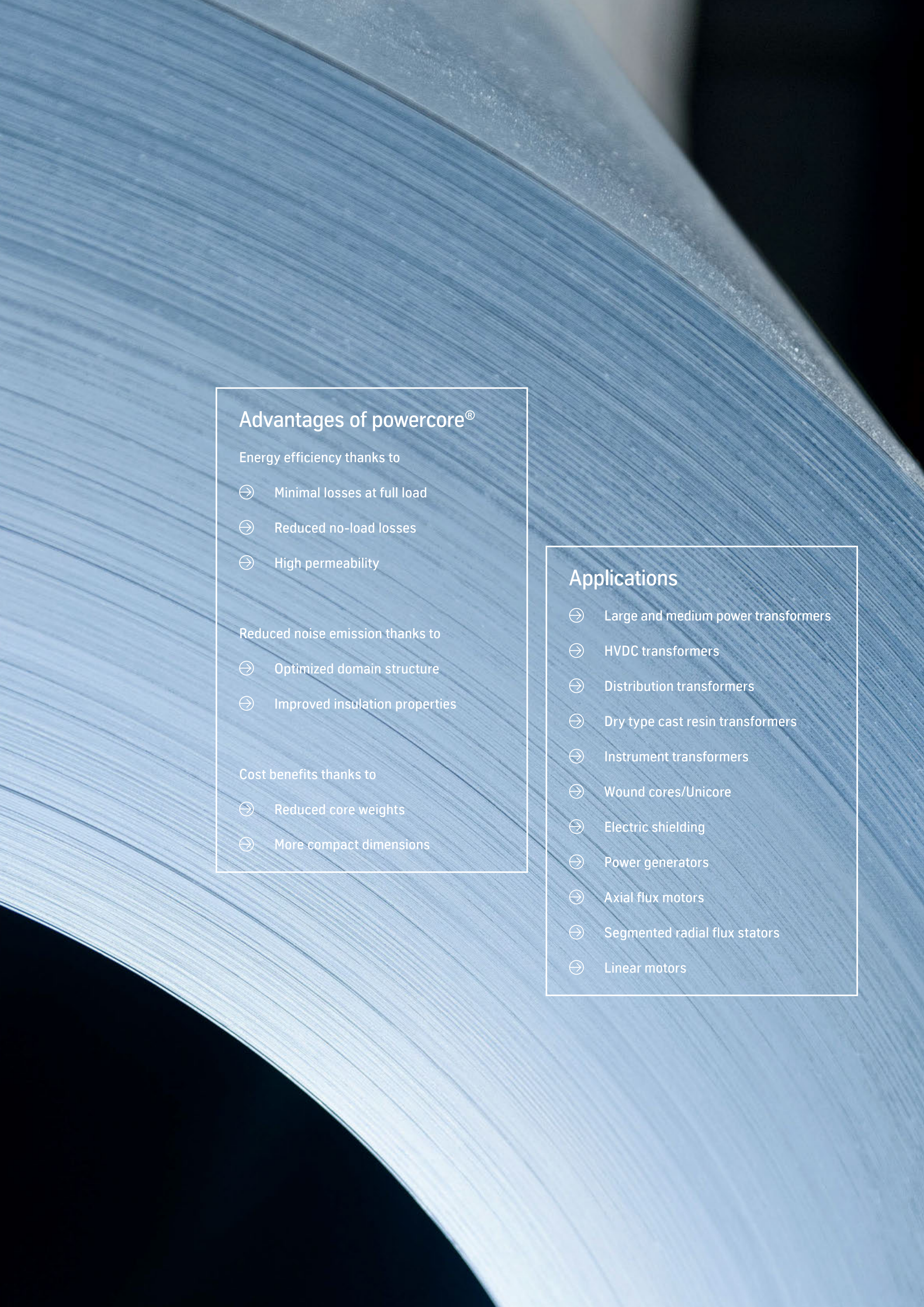
HRB 15T	75 – 85
HV0.1	185 – 200

Stacking factor, density

0.20 mm	95.0 %
0.23 mm	95.5 %
0.27 mm	96.0 %
0.30 mm	96.5 %
0.35 mm	97.0 %

Density p_m	7.65 kg/dm³

Other properties and tolerances on request.



Advantages of powercore®

Energy efficiency thanks to

- Minimal losses at full load
- Reduced no-load losses
- High permeability

Reduced noise emission thanks to

- Optimized domain structure
- Improved insulation properties

Cost benefits thanks to

- Reduced core weights
- More compact dimensions

Applications

- Large and medium power transformers
- HVDC transformers
- Distribution transformers
- Dry type cast resin transformers
- Instrument transformers
- Wound cores/Unicore
- Electric shielding
- Power generators
- Axial flux motors
- Segmented radial flux stators
- Linear motors

powercore® – further processing information

Grain oriented electrical steel is used to build magnetic cores. It should be noted that the best magnetic properties are found only in the rolling direction. If the magnetization is outside the rolling direction, core loss will increase substantially, e.g. at 90° to the rolling direction, the loss increases by a factor of more than three and at 60° it increases by a factor of more than four. It is therefore essential that the steel is magnetized as precisely as possible along the rolling direction in the whole magnetic circuit.

Mechanical stress

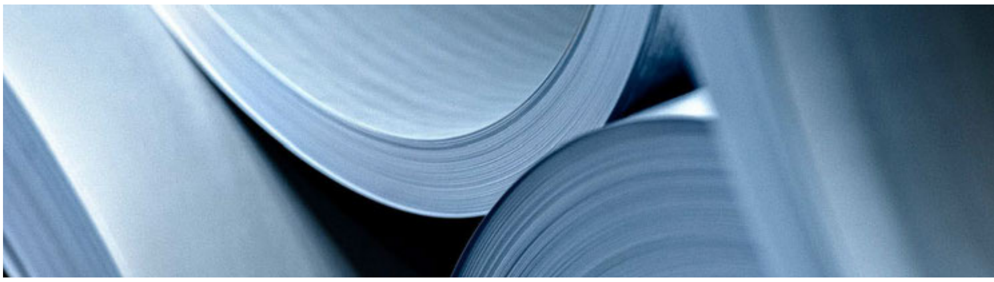
Mechanical stress has a highly negative effect on the magnetic properties of grain oriented electrical steel. The strips can become exposed to this type of stress for a variety of reasons:

- External forces (external stresses)
- Plastic deformation (internal stresses)

External stress is caused by excessive or uneven compression forcing the magnetic core laminations into a wavy or curved shape.

Internal stress is generated along the cut edges during each slitting operation or as a result of bending the sheet or subjecting it to tension beyond the yield point.

This sometimes unavoidable stress can be almost completely eliminated by stress relief annealing. Material can be annealed in a continuous annealing line under air (short-time annealing) or in a box annealing line under a nitrogen atmosphere (long-time annealing). Whether or not the material is stress relief annealed depends on the conditions at the customers place of installation.



Annealing by the customer

Short-time annealing
Laminations are usually subjected to short-time annealing in a roller furnace. This process takes a few minutes and requires a soaking time of 1 to 2 minutes at a maximum temperature of 860 °C. Since the laminations are annealed under an air atmosphere, the cut edges oxidize, thus creating an insulating coating. Any grease or oil from earlier processing stages is burnt off and is generally harmless in small quantities.

Long-time annealing
Wound cores and stacking transformers undergo long-time annealing in a box-type furnace. Long-time annealing should be carried out under the following conditions:

- Soaking temperature: min. 820 °C, max. 840 °C to 850 °C
- Soaking time: 2 hours (the coolest part of the material must be at least 800 °C)
- Cooling: preferably within the furnace to about 200 °C to 300 °C
- Protective atmosphere: preferably 100 % nitrogen. The addition of hydrogen is not recommended.

The heating, soaking and cooling times are largely determined by the type and size of furnace and the amount of annealing material. The annealing cycle must be adapted to the above parameters. As a general rule, heating the material too quickly may result in local overheating, especially in the outer cores. This risk can be reduced by controlling the temperature with a thermocouple near the heating conductors. The soaking time must be long enough to ensure that the annealing material reaches the soaking temperature (minimum 800 °C) throughout.

If the material cools down too quickly, the cores may warp or distort. It is further recommended that the soaking temperature is controlled by thermocouples positioned at the hottest and the coolest points of the annealing material. The cores should be allowed to cool down in the furnace to a temperature between 200 °C to 300 °C to avoid quenching effects during unloading. The annealing material must be free from grease, oil and other organic substances to prevent carburization.

Domain refined material
Stress relief annealing of laser-irradiated powercore® reverses the reduction in core loss produced by the laser treatment. The special design of our laser beam ensures that the excellent adhesive properties and the high resistance value of the insulation are preserved in our laser-irradiated powercore® grades. As a result, laser-irradiated powercore® grades show the same favorable noise behavior in the finished transformers as powercore® grades that have not been laser treated.

For further information, please visit our website at

www.thyssenkrupp-electrical-steel.com

Steel
Electrical Steel

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