

Electrical Steel

# Grain oriented electrical steel powercore<sup>®</sup>

Product range



thyssenkrupp

# powercore<sup>®</sup> is the core material for the future

Grain oriented electrical steel is a highly sophisticated high-tech core material. It is used in transformers to increase or reduce electrical voltages and currents. That is the only way that electricity can be transported over long distances with as little loss as possible.

Premium powercore<sup>®</sup> electrical steel grades significantly reduce noise emissions in transformers, a distinct advantage in the light of growing urbanization and industrialization. powercore<sup>®</sup> electrical steel is so energy-efficient that it is now possible to build considerably smaller transformers with the same power output.

As energy demand grows continuously, powercore<sup>®</sup> grain oriented electrical steel significantly contribute to protecting the environment around the world and to conserving energy resources.

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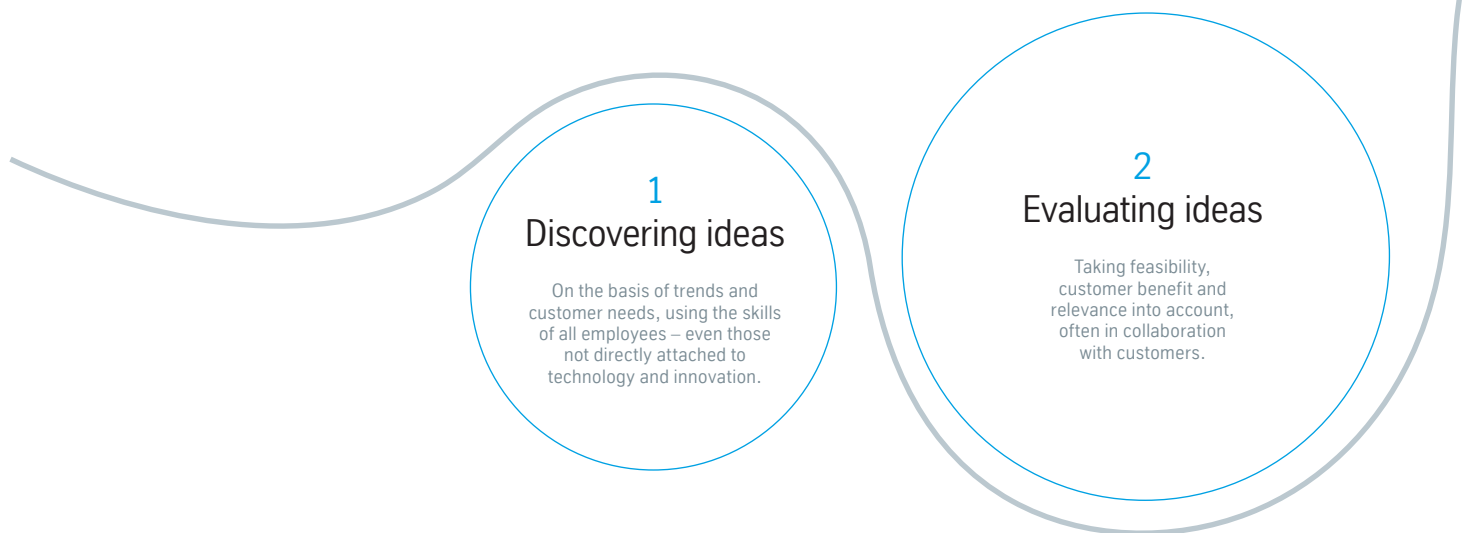
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Further processing information

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# Innovation & cooperation



With the high-tech material steel, successful innovations most often occur when the boundaries of individual disciplines are transcended.

Our products emerge both through intensive communication between sales, development and production and the close partnering relationships with our customers. Our proactive network also includes universities, institutes and industry partners.

In this interplay of various types of expertise, we utilize modern laboratory and pilot plants as well as simulation tools to advance the development of high-tech steels, materials, coatings and processes.

A further instrument that helps us stay ahead of the state of the art is our systematic quality management. We also involve our suppliers in this system to enable us, so that we can optimally implement our extremely demanding standards and those of our customers and business partners.

3

### Developing ideas

Evaluation of potential, development of prototypes, calculation of the necessary data in simulation tests as preparation for laboratory experiments.

4

### Preparing the product concept

Performance of laboratory experiments and production of sample coils, interdisciplinary testing of technical and economic feasibility, ideally on a pilot plant.

5

### Developing the product

After being successfully tested, products are developed to production maturity through further operating trials, also involving the preparation of production equipment.

6

### Market rollout

Series production commences following preparation of a detailed marketing concept, implementation of all necessary further-developed product and production features, and customer approval.

Mindful of our responsibility at all times.

We are committed to environmental compatibility and sustainability in everything we do. From the systematic reuse of water in our production and the use of process gases for our own heating and electrical generation needs to the resource-conserving utilization of all raw materials and the efficient recyclability of our products.

# Our vision of the future – Transformer 2020

TRANSFORM is an umbrella organization comprising only premium European suppliers in the transformer industry. All TRANSFORM activities and events pursue the same goal of encouraging businesses to share information about the key components in power transformers.

Together with the partners of the TRANSFORM network, we developed our vision of a future power transformer. It is called Transformer 2020.

As suppliers of essential components, the TRANSFORM partners collectively cover the full range of power transformers. The innovative power of these premium suppliers has now been consolidated for the first time as part of the Transformer 2020 project. The aim of this technology study was to gain a clearer insight into the challenges faced by customers and to identify possible approaches to finding solutions. Along with the technical experts of the TRANSFORM partner companies, the Technical Universities of Berlin and Dresden, the University of Stuttgart, the Fraunhofer Institute for Production Technologies in Aachen and the specialized institute PMO for Usability Engineering in Munich were also on board and shared their recognized expertise.

Innovations were identified for each module of the power transformer and subsequently implemented during the study. In terms of the overall concept, this has led to significant improvements of important parameters such as power loss, noise emissions and size.

The core of the next generation transformer is made of powercore® highly permeable grain oriented electrical steel. It is a highly demanding metallurgical steel product which as a core material forms the heart of the transformer. It is available in a wide variety of thicknesses (0.30; 0.27; 0.23 mm). The new grain oriented electrical steel 0.20 mm thickness demonstrates high permeability properties and low specific losses. This enables the OEMs to meet the requirements of the European Ecodesign regulation for 2021. Stacking more laminates inside a cross section of the transformer core further optimizes the transformer design to reduce losses and noise.



Grain oriented electrical steel - the core material at the heart of a transformer.

# The energy transition is not feasible without powercore®

It is possibly the most underrated material of the future at the moment: electrical steel. Nothing less than our energy supply and the success of the energy transition depend on it, because electrical steel plays a key role wherever electrical energy is efficiently generated, converted or used. The best example are transformers.

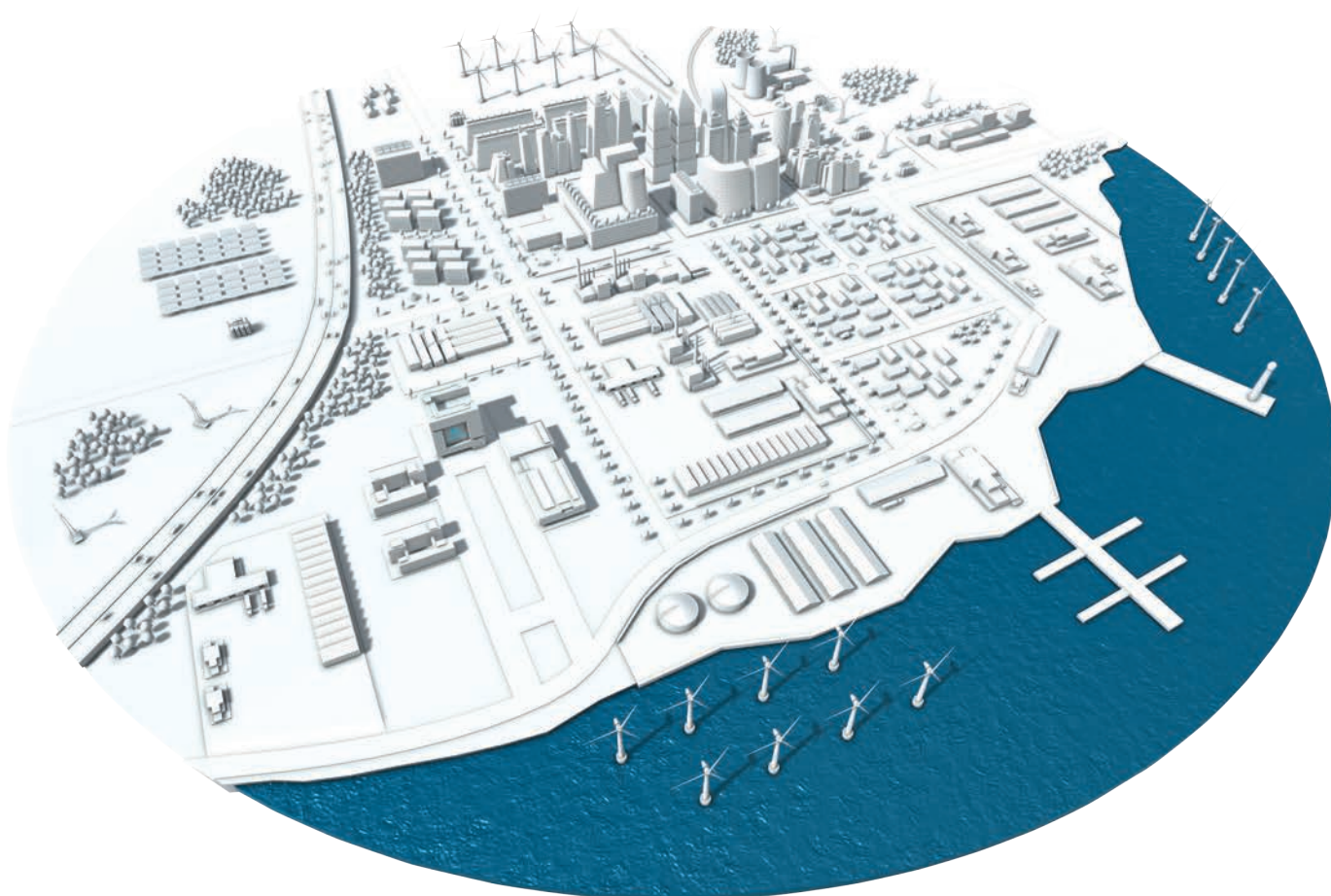
Transformers need grain oriented electrical steel to be able to function efficiently. Without transformers, we would have no electricity, neither in the private nor the industrial sector.

Demand for electrical energy is constantly increasing. According to the International Energy Agency (IEA), electricity demand will increase by some two thirds over the next 25 years. The aim is to meet this increasing demand by using renewable energies. On the one hand, because fossil fuels are finite. And on the other hand, because the use of oil, coal and gas accelerates climate change and thus makes a move away from conventional energy generation unavoidable.

However, this also means that energy grids and transformers will have to change in the future to be able to feed this renewable energy into the grid.

For instance, new power lines will be required, some over several thousand kilometres in length, to transport renewable energy generated by wind energy in windy regions or at sea to electricity consumers. Moreover, the volatility of renewable energy generation requires the grids to efficiently and intelligently link generation and consumption with each other. These smart grids denote the communicative integration of energy system stakeholders in generation, transport, storage, distribution and consumption into the energy supply grid.





Our high-tech materials  
make a major contribu-  
tion to sustainability.

# Grain oriented electrical steel

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

powercore® H grades have a sharper crystallographic texture than powercore® C grades. This, combined with a performing insulation coating, improves magnetic domain structure for a reduction of core loss and noise, making the powercore® H grades the material of choice for Ecodesign power transformers.

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

powercore® H is the core material for the future!



powercore® C



# Premium powercore® grades for eco-efficient transformers

The requirements of grain oriented electrical steel as a core material have changed considerably in recent years and will continue to do so in the future. With vast experience and excellent technical expertise, we manufacture grain oriented electrical steels which fulfil the highest standards worldwide.

With our powercore® electrical steel, regulations for energy efficient transformers, for instance the Ecodesign regulation, can be implemented in a targeted manner. This implementation requires an enormous technological push: only with the best grain oriented electrical steels can eco-efficient transformers be built. That is why for many years now we have been making innovative investments to achieve that goal.

Our research and development team in Gelsenkirchen and Isbergues is permanently researching the optimization of our product properties and the production process to make our premium powercore® electrical steel even better for you.

With a technological infrastructure and high material competence, we are and remain your reliable partner for a better world with electricity.

## Production sites



Gelsenkirchen

Germany



Isbergues

France



Nashik

India





## Applications

- ➞ Large power transformers
- ➞ Distribution transformers
- ➞ Small transformers
- ➞ Current transformers
- ➞ Shunt reactors
- ➞ Wound cores
- ➞ Power generators

powercore® C: Guaranteed magnetic properties

Grade	Thickness [mm]	Thickness [inch]	Typical core loss at				Guaranteed core loss at		Typical polarization at	Guaranteed polarization at
			1.5 T	1.7 T	1.5 T	1.7 T	1.7 T	1.7 T		
			50 Hz	50 Hz	60 Hz	60 Hz	50 Hz	60 Hz	800 A/m	800 A/m
			W/kg	W/kg	W/lb	W/lb	W/kg	W/lb	typ. T	min. T
C 120-23	0.23	0.009	0.77	1.18	0.46	0.71	1.20	0.72	1.83	1.78
C 120-27	0.27	0.011	0.80	1.18	0.48	0.71	1.20	0.72	1.83	1.80
C 130-27	0.27	0.011	0.83	1.23	0.50	0.74	1.30	0.78	1.83	1.78
C 120-30	0.30	0.012	0.82	1.18	0.49	0.71	1.20	0.72	1.83	1.80
C 130-30	0.30	0.012	0.84	1.23	0.50	0.74	1.30	0.78	1.83	1.80
C 150-30	0.30	0.012	0.93	1.43	0.56	0.85	1.50	0.89	1.78	1.75
C 165-35	0.35	0.014	1.00	1.48	0.60	0.88	1.65	0.99	1.78	1.75

All grades may be delivered with laser domain refinement if not agreed otherwise.

## powercore® H: Guaranteed magnetic properties

Grade	Thickness [mm]	Thickness [inch]	Typical core loss at				Guaranteed core loss at		Typical polarization at	Guaranteed polarization at
			1.5 T	1.7 T	1.5 T	1.7 T	1.7 T	1.7 T		
			50 Hz	50 Hz	60 Hz	60 Hz	50 Hz	60 Hz		
			W/kg	W/kg	W/lb	W/lb	W/kg	W/lb		
H 20*	0.20	0.008								
H 075-23 L	0.23	0.009	0.55	0.74	0.33	0.44	0.75	0.45	1.91	1.88
H 080-23 L	0.23	0.009	0.57	0.78	0.34	0.47	0.80	0.48	1.91	1.88
H 085-23 L	0.23	0.009	0.60	0.83	0.36	0.50	0.85	0.51	1.90	1.88
H 090-23	0.23	0.009	0.62	0.88	0.37	0.53	0.90	0.54	1.90	1.88
H 100-23	0.23	0.009	0.67	0.98	0.40	0.59	1.00	0.60	1.88	1.85
H 085-27 L	0.27	0.011	0.63	0.83	0.38	0.50	0.85	0.51	1.91	1.88
H 090-27 L	0.27	0.011	0.65	0.88	0.39	0.53	0.90	0.54	1.91	1.88
H 095-27	0.27	0.011	0.68	0.93	0.41	0.56	0.95	0.57	1.91	1.88
H 100-27	0.27	0.011	0.71	0.98	0.43	0.59	1.00	0.60	1.89	1.88
H 110-27	0.27	0.011	0.76	1.08	0.46	0.65	1.10	0.66	1.89	1.88
H 100-30	0.30	0.012	0.72	0.98	0.44	0.59	1.00	0.60	1.91	1.88
H 105-30	0.30	0.012	0.75	1.03	0.45	0.62	1.05	0.63	1.91	1.88
H 110-30	0.30	0.012	0.77	1.08	0.46	0.65	1.10	0.66	1.90	1.88

\* powercore® H 20 is suitable for distribution and power transformers at industrial frequencies as well as for devices running at medium frequencies.  
L = Magnetic domain refined by laser scribing. Other grades may be delivered with laser domain refinement if not agreed otherwise.

# Insulation types

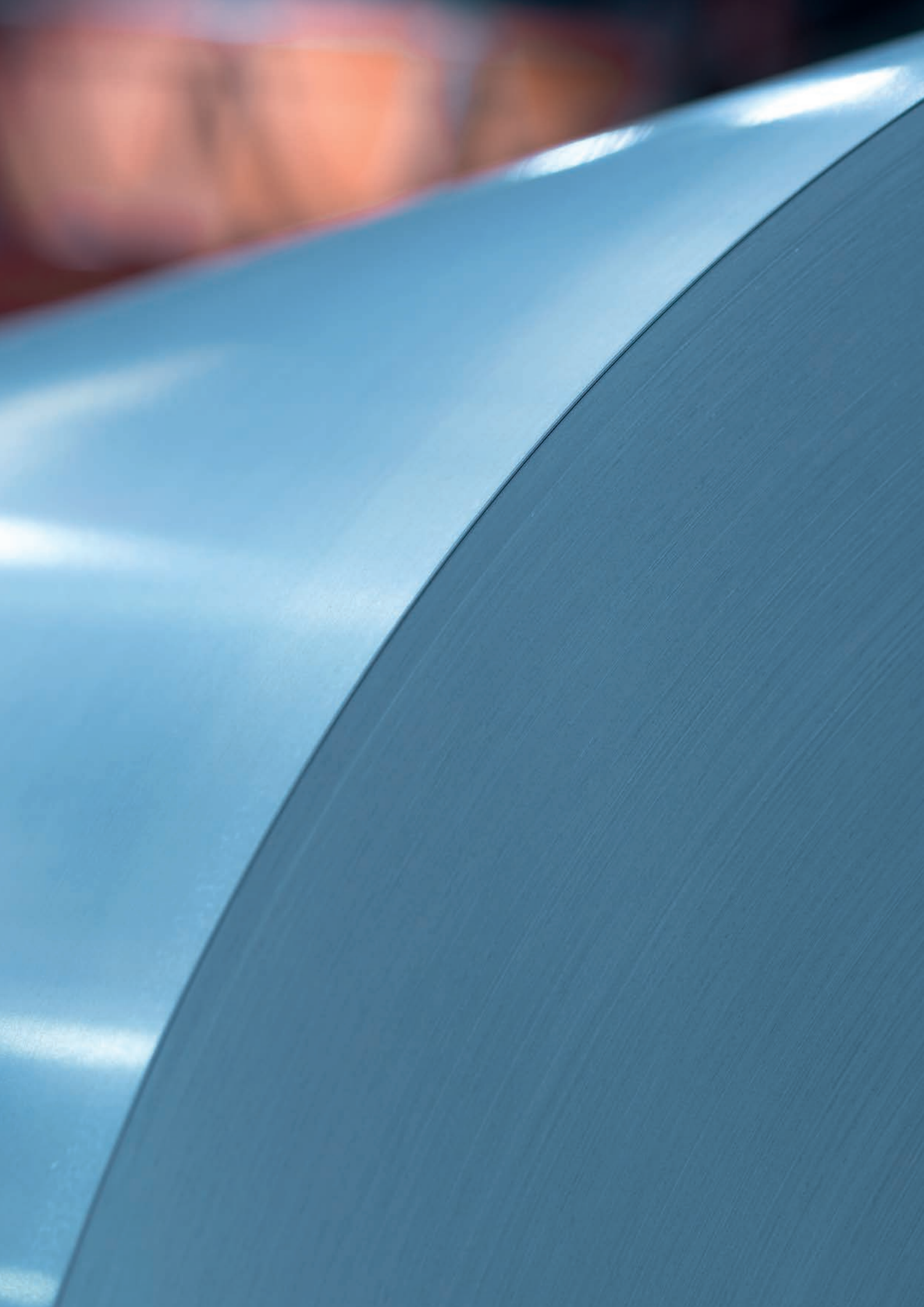
The grain oriented electrical steel is supplied with a thin anorganic coating on the glass film layer which forms during annealing. A coating thickness of 2 to 5 µm provides good electrical resistance and a high stacking factor.

The coating, which is annealing resistant up to 840 °C, enables wound cores and punched laminations to be stress relief annealed. The coating is chemically resistant to any fluid it may be exposed to during the production process. It is unaffected by, and likewise does not affect, the different types of transformer oils.

We offer two types of insulation coating: Chrome containing insulation coating and chromium-free coating. From technological point of view both coatings are similar.

Insulation types			
Color		Annealing resistance	
Color deviations may occur, but will not affect the properties	Phosphate over glass film: grey	under inert gas as per DIN IEC 60404-12	840 °C/2 h
Coated sides		Designation according to IEC 60404-1-1	
both sides		EC-5-G	
Thickness of coating		Designation according to ASTM A976	
2 µm-5 µm		C-5 over C-2	
Surface insulation resistance		Chemical resistance	
at room temperature as per DIN IEC 60404-11	>10 Ω cm2	to transformer oil	good





# Characteristics

## Dimensions

### Standard strips

Inside diameter	508 mm
Width	950-1,000 mm
Nominal thickness	0.23 mm
	0.27 mm
	0.30 mm
	0.35 mm

### Slit width

Inside diameter	508 mm
Width	≥6 mm
Nominal thickness	0.23 mm
	0.27 mm
	0.30 mm
	0.35 mm

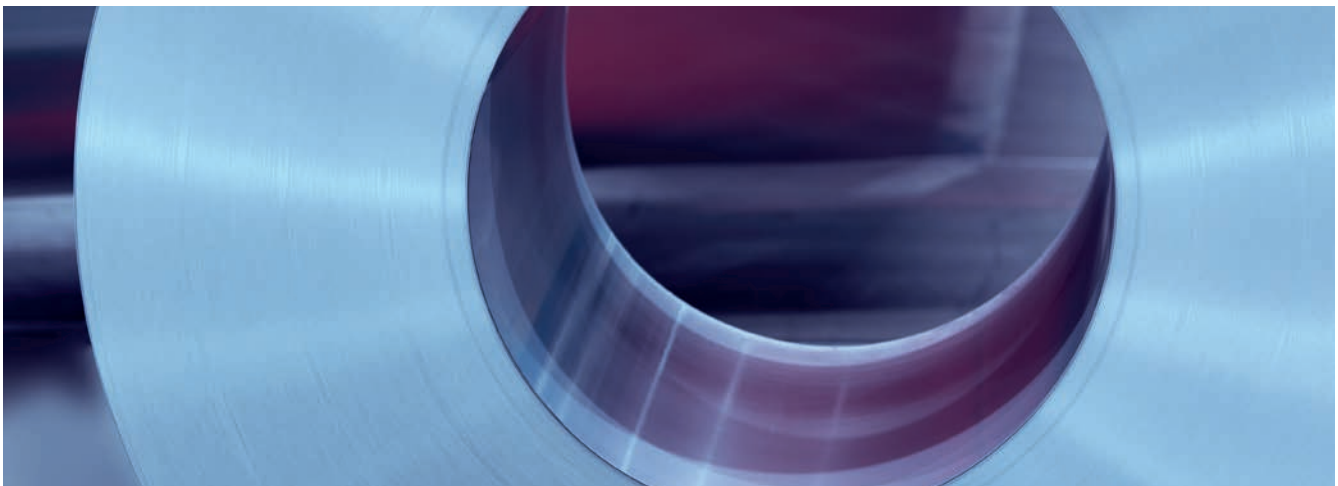
## Geometric tolerances

### Thickness tolerances

Max. tolerance on the nominal thickness	±0.020 mm
Max. difference in thickness parallel to the direction of rolling within a sheet or in a length of strip of 1,500 mm	0.025 mm
Max. difference in thickness perpendicular to the direction of rolling at a minimum distance of 40 mm from the edges	0.020 mm

### Tolerances for widths

Standard widths	±1 mm
Slit width* ≥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 stipulated with order	



## Other characteristics and tolerances

## Residual curvature

Max. distance for a sample 500 mm in length applicable for width >150 mm	35 mm
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## Edge camber

Max. edge camber for a measuring length of 1,500 mm applicable for width >150 mm	0.5 mm
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Deviation from the shearing  
line due to internal stresses

Max. measured gap within a strip length of 1,500 mm applicable for width >500 mm	1 mm
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Flatness  
(wave factor)

Max. wave factor applicable for width >150 mm	1.5 %
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## Burr height (only for slit width)

Max. burr height	0.025 mm
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The measuring methods for thickness and width are given in the product standards EN 10107 and IEC 60404-8-7. All other measuring methods and definitions are given in EN 10251 and IEC 60404-9. The quoted values are in many cases better than those specified in the EN- or IEC-Norm.

## Typical physical properties

Ultimate tensile strength  $R_m$ 

longitudinal in rolling direction	330-370 MPa
transverse to rolling direction	390-420 MPa

Elongation  $A_{l=80}$ 

longitudinal in rolling direction	6-14 %
transverse to rolling direction	24-48 %

Yield point  $R_{p0.2}$ 

longitudinal in rolling direction	300-340 MPa
transverse to rolling direction	330-360 MPa

## Hardness

HRB 15T	75-85
HV 0.1	175-195

Saturation polarization  $J_s$ 

2.03 T

## Stacking factor, thickness

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

Coercive field strength  $H_s$ 

5 A/m

Curie temperature  $T_c$ 

745 °C/1,345 °F

Density  $p_m$ 7.65 kg/dm<sup>3</sup>Electrical resistivity  $p_e$ 0.48  $\mu\Omega\text{m}$

# 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

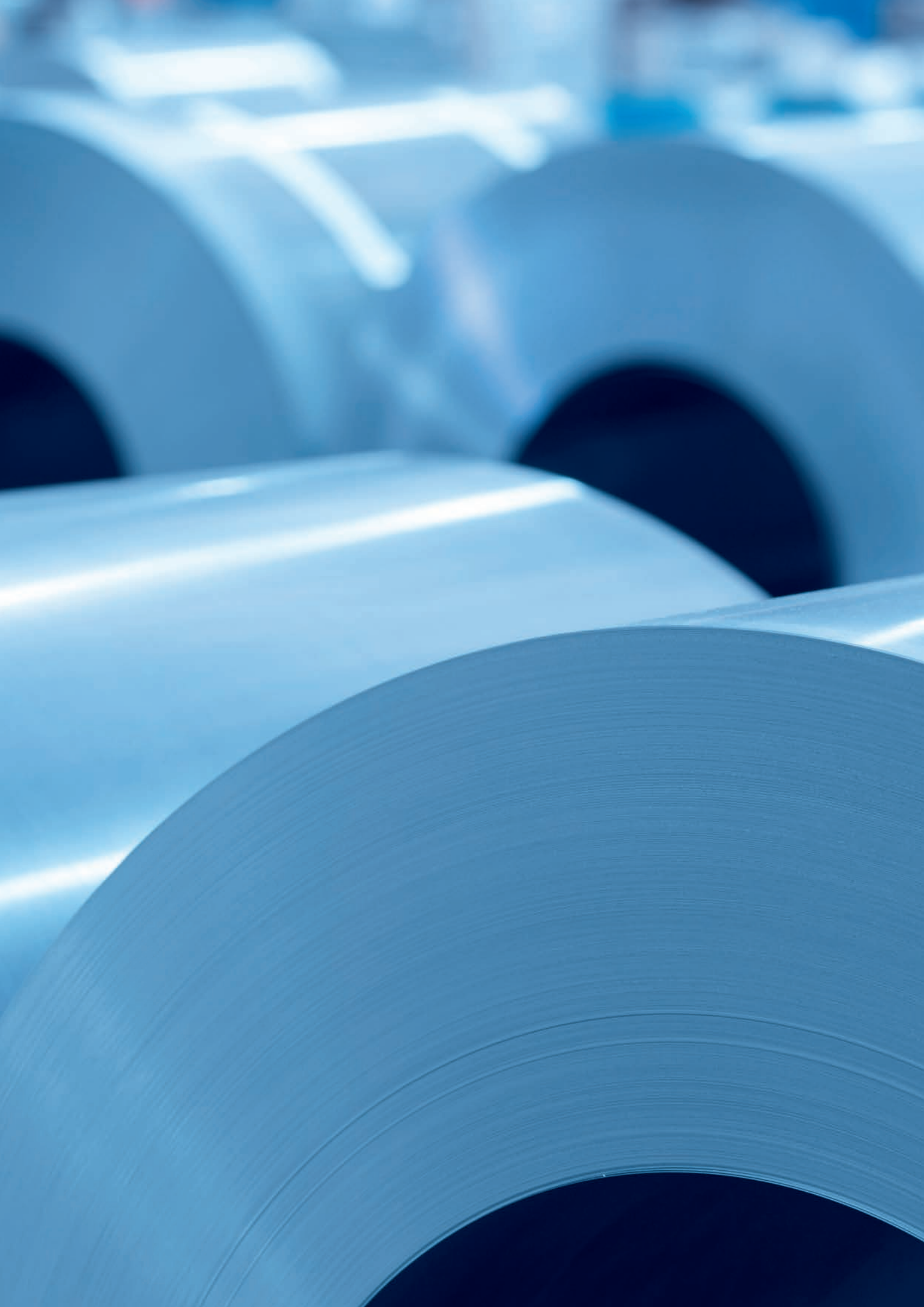
allowed to cool down in the furnace to a temperature between 200 °C to 300 °C to avoid quenching effects during unloading. The annealing material must be free from grease, oil and other organic substances to prevent carburization.

#### **Domain refined material**

Stress relief annealing of laser-irradiated powercore® H 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® H grades. As a result, laser-irradiated powercore® H grades show the same favorable noise behavior in the finished transformers as powercore® H grades that have not been laser treated.









For more information, visit us at:

[www.thyssenkrupp-steel.com/en/electricalsteel](http://www.thyssenkrupp-steel.com/en/electricalsteel)



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.

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Electrical Steel

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