



**Asia-Pacific  
Economic Cooperation**

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**2017/EWG/EGEEC/WKSP2/004**

## **3D Wound Core Technology Development in China**

Submitted by: China Transformer Association



**Workshop on Reducing Losses in Power  
Distribution Through Improved Efficiency of  
Distribution Transformers**

**Jeju, Korea  
28 March 2017**



Asia-Pacific  
Economic Cooperation



## Reducing Losses in Power Distribution through Improved Efficiency of Distribution Transformers (EWG 05 2015A)

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# 3D Wound Core Technology Development in China

28 March 2017 | Jeju Island, Korea

Liang Qingning

China Transformer Association

ORGANISERS:



International Copper  
Association Southeast Asia  
Copper Alliance



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# Part One

前言

Preface



- ✓ 立体卷铁心技术是变压器节能的重要方式，近年来，中国积极推动世界节能减排事业的发展，在配电变压器能效提升方面制定相关政策，进而共同加速立体卷铁心技术提升。
- ✓ 3D wound core technology is an important means for technology energy saving. In Recent year, China is dedicated to globe energy saving activity development and has made several policies on energy efficiency development of distribution transformer, which accelerated 3D wound core technology promotion.

**三部委 Three Ministries (MIIT, AQSIQ, and NDRC)**

《配电变压器能效提升计划（2015-2017）》

*Distribution Transformer energy-saving promotion program (2015-2017)*

**工信部 Ministry of Industry and Information Technology(MIIT)**

变压器“能效之星”产品目录（2016）

*2016 Transformer “Energy star” catalog*

**发改委 National Development and Reform Commission(NDRC)**

《战略性新兴产业重点产品和服务指导目录》2016版

*2016 Strategic Emerging Industry Key Product and Service Guidance Catalog*

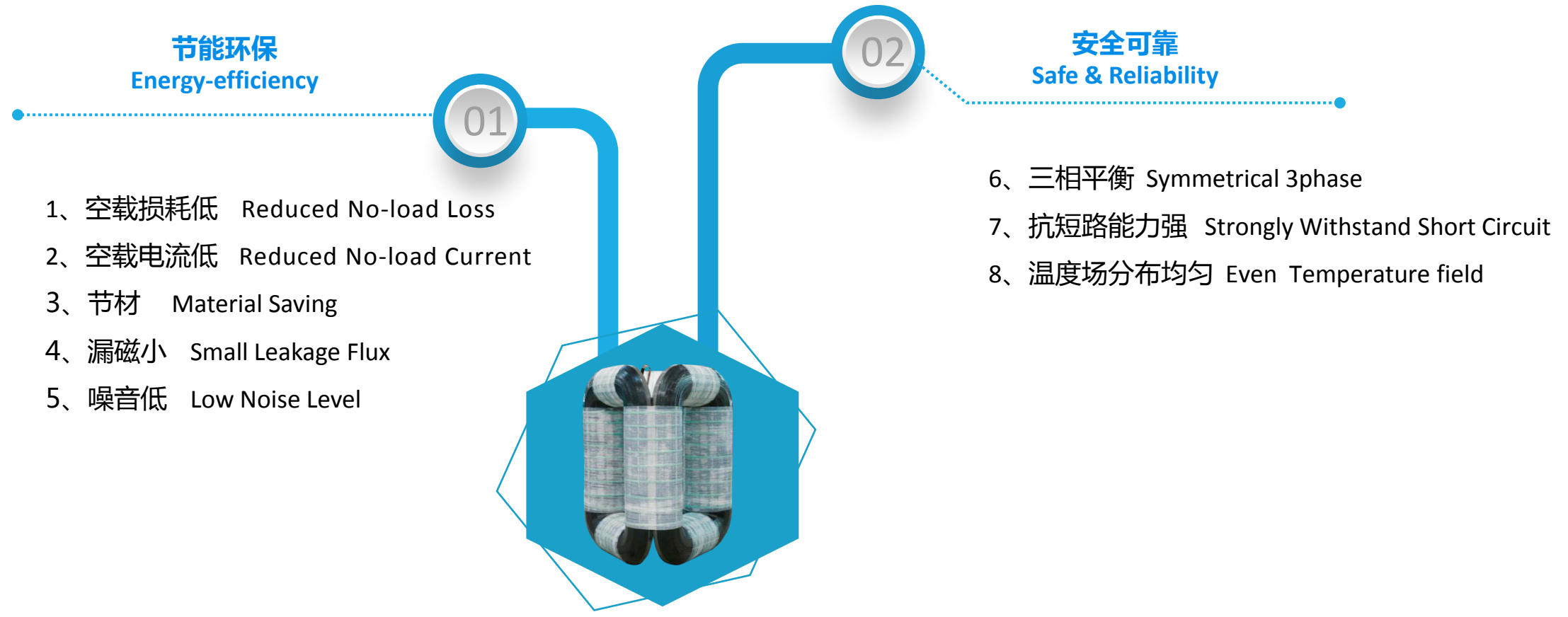
# Part Two

## 立体卷铁心技术简介

3D Wound Core Technology Brief Introduction



 **技术优势**  
**Comprehensive Features**





## 优点一：空载损耗低

### Advantage 1: Low No-load Loss

变压器空载损耗计算公式：

Here is the formula to calculate no-load loss of transformer:



$$P_0 = K_0 \times G \times P_t$$

$K_0$

#### 工艺系数 Technology coefficient

铁心连续地卷绕而成；采用完全退火工艺，立体卷铁心工艺系数可以达到1.01 ~ 1.05，而叠铁心工艺系数为1.05 ~ 1.35。

Continuously winding core & completely annealing, technological coefficient of 3D wound core is 1.01-1.05, while EI core is 1.05-1.35.

$G$

#### 铁心重量 Core weight

铁心重量由于结构和工艺改良，约减少25%。

Core weight reduces about 25% because of optimizing structure & production.

$P_t$

#### 铁心材料单位损耗 Material unit loss

铁心截面填充系数高，磁感应强度B降低， $P_t$ 下降。

High lamination factor will reduce magnetic flux density B. Then  $P_t$  is reduced.





## 优点二：空载电流低

### Advantage 2: Low No-load Current

#### 立体卷铁心 3D Wound Core

- 三相磁路无接缝
- Without air gaps in magnetic circuit
- 磁力线与铁心材料易磁化方向完全一致
- The direction of magnetic field line is entirely consistent with the direction for core material easy to magnetize
- 退火工艺，完全恢复硅钢磁性能
- Fully recovery of silicon steel performance by annealing

VS

- 磁路中接缝形成的空气隙加大了磁阻
- Lots of seams and air gaps in the magnetic circuit create resistance
- 铁心角部内磁力线与铁心材料易磁化方向存在夹角
- An angle between the magnetic field lines and with the direction for core material easy to magnetize
- 采取冲裁、叠片、拆、插铁轭等工序，受毛刺、接缝处理等工艺水平影响
- Burrs and seams occur during the processes of cutting, laminating, yoke installing influence the no-load current

#### 平面铁心 EI Core





### 优点三：噪音低

#### Advantage 3: Low Noise Level

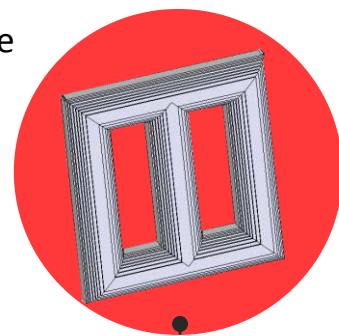
##### 立体卷铁心 3D Wound Core

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- Without air gaps in magnetic circuit
- 磁力线与铁心材料易磁化方向完全一致
- The direction of magnetic field line is entirely consistent with the direction for core material easy to magnetize
- 退火工艺，完全恢复硅钢磁性能
- Full recovery of silicon steel performance by annealing
- 三相铁心为自稳结构，无需夹紧。一般可比叠铁心变压器降低10~25分贝，基本达到静音状态
- Core is of self-stable structure without any clamping. In comparison with EI core, sound level can be reduced by 10dB-25dB, which is nearly muted

VS

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- 需夹紧成型，铁心的磁致伸缩现象因夹紧不均匀导致噪声增大
- Core needs to clamp. Magnetostrictive effect causes larger noise due to uneven clamping

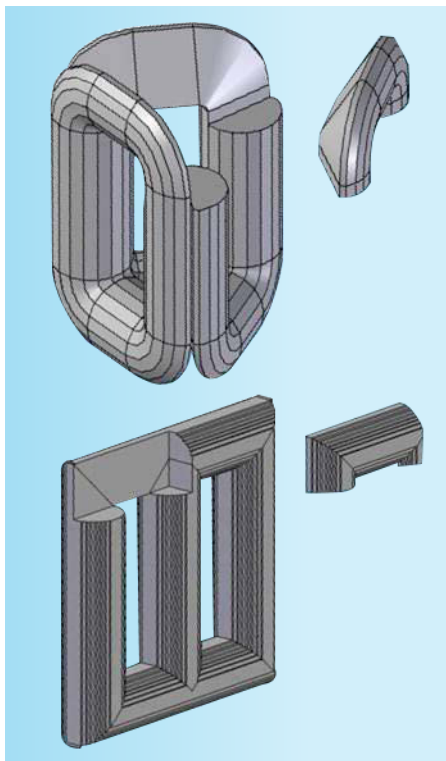
##### 平面铁心 EI Core





## 优点四：节材(铁心材料)

### Advantage 4: Material Saving(Core material)



#### 相同方案情况下

#### Same design plan

由图可见，立体卷铁心铁轭部分比叠铁心少25%，约节省10%硅钢片

Yoke cross section of 3D wound core is almost 75% of the EI core, which can save around 10% of silicon steel.

单框为圆角，节省约5%硅钢片

Angle parts of a single frame of 3D wound core are smooth and round, which can also save 5% of silicon steel than EI core.

材料利用率接近100%，比叠铁心高约5%

Material utilization rate of 3D wound core is nearly 100%, around 5% higher than EI core.

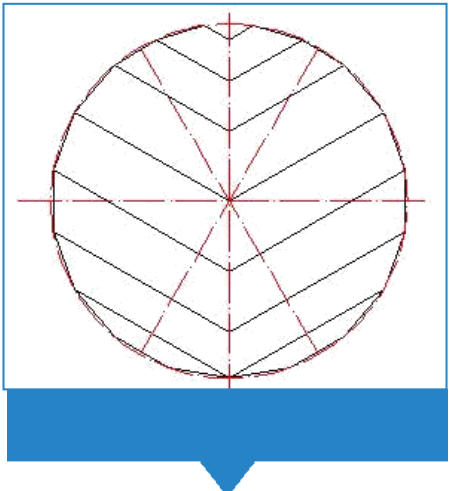
#### 立体卷铁心方案优化（空载损耗降低）

#### Optimizing design plan due to low NLL

硅钢片材料用量进一步下降。

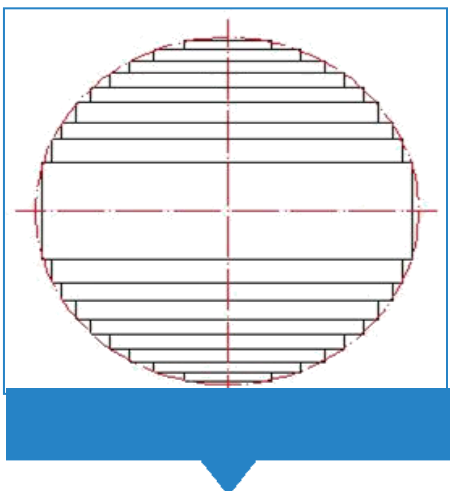
Silicon steel sheet material consumption decrease more.

优点四：节材（导线材料）  
Advantage 4: Material Saving(Conductor)



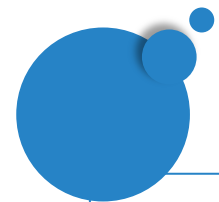
立体卷铁心心柱截面图  
Sectional drawing of 3D wound core limb

- 填充系数
- Lamination factor 0.95~0.96



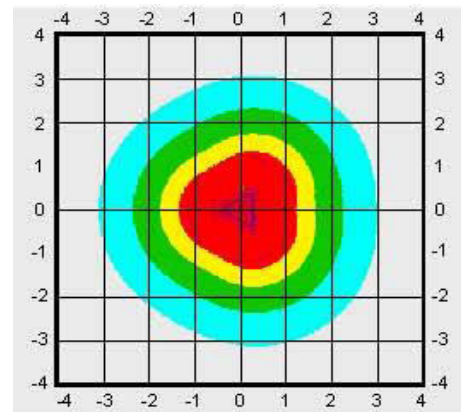
叠铁心、平面卷铁心心柱截面图  
Sectional drawing of EI or planar wound core limb

- 填充系数
- Lamination factor 0.89~0.925

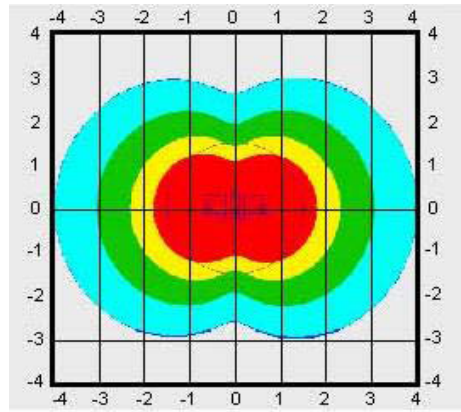


- 立体卷铁心截面填充系数高
- Cross section lamination factor of 3D wound core is higher
- 有效面积相同情况下，立体卷铁心心柱直径小
- Provided the effective areas are exactly the same, the diameter of 3D wound core limb is smaller than that of EI core
- 从而减少线圈导线长度，节约绕组线材。同时也可以降低负载损耗
- As a result, less conductor is needed for coils, which also helps to reduce the load loss.

优点五：漏磁小  
Advantage 5: Small Magnetic Flux Leakage



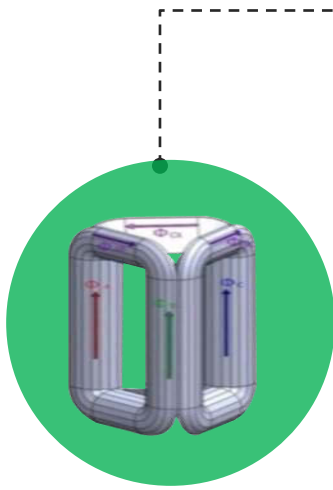
立体卷铁心磁场俯视图  
Vertical view of magnetic field for 3D wound core



平面叠铁心磁场俯视图  
Vertical view of magnetic field for planar EI Core

- ✓ 立体卷铁心结构可大大降低变压器周围的杂散磁场。空间漏磁小，仅为传统结构变压器的一半，减少电磁辐射。
- ✓ 3D wound core structure results in a greatly reduced electromagnetic stray field around the transformer. The magnetic flux leakage is only half of EI core.

❖ 优点六：三相平衡  
Advantage 6: Symmetrical 3 Phase

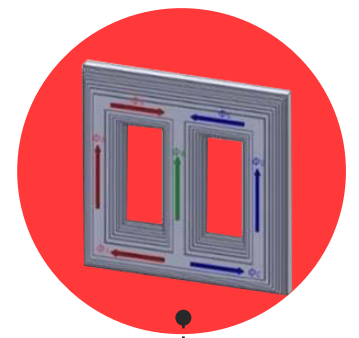


立体卷铁心  
3D Wound Core

- 三个心柱的磁路长度一致，且最短
- Symmetrical 3-phase & shortest magnetic circuit

VS

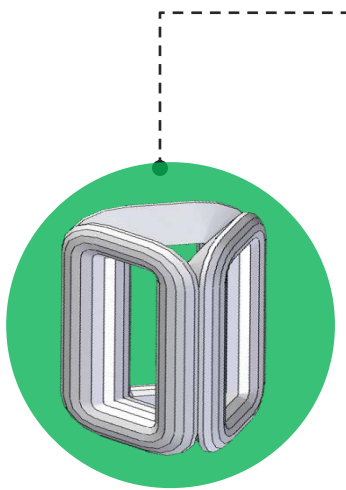
- A-C磁路比A-B、B-C的磁路长1/2
- Magnetic circuit A-C is 1/2 longer than A-B and B-C



平面铁心  
EI Core

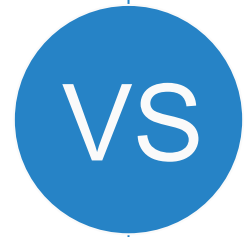


### 优点七：抗短路能力强 Advantage 7: Strongly Withstand Short Circuit

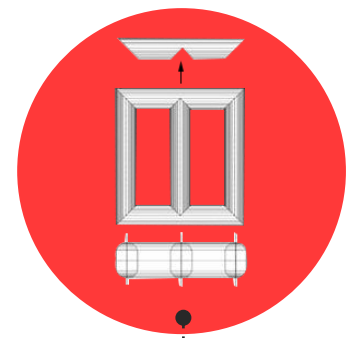


立体卷铁心  
3D Wound Core

- 铁心连续地卷绕而成，铁心坚固，且三相受力均匀对称
- 3D wound core is firm by continuously winding; and three phases are symmetrical



- 铁心由不同规格、不同形状的单片叠置而成，片与片之间没有可靠连接，尤其上铁轭在生产过程中经过拆插，当变压器受到冲击时，上铁轭容易冲散
- The core is stacked by different size and shape sheets without reliable connection, upper yoke is easily broken up by impact



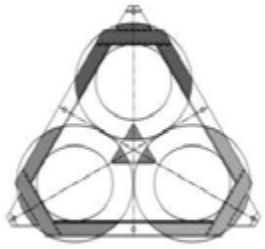
平面铁心  
EI Core



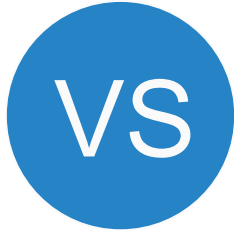
### 优点七：抗短路能力强

### Advantage 7: Strongly Withstand Short Circuit

立体卷铁心  
3D Wound Core

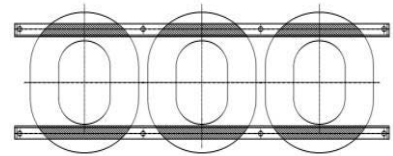


- 夹件为三角形焊接成一体的框架结构，整体强度高
- The clamps are weld together in triangular structure. It is of high
- 三相线圈压紧情况一致
- Uniformed clamping for three-phase windings



- 夹件为独立的长形结构件，整体稳定性差；夹件跨度大，易变形
- The clamps are separate elongated structure parts with weak stability, large span and easy deformation.
- B相线圈压紧情况较差
- Clamping in B phase winding is week

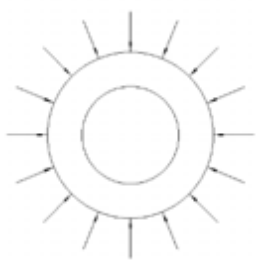
平面铁心  
EI Core





**优点七：抗短路能力强**  
Advantage 7: Strongly Withstand Short Circuit

**立体卷铁心**  
3D Wound Core

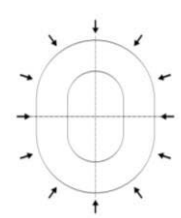
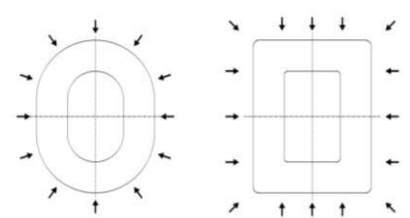


- 圆形同心式线圈，辐向受力均匀
- Concentric coil winding, radial stress uniformly

VS

- 非圆形同心式线圈，各点受力不一致
- Non-concentric coil, stress inconformity

**平面铁心**  
EI Core



优点八：温度场分布均匀  
Advantage 8: Even Temperature Field

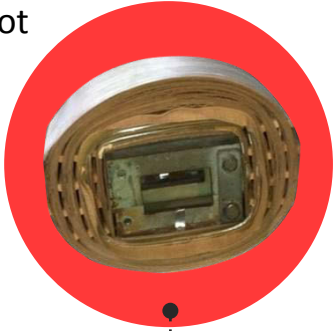


立体卷铁心  
3D Wound Core

- 圆形线圈，油道均匀
- Circular Coil, even oil duct
- 三相线圈正三角形排布，热点温升低
- Triangular layout of three phase winding, low hot spot temperature

VS

- 相间相邻部位取消了线圈的油道
- Cancel oil duct between phases border part
- B相线圈受其他两相线圈影响，热点温升偏高
- Affected by other two phase windings, hot spot temperature rise of B is high



平面铁心  
EI Core

# Part Three

## 立体卷铁心技术发展情况

3D Wound Core Technology Improvement



## 前言 Preface

- 具有明显节能减排优势的立体卷铁心技术，符合可持续发展的理念。近年来，中国变压器行业致力立体卷铁心技术研究，分享立体卷铁心技术，在节能、环保、高电压等级领域持续研发，推动环保事业的发展。
- 3D wound core technology meets the concept of sustainable development with its obvious energy saving advantage. Nowadays, Chinese transformer industry is committed to continuous research of 3D technology in energy saving, environmental protection, high voltage level, and sharing technology.

## 非晶合金立体卷铁心变压器

Amorphous Alloy 3D Wound Core Transformer





## 非晶合金立体卷铁心变压器

### Amorphous Alloy 3D Wound Core Transformer



非晶立体卷铁心 = 最理想的结构 + 最节能的材料  
Amorphous alloy 3D wound Core  
= Most ideal Structure + most energy saving material

世界首创

Globally

Initiate

专利技术

Patent

Technology

### 非晶合金立体卷铁心变压器 Amorphous Alloy 3D Wound Core Transformer

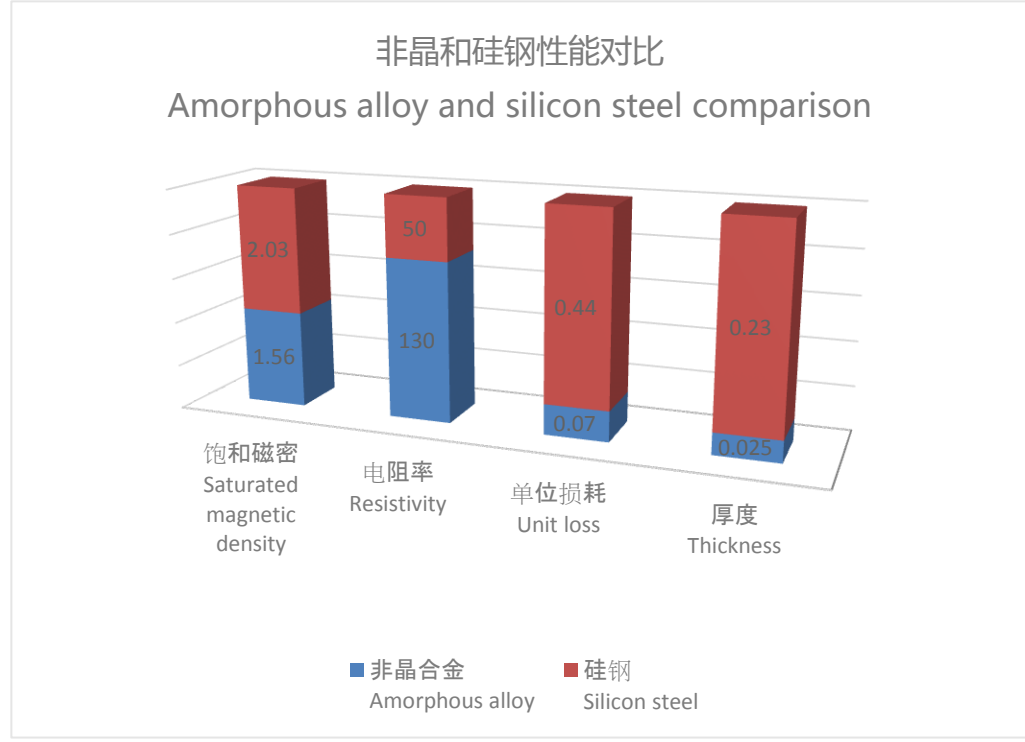


#### 最节能的材料

#### Most energy saving material


- 非晶合金是一种新的具有优异软磁性能的材料。异于硅钢的晶体结构，具有电磁性能优异、单位铁损低、饱和磁感应强度高优点。
- Amorphous alloy, a new and excellent soft magnetic material, is introduced to enhance efficiency of transformers. Amorphous alloy of special crystal structure differs from silicon steel in better excellent EMC, lower unit loss and higher saturated flux density, etc.

非晶和硅钢性能对比  
Amorphous alloy and silicon steel comparison



注：电阻率单位为Ω·cm；单位损耗铁磁密为1T，单位为W/KG；厚度单位为mm。

Note: Resistivity is in Ω·cm; magnetic density of unit loss is 1T in W/KG. Thickness is in mm.

 **非晶合金立体卷铁心变压器**  
Amorphous Alloy 3D Wound Core Transformer

**优势 Advantages**

**三相平衡 Symmetrical 3phase**


**抗短路能力强 Strongly Withstand Short Circuit**

**温度场分布均匀 Even Temperature Field**

**铁心坚固、无接缝 Firm and Seamless**

- 连续卷绕，闭口结构，一体式固化，无碎片
- Continuously winding, close structure, uniformed curing, no chip

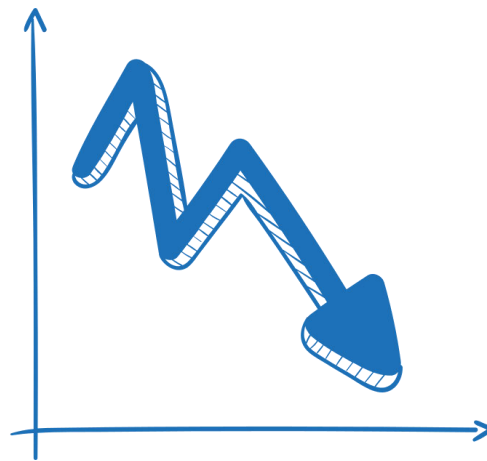


 非晶合金立体卷铁心变压器  
Amorphous Alloy 3D Wound Core Transformer

节能 Energy Saving

- 空载损耗平均比标准下降20%
- No-load loss is average 20% lower than the standard

**20%**



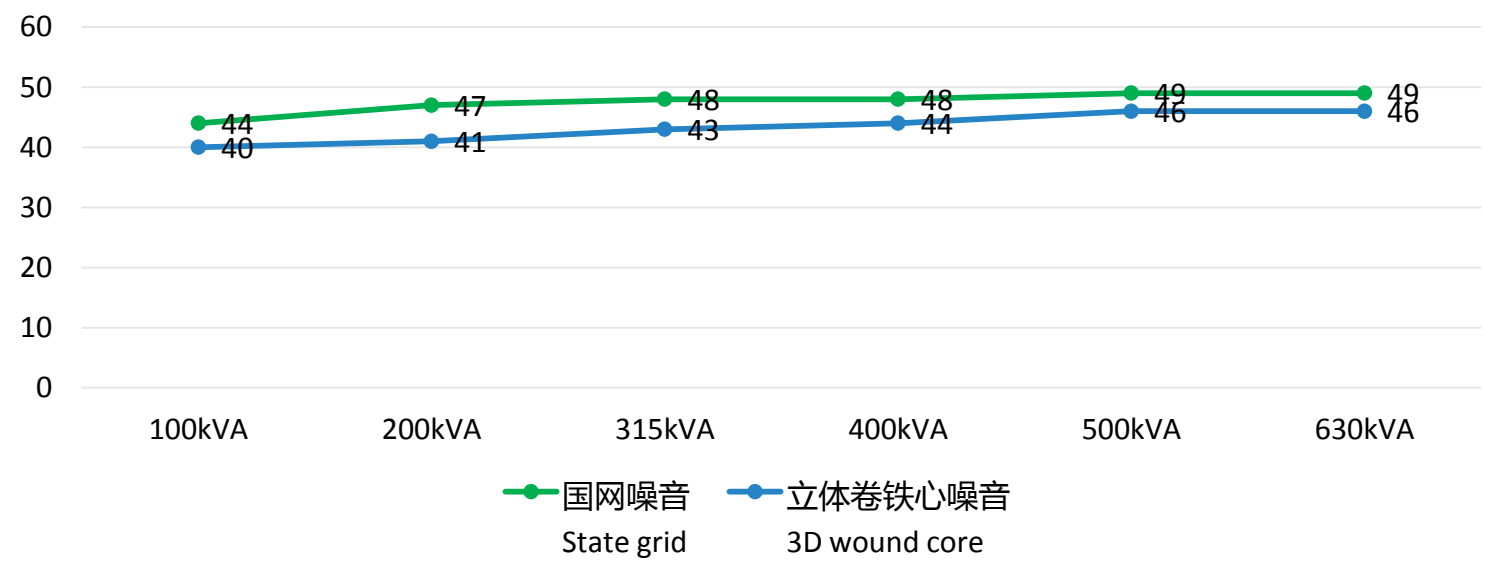
- 空载电流平均比标准下降75%
- No-load loss is average 75% lower than the standard

**75%**

非晶合金立体卷铁心变压器  
Amorphous Alloy 3D Wound Core Transformer

低噪声 Lower Noise Level

国网产品与立体卷铁心产品噪音水平对比(dB)  
State Grid and 3D Product Comparison on Sound Level (dB)

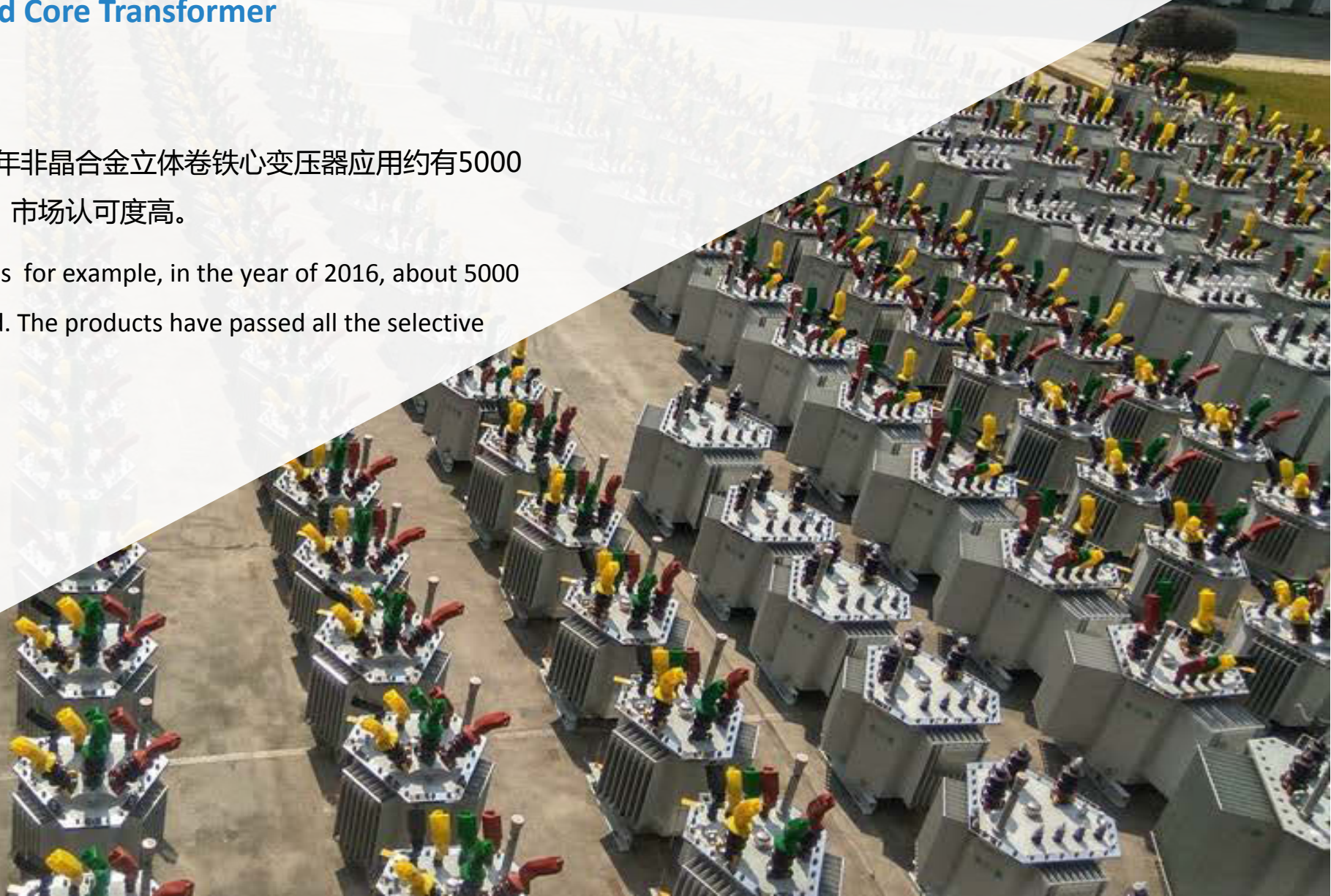





## 非晶合金立体卷铁心变压器 Amorphous Alloy 3D Wound Core Transformer

### 目前市场情况 Market Share

- 以南网广东、云南两省为例，2016年非晶合金立体卷铁心变压器应用约有5000台。产品经过多次抽检，全部合格，市场认可度高。
- Take Guangdong and Yunnan provinces for example, in the year of 2016, about 5000 transformers are sold to Southern Grid. The products have passed all the selective checks.





 非晶合金立体卷铁心变压器  
Amorphous Alloy 3D Wound Core Transformer

中国专利优秀奖 National Patent Award

- 非晶立体卷铁心油浸式变压器获得中国专利优秀奖。
- Patent of amorphous alloy 3D wound core oil-immersed transformer won as China excellent intelligent property.

第十八届中国专利优秀奖项目名单  
18<sup>th</sup> China intelligence property award list  
(568项)

序号	专利号	专利名称	专利权人	发明人
457	ZL201220241988.7	立体三角形结构的非晶合金变压器铁芯	海鸿电气有限公司	许凯旋, 郭献清



敞开式立体卷铁心干式变压器  
Open Ventilated 3D Wound Core  
Dry Type Transformer





### 敞开式立体卷铁心干式变压器 Open Ventilated 3D Wound Core Dry Type Transformer



- ▶ 立体卷铁心性能优点 3D Wound Core Performance Advantages
- ▶ 环保 Environmental Friendly
- ▶ 局放小 Lower Partial Discharge
- ▶ 绝缘等级高 High Insulation Level
- ▶ 耐候性能强 Strong Climate Resistance
- ▶ 防潮防尘 Anti-moisture & Dust-proof
- ▶ 防火 Anti-fire

 敞开式立体卷铁心干式变压器  
Open Ventilated 3D Wound Core Dry Type Transformer

**环保 Environmental Friendly**

- 生产工序简单，大部分材料采用可再生材料，线圈可分解回收处理，不会对环境造成危害。
- Production process is simple. Most of the material uses recyclable materials. The coil can be decomposed. It will not cause harm to the environment.





## 敞开式立体卷铁心干式变压器 Open Ventilated 3D Wound Core Dry Type Transformer

### 局放小 Small Partial Discharge

- 绝缘系统合理，材料可靠，铁心无尖角，局部放电量小于5pC。
- Reasonable insulation system; reliable material; core with no sharp corner. PD can be less than 5pC.

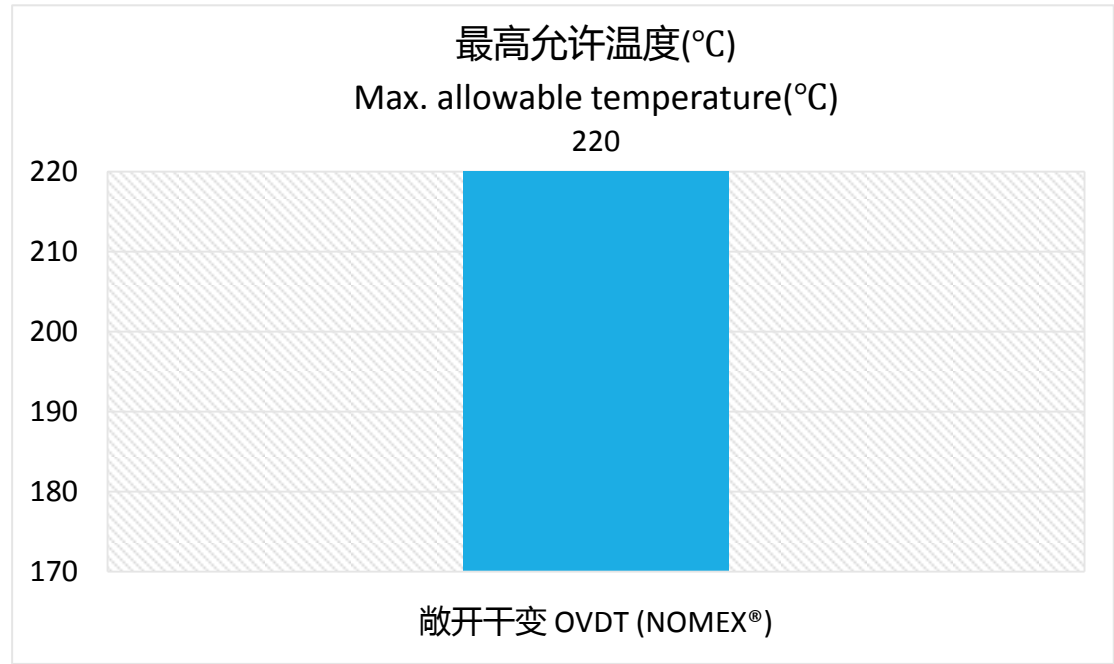




 敞开式立体卷铁心干式变压器  
Open Ventilated 3D Wound Core Dry Type Transformer

绝缘等级高 High Insulation Level

- 绝缘等级为R级，最高允许温度为220°C。采用饼式线圈结构，散热能力强。过载能力强。
- Insulation class R, maximum allowable temperature 220°C . Disc coil structure, strong heat dissipation ability. Overload capacity is strong.





## 敞开式立体卷铁心干式变压器

### Open Ventilated 3D Wound Core Dry Type Transformer

#### 耐候性能强 Strong Climate Resistance

- 采用德国艾伦塔斯绝缘漆与美国杜邦NOMEX<sup>®</sup>纸形成混合绝缘系统。产品整体浸漆，在高寒及温差大的运行环境下，线圈不龟裂。
- Insulation paint and the U.S. DuPont NOMEX<sup>®</sup> paper mixture insulation system, entirely VPI, enable the core and coils to cope with extremely freezing and horrid climate and free from cracking.

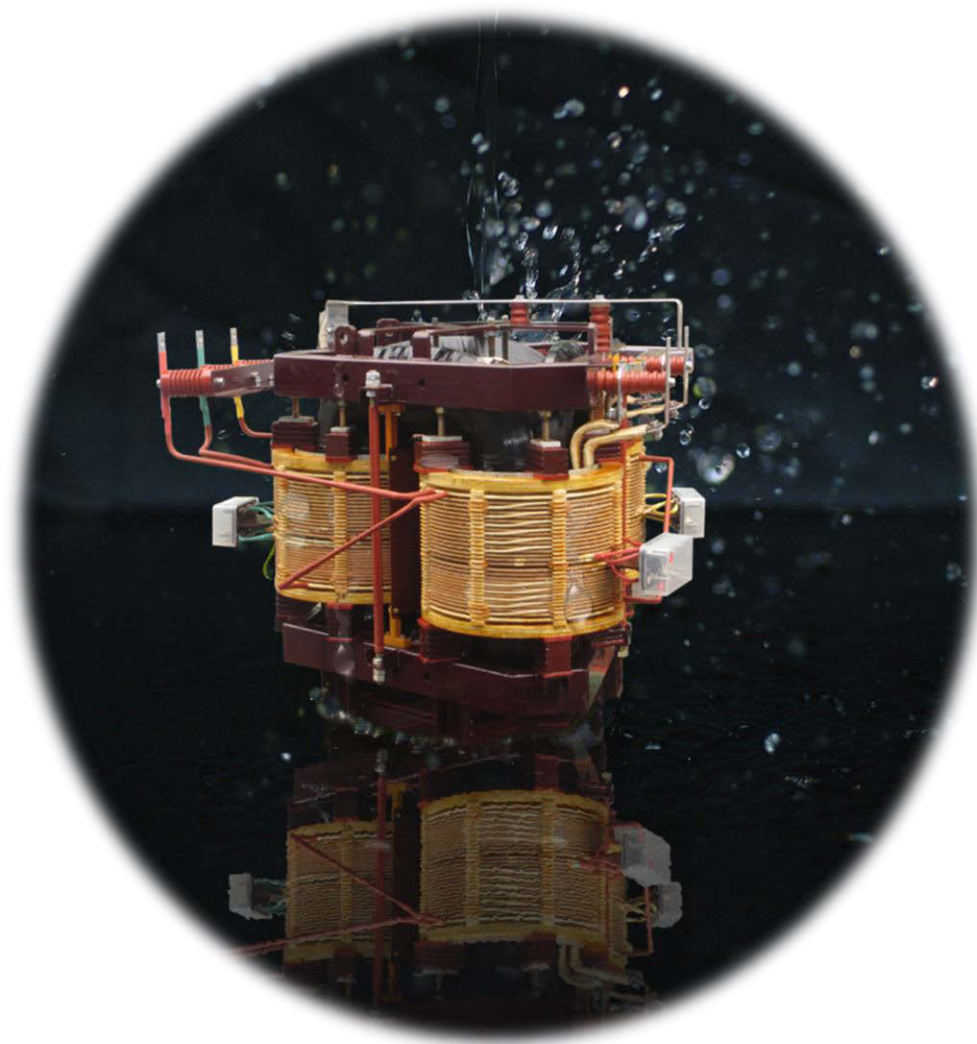




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防潮防尘 Anti-moisture & Dust-proof

- 产品进行极端受潮试验和污秽试验，绝缘性能仍十分可靠。
- Subject product to extreme damp and dusty tests. And the insulation performance is still reliable.



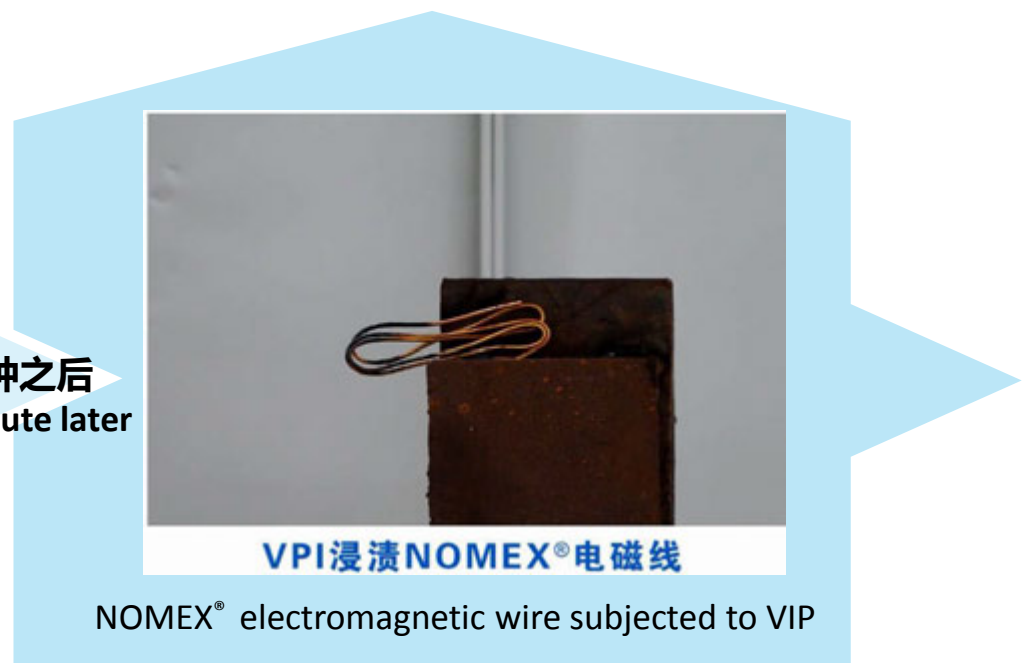
❖ 敞开式立体卷铁心干式变压器  
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防火 Anti-fire

- 绝缘纸耐热阻燃，在750°C以下不会释放出有害气体，更安全。
- Insulation paper is fire retarded. It will not release harmful gas below 750°C.



一分钟之后  
One minute later





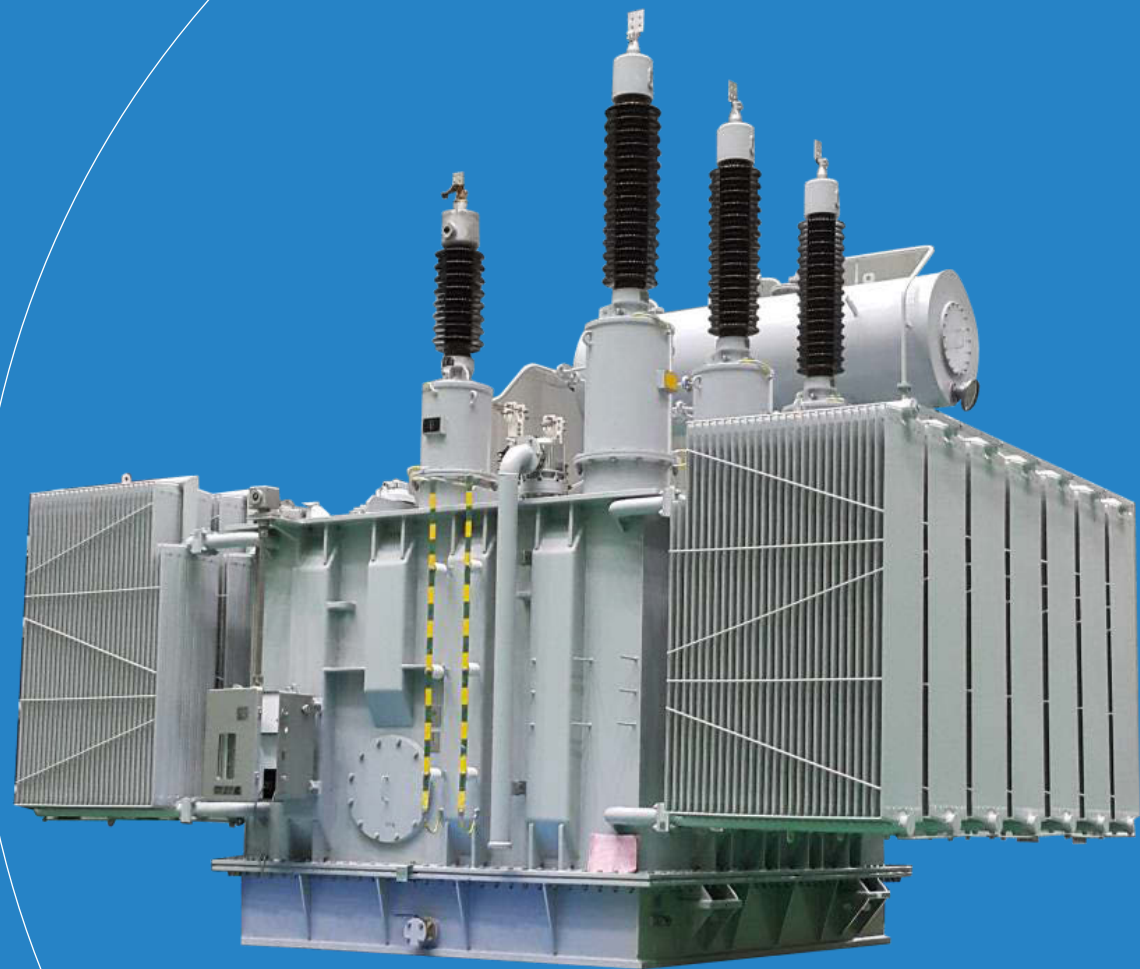
## 敞开式立体卷铁心干式变压器

### Open Ventilated 3D Wound Core Dry Type Transformer

- 敞开式立体卷铁心变压器获第五届绿色制造科学技术进步奖
- 3D OVDT Won the 5th Period Green Manufacturing Science & Technology Progress Award

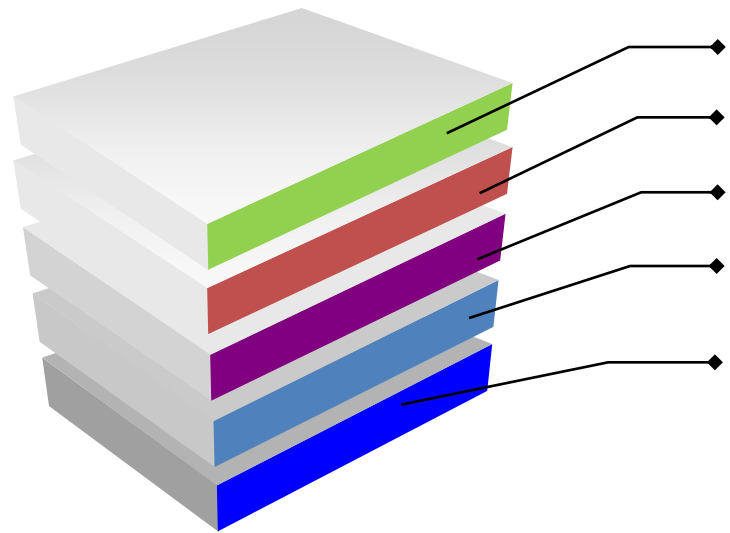


110kV立体卷铁心电力变压器  
110kV 3D Wound Core Power Transformer



 110kV立体卷铁心电力变压器  
110kV 3D Wound Core Power Transformer

优点 Advantages



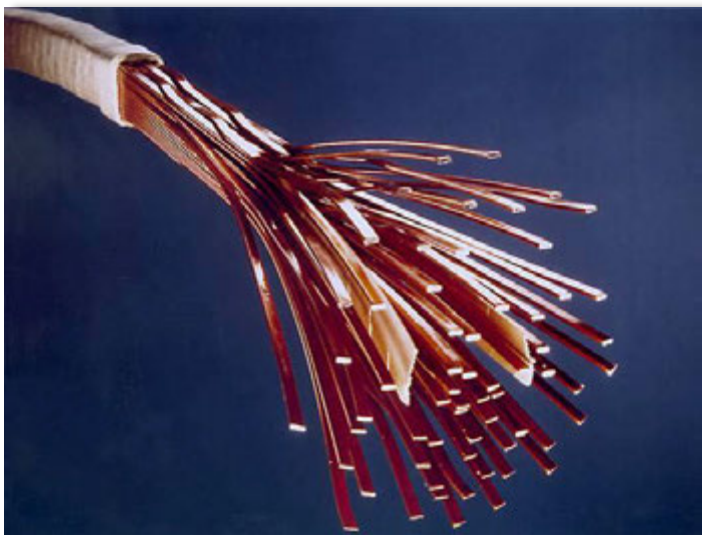
- 投入少 → 省钱 Small Investment → Cost-effective
- 损耗低 → 省电 Low Loss → Power Saving
- 噪音低 → 安静 Low Noise → Quiet
- 局放低 → 安全 Low Partial Discharge → Safe
- 电场磁场强度低 (漏磁小) → 环保  
Low EMC (Small Flux Leakage) → Environmental Protection





## 110kV立体卷铁心电力变压器 110kV 3D Wound Core Power Transformer

材料工艺双重保证 Material Technology Dual Assurance



- ✓ 低压线圈采用换位导线（自粘导线）
- ✓ Transposed Conductor Wire for LV Coil (Self-adhered Lead)



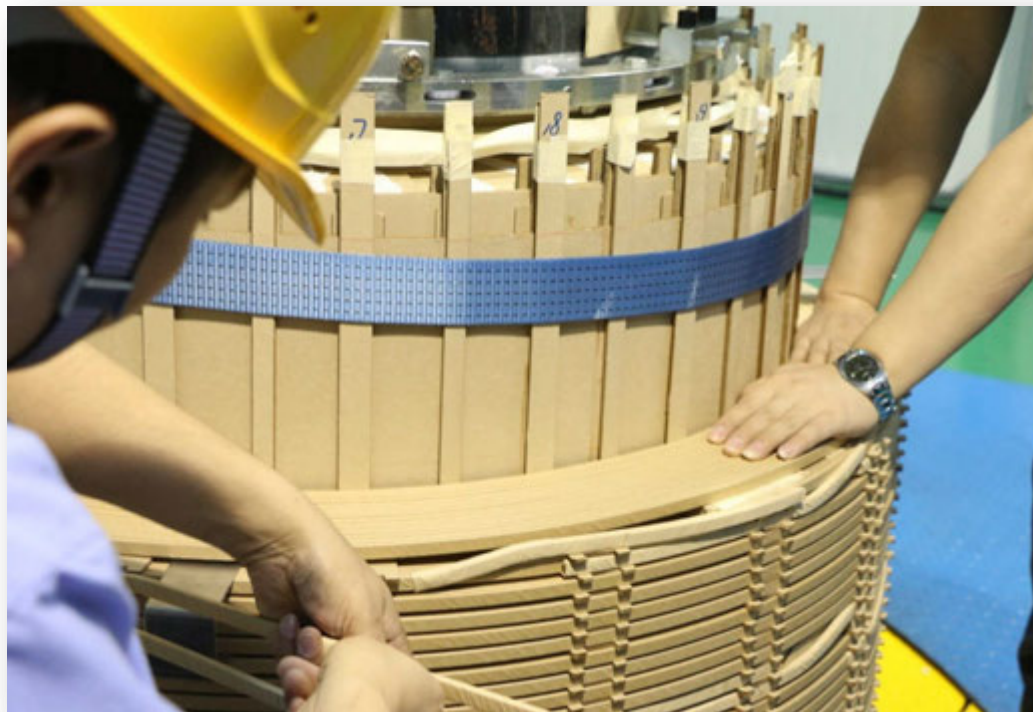
- ✓ 优良的线圈工艺
- ✓ Excellent Coil Winding Technique



 110kV立体卷铁心电力变压器  
110kV 3D Wound Core Power Transformer

**器身优势 Active Part Advantage**

- 线圈采用套绕工艺，消除线圈套装时所预留的工艺间隙。
- Winding adopts set-winding technique to cancel the technical gap reserved by winding sheath.

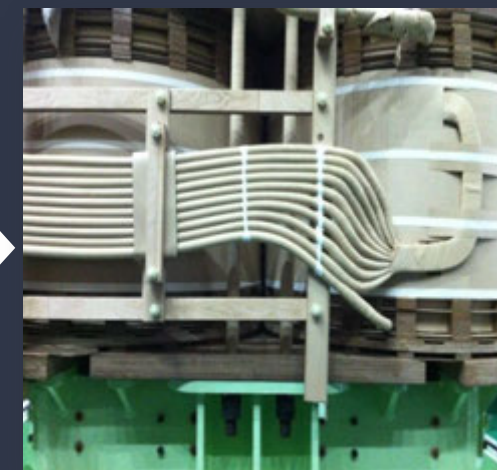




## 110kV立体卷铁心电力变压器 110kV 3D Wound Core Power Transformer

### 局放低 Low Partial Discharge

国家标准 Chinese National Standard	行业水平 Industry Level	立体卷铁心产品水平 3D Wound Core Product Level
300PC以内 Within 300PC	50 ~ 100PC	20PC以内 Within 20PC



- 铁心用硅钢带材卷绕而成，铁心没有尖角
- Core winded by silicon steel, no sharp corner

- 铁心经过高温退火消除毛刺
- Burr removed by high temperature annealing

- 合理的绝缘结构和优质的原材料为产品提供保障
- Reasonable insulation structure & excellent material



# 110kV立体卷铁心电力变压器 110kV 3D Wound Core Power Transformer

## 电磁场对环境的影响 EMF Impact to Environment

- 目前虽然没有强制要求，但电磁场的辐射已被居民高度关注。
- Currently there is no compulsive requirement for EMF radiation, but paid closed attention by resident.

国家标准 Chinese National Standard	行业水平 Industry Level	立体卷铁心产品水平 3D Wound Core Product Level
500nT	300 ~ 400nT	200 ~ 250nT



# Part Four

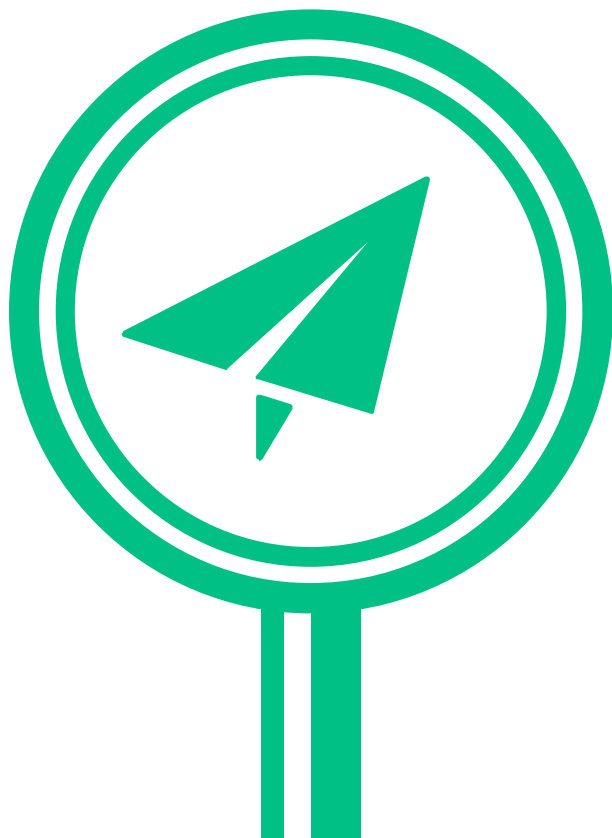
结语

Conclusion





## 结语 Conclusion



- 随着立体卷铁心技术的日益成熟，其节能减排的优势愈发突出。立体卷铁心技术的发展进步，定为中国乃至世界的节能环保事业作出更大贡献。
- 3D wound core is becoming perfect with its more obvious advantages of energy-saving emission reduction. The developing technology will make greater contributions to China and the world on energy-saving emission reduction activity.

# 谢谢聆听

THANK YOU FOR YOUR ATTENTION

