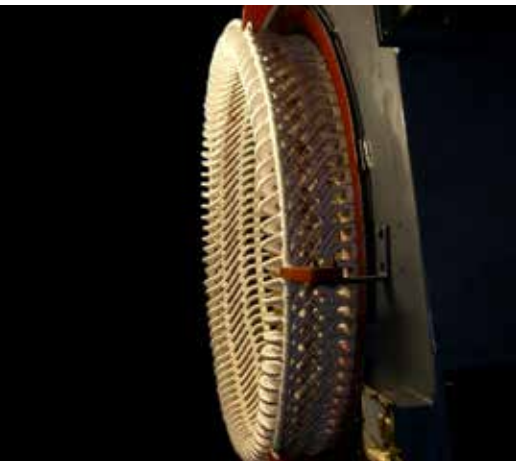
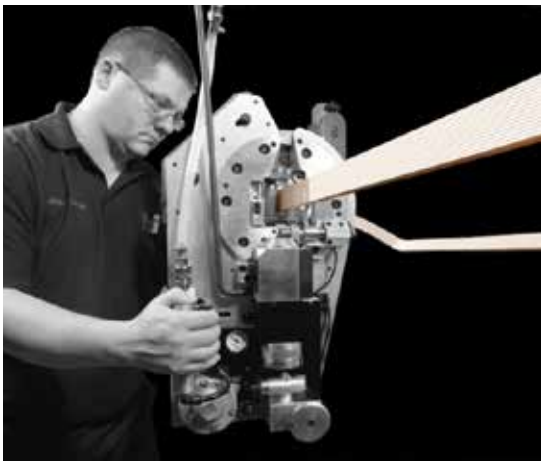
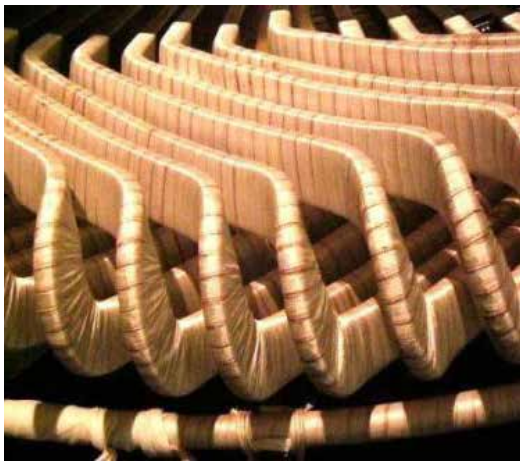
Houghton International
High Voltage Coils

Global Manufacturing Specialists

CASE STUDY:

Ainsworth Inc, Canada

6.8MW Hydro Rewind

"Our completion schedule for the project was on a very short time line so the delivery of the 256 coils was critical.

Houghton International supported us throughout the project from the original coil measuring process all the way to delivery of the final shipment.

The coils were manufactured as per our dedicated needs and were very easy to work with. The stator fit was good and the best feature was that the end turns were flexible where the slot section was fully cured."

John Herrington, *Business Manager*

WELCOME

Houghton International is the UK's leading manufacturer and supplier of specialist high voltage coils for the global market.

With over 30 years' of manufacturing and repair experience, we offer:

- Supply and manufacture of premium high voltage coils and auxiliary winding kits
- Specialist electro mechanical engineering support
- Computer aided design, performance upgrade and reverse engineering capabilities
- Worldwide in situ support services

We have recently completed a major investment programme and our new dedicated High Voltage / High Tension coil manufacturing facility comprises state of the art technology to produce a comprehensive range of coils to meet increased global demand from repairers and original equipment manufacturers (OEMs).

We pride ourselves on our attention to detail, providing a high quality product and the highest level of customer service. We understand the needs of repairers, OEMs and their customers because we are also repairers ourselves. We keep our customers updated through on-going dialogue and reporting. Through our specialist skilled staff we provide a personal, focused, fast and efficient, customer needs driven service. We deliver on time and to budget.

Through our commitment to innovation and culture of continuous improvement, we have developed unique insulation systems to provide our customers with the bespoke coils they require. This includes HiFLEX™, our world leading fully cured, totally flexible insulation system.

Our quality assurance model, accredited to ISO 9001:2008, is designed around the requirements of each individual type of coil, meaning we create a dedicated quality management system bespoke to each individual product. This process consistently produces industry leading insulation systems.

We listen to our customers and provide the expertise and knowledge to tailor the optimum solution for their application. That's why our customers keep coming back to us.

Please contact us to learn how we can add value to your next project.

Michael Mitten
Chief Executive Officer

everyone matters

OUR EXPERTISE
OUR PEOPLE
OUR QUALITY

TECHNICAL CAPABILITY & CAPACITY

We manufacture coils up to 15kV with the capability for diamond coils up to 6.4 meters (21ft) in length knuckle to knuckle, 4.5 meters (14.10ft) slot pressing capabilities and a span of 1.82 meters (6ft).

Experienced in the manufacturing of half bar systems, which are used in the winding of turbo generator machines up to 70 MW.

Computer Aided Design (CAD) function.

A comprehensive range of:

- Automated shaping machines
- Electrically heated hydraulic presses

ON-SITE FIELD REWIND SERVICES

Through a team of specialist pre-formed winding technicians we are able to support our customers by carrying out rewinding projects in their facilities or on-site on a global basis.

TESTING

In-house testing facility; lamination, turn to turn, tan-delta & tip up and hi-pot. All coils are produced to meet the relevant electrical standards, such as BS EN 60034, BS EN 50209, BS EN 60207 and IEEE 1553 & 1043. We can also test to customers specific criteria if required.

WINDING MATERIAL KIT

Winding forks are manufactured to suit each set of coils. These are supplied to assist with the safe insertion of the coils into the slots of the stator.

QUALITY ASSURANCE

Houghton International operate in sectors where quality procedures and the safety of equipment are critical.

As such we have developed a rigorous quality policy with processes and procedures to ensure that everything we do is of the highest standard. These policies and procedures are reviewed across all areas of the business on an on-going basis which reflects our culture of continuous improvement.

Quality assurance checks are conducted at each stage of the manufacturing process.

Our quality management system is accredited to BS EN ISO 9001:2008, electrical tests to BS EN 60034.

All coils are individually quality assurance checked prior to dispatch. As part of our commitment to total quality assurance and the development of our supply chain we have strong established relationships with our suppliers.

Our occupational health and safety management system is accredited to OHSAS 18001:2007.

PACKAGING AND SHIPPING

All packaging conforms to recognised international standards. All coils are delivered in made to measure packaging incorporating a foil vacuum sealed bag system inside a moisture proof wooden crate.

A panel of freight forwarders is used to ensure the most competitive global shipping by sea or air.

DOCUMENTATION

All export documentation, airway and seaway bills are supplied along with commercial invoices, packing lists and manufacturers test certificates.

If required we can raise Certificates of Origin directly from the local Chamber of Commerce.

OUR PEOPLE

We recognise that people are our most important asset. We have a highly skilled team that successfully combines youth with experience.

We employ for attitude and train for skill. We aim to be the employer of choice for talented people and invest in them to ensure that they have the opportunities to develop. In return we expect loyalty, a total focus on our customers' needs, delivery to deadlines and commitment to our total quality process.

We are totally committed to our apprentice programme. 14% of employees are apprentices undergoing a four year structured programme and upon successful completion there will be further opportunities of on-going personal development in addition to career progression within the company.

At Houghton International 'everyone matters'.

WHAT MAKES A PREMIUM HIGH VOLTAGE COIL?

There are two fundamentally different insulation systems ranging across almost all types of high voltage (HV) rotating electrical machines.

Vacuum Pressure Impregnation (VPI) which requires the main insulation of epoxy, polyester or silicone resin to be introduced to a winding after coil insertion inside a pressure chamber. The impregnated stator is then baked in an oven to cure the resin, thus completing the insulation system. The machine is then fully tested at high voltage to ensure dielectric integrity and compliance to international repair standards, i.e. BS EN ISO 60034.

Resin rich insulation technology, for which a high quality epoxy resin insulation is applied and consolidated during the coil manufacturing process. This means the individual coils and the connected winding are fully tested thus guaranteeing the individual dielectric integrity of each HV coil.

There are many differing schools of thought on which system is the most appropriate.

This view depends on experience, personal preference, manufacturing cost, verified technical data, whether the machine is being built new or is undergoing repair and the application, such as pump or alternator.

VPI systems can offer an improved degree of sealant against moisture ingress and, arguably, heat dissipation compared to resin rich coils. However, there are questions against consistency of impregnation throughout the slot portion of a VPI coil giving rise to concerns about Corona Discharge undermining the insulations system's integrity.

INSULATION SYSTEM

The insulation system of a HV motor or alternator is critical in terms of its performance, longevity and value as an investment to the asset owner. Selecting the appropriate insulation requires consideration of application, circumstance, atmospheric condition and geographic location.

Houghton International has developed a range of systems that cover the broad scope of requirements faced by our expanding customer base.

CORONA DISCHARGE PROTECTION

Corona Discharge is an electrical phenomenon created by the ionization of air around a conductor as a side effect of an electric field with a high potential gradient or strength.

In high voltage rotating machines, Corona activity is present at 6600V and above, increasing in intensity and severity as the machine's potential gradient rises. The protection against Corona Discharge and its adverse debilitating effects on a winding's insulation is what governs the design concept and features of a premium HV coil.

Every HV coil should posses a conductive outer layer which grounds the coil in the slot. It should also feature a stress grading system which protects the coil as it leaves the slot, where the potential gradient is at its greatest and Corona activity is therefore most intense.

TAN δ / TIP UP

Tan δ and Tip Up is the accepted measure of a premium HV coil. What is measured is the AC power factor involved in the passage of AC leakage current through the insulation wall.

This measures the air gaps or void content in a cured HV coil. This measure is taken using a Schering bridge rectifier, which quantifies the capacitive content of insulation through the slot portion of the coil.

Most standards require only a sample percentage of coils out of an entire coil set to be tested. However, we advise testing the entire coil set in order to ensure dielectric integrity and machine longevity.

FIT

When describing fit we refer to how closely together the coil fits into the stator slot. Any area of the slot section that is not ground leaves an air gap, meaning Corona Discharge activity will occur above 6600V.

Variances in fit promote Corona activity, hence our coils are manufactured to +/- 0.15mm across the length of the coil cell.

By applying the semiconductive coating to the surface, a good coil to slot fit will ensure an acceptable number of points of contact between the two. This will bring the entire surface of the semiconductive coating essentially to ground potential thereby preventing the possibility of partial discharge. To achieve this, we usually work to a surface resistivity in the range of 2 to 20 KΩ/square. If the resistivity is too high, a proper circuit will not be established and if it is too low, the stator laminations will become shorted. This material usually extends axially by 1 inch (25 mm) or more beyond the core.

Hot pressed resin rich slot sections guarantee such a fit, where VPI systems rely on sufficient resin penetration to ensure the main wall is adequately ground.

SHAPE CONSISTENCY

Shape consistency is a critical feature because the more fitting the shape of the coil, the less mechanical stresses are placed on it during the insertion process.

Shape consistency is critical because across a significant number of coils, if the shape is out, the engineer can lose the space available, which creates many problems, not least placing further adverse stresses that can increase the likelihood of failure.

Houghton International's tried and tested methods of controlling shape consistency have underlined our value to the people who work with our products.

DIELECTRIC INTEGRITY

Routine electrical tests are carried out according to BS EN 60034, BS EN 50209 and IEEE 286.

Typical routine testing regimes:

- Surge comparison or turn to turn test: 2(U+ 1000)
- Tan δ / Tip Up (to various standards).
  Measured at intervals of 0.2 U_N
  Loss tangent maximum increment = 5 x 10^{-3}
- Hi-pot (AC flash) test ($2U_N$ + 1000)1.2
- Lamination test
  (when there are multiple conductors / turn) @ 240vAC
- Measure surface resistivity of the coil semiconductive coating to a range of 2 to 20 KΩ/square.

INDEPENDENT TESTING

Criteria

HiFLEX™ coils were subjected to the following tests by a leading independent Canadian testing laboratory, with satisfactory results:

- Visual inspection and tap tests on the coils before and after VE test
- Partial discharge (PD) analysis at 7.3kV before the VE tests, as per IEEE Standard 1434-2000
- Dissipation factor (DF) measurements as per IEEE Standard 286-2000 from 2kV to 16kV in 2kV steps before the VE test
- Turn to turn insulation test before VE test as per IEEE Standard 522-2004
- Voltage endurance test as per IEEE Standard 1043-1996 at 31.7kV, 90°C for 500 hours
- Dissection and microscopic examination of coil after VE test
- Insulation thickness measurements of one coil after VE test

Results

Turn Insulation Test complied to:

- As per IEEE Standard 522-2004
- 5 successive voltages were applied to the coils with both polarities before the VE test

Voltage Endurance Test

- Coils were satisfactorily subjected to an accelerated insulation-ageing program
- As per IEEE Standard 1043-1996 and IEEE Standard 1553-2002
- Test parameters were 31.7kV at 90°C for 500 hours
- Both coils passed the 250 hours required by IEEE 1553. Coil 1 passed by 161% and coil 2 passed by 182%

SELECTING YOUR INSULATION SYSTEM

Insulation System:		HiBRID™	HiFLEX™	HiRES™	HiVAX™
Description		Resin rich hot pressed cell incorporating VPI accepting material applied to the coil extensions	Resin rich hot pressed cell incorporating fully cured flexible coil extensions	Resin rich hot pressed cell incorporating B stage material applied to the coil extensions	Green coil requiring full VPI impregnation
Voltage Range @ 50Hz	≤ 3,000V	✓	✓	✓	✓
	≥3,000V ≤ 6,000V	✓	✓	✓	✓
	≥ 6,600V ≤15,000V	✓	✓	✓	✓
Guaranteed Flexibility		✓	✓		✓
Full Corona Protection on Coils ≥ 6,000V		✓	✓	✓	✓
Guaranteed Storage Life Under Approved Conditions			✓		
Optional Tropical Climate Protection			✓	✓	
Guaranteed Tan δ / Tip Up Integrity		✓	✓	✓	
Thermal Performance: Class F155°C		✓	✓	✓	✓
Class F155°C		✓	✓	✓	✓
Class H180°C					✓
Class C220°C					✓
Surge Comparison or Turn To Turn Tested To $2U_N$+ 1000V		✓	✓	✓	✓*
AC Flash Tested To $(2U_N + 1000)1.2$		✓	✓	✓	
Moisture Proof Capability		✓	✓	✓	✓
Oven Baking Required To Cure		✓		✓	✓
Fully Cured Before Insertion			✓		
Tested Before Dispatch		✓	✓	✓	✓

* Voltage may depend on turn insulation material and coil specification.

Insulation System:		HiBRID™
Description		Resin rich hot pressed cell incorporating VPI accepting material applied to the coil extensions
Voltage Range @ 50Hz	≤ 3,000V	✓
	≥3,000V ≤ 6,000V	✓
	≥ 6,600V ≤15,000V	✓
Guaranteed Flexibility		✓
Full Corona Protection on Coils ≥ 6,000V		✓
Guaranteed Storage Life Under Approved Conditions		
Optional Tropical Climate Protection		
Guaranteed Tan δ / Tip Up Integrity		✓
Thermal Performance: Class F155°C		✓
Class F155°C		✓
Class H180°C		
Class C220°C		
Surge Comparison or Turn To Turn Tested To $2U_N$+ 1000V		✓
AC Flash Tested To $(2U_N + 1000)1.2$		
Moisture Proof Capability		✓
Oven Baking Required To Cure		✓
Fully Cured Before Insertion		
Tested Before Dispatch		✓

HiBRID™

Our unique insulation system combining the merits of VPI and resin rich technology

HiBRID™ is a fully testable and flexible system pre VPI, and a fully waterproof system post VPI.

It guarantees the virtues that both VPI and resin rich technology offer, with the drawbacks of neither.

Our experience showed inherent electrical failures occurred inside the slot of VPI machines, leaving a life expectancy of roughly 5 – 6 years.

However, resin rich systems acted in reverse. The life expectancy was longer but the failures occurred in the outhang (coil extension) rather than inside the slot.

HiBRID™ comprises a hot pressed resin rich cell, scarfed into a VPI accepting outhang (coil extension), providing:

- Guaranteed slot fill
- World leading tan delta figures
- Excellent flexibility
- All coils are fully testable prior to varnishing

Insulation System:		HiFLEX™
Description		Resin rich hot pressed cell incorporating fully cured flexible coil extensions
Voltage Range @ 50Hz	≤ 3,000V	✓
	≥3,000V ≤ 6,000V	✓
	≥ 6,600V ≤15,000V	✓
Guaranteed Flexibility		✓
Full Corona Protection on Coils ≥ 6,000V		✓
Guaranteed Storage Life Under Approved Conditions		✓
Optional Tropical Climate Protection		✓
Guaranteed Tan δ / Tip Up Integrity		✓
Thermal Performance: Class F155°C		✓
Class F155°C		✓
Class H180°C		
Class C220°C		
Surge Comparison or Turn To Turn Tested To $2U_N$+ 1000V		✓
AC Flash Tested To $(2U_N + 1000)1.2$		✓
Moisture Proof Capability		✓
Oven Baking Required To Cure		
Fully Cured Before Insertion		✓
Tested Before Dispatch		✓

HiFLEX™

Our world leading, fully cured, totally flexible insulation system

HiFLEX™ is a fully cured film / mica paper / film tape with unidirectional glass to enhance mechanical characteristics, bound with an acrylic resin.

- Coils are fully tested at point of manufacture guaranteeing dielectric integrity
- Coils can then be step-down tested before being inserted and throughout the repair process
- HiFLEX™ coils are fully cured but totally flexible in the end-winding (coil extension)
- Requires no baking after winding
- Requires no varnishing or impregnation
- Guaranteed storage life – the coils are fully cured so they cannot change state in storage
- Coils are supplied in a vacuum packed, moisture proof bag inside a heavy duty wooden crate as standard
- Class F 155°C as standard > 6.6kV
- Allows total flexibility in its endwinding (coil extension), which can remain flexible for the machine's cycle
- Guaranteed flexibility of the coils, which is ideal for large two-pole windings, rewinding in situ and for skewed alternator coils

Insulation System:		HiRES™
Description		Resin rich hot pressed cell incorporating B stage material applied to the coil extensions
Voltage Range @ 50Hz	≤ 3,000V	✓
	≥3,000V ≤ 6,000V	✓
	≥ 6,600V ≤15,000V	✓
Guaranteed Flexibility		
Full Corona Protection on Coils ≥ 6,000V		✓
Guaranteed Storage Life Under Approved Conditions		
Optional Tropical Climate Protection		
Guaranteed Tan δ / Tip Up Integrity		✓
Thermal Performance: Class F155°C		✓
Class F155°C		✓
Class H180°C		
Class C220°C		
Surge Comparison or Turn To Turn Tested To $2U_N$+ 1000V		✓
AC Flash Tested To $(2U_N + 1000)1.2$		✓
Moisture Proof Capability		✓
Oven Baking Required To Cure		✓
Fully Cured Before Insertion		
Tested Before Dispatch		✓

HiRES™

Our B-stage end winding solution

HiRES™ is our insulation system that comprises a hot-pressed B-Stage Epoxy cell scarfed into a calcined mica and B-Stage end winding (coil extension).

HiRES™ has excellent windability. However, rewinders or manufacturers in tropical areas should consider the HiFLEX™ system.

Our B-Stage cell provides the highest quality and windability.

HiRES™ provides industry leading tan delta figures.

Insulation System:		HiVAX™
Description		Green coil requiring full VPI impregnation
Voltage Range @ 50Hz	≤ 3,000V	✓
	≥3,000V ≤ 6,000V	✓
	≥ 6,600V ≤15,000V	✓
Guaranteed Flexibility		✓
Full Corona Protection on Coils ≥ 6,000V		✓
Guaranteed Storage Life Under Approved Conditions		
Optional Tropical Climate Protection		
Guaranteed Tan δ / Tip Up Integrity		
Thermal Performance: Class F155°C		✓
Class F155°C		✓
Class H180°C		✓
Class C220°C		✓
Surge Comparison or Turn To Turn Tested To $2U_N$+ 1000V		✓*
AC Flash Tested To $(2U_N + 1000)1.2$		
Moisture Proof Capability		✓
Oven Baking Required To Cure		✓
Fully Cured Before Insertion		
Tested Before Dispatch		✓

* Voltage may depend on turn insulation material and coil specification.

HiVAX™

Our unique rewinding system

HiVAX™ is our Vacuum Pressure Impregnation (VPI) insulation system.

VPI technology offers a range of benefits compared to resin rich systems, including improved sealant against moisture ingress and greater heat dissipation.

VPI technology works at higher ambient temperatures if a silicone-based resin is used for impregnation.

Resin rich technology hits a temperature plateau at Class F, whereas VPI technology has the ability to go up to a working Class C or 220°C.

HiVAX™ is ideal for AC traction windings and all machines working at high temperatures.

HiVAX™ is recommended for short lead times as there are no pressing times, so reducing the production process.

WHAT OUR CUSTOMERS SAY

LOUIS ALLIS, USA

"Louis Allis would like to thank Houghton International for the exceptional high voltage coils you provided our company on a critical job. A complete set of your 13,800V HiFLEX™ series coils were used on a 1,250kW generator rewind that was performed here in the States.

The coils were very easy to work with. The stator fit was good and the best feature was that the end turns were flexible where the slot section was fully cured. This is the first time we have ever seen this. Most 13,800V coils are fully cured, requiring special care so as to not flex or bend the coil in any manner. These were exceptional coils. We look forward to future work with Houghton International and plan on coming to your company for future needs in high voltage coils."

Keith Hancock, Inside Sales

ROLLS-ROYCE, UK

"The diligence, innovation and timeliness applied to the conduct of this contract has assisted Rolls-Royce enormously in what is an exceptionally challenging development motor programme and your teams contribution cannot be underestimated."

Nicky Moore, Senior Procurement Engineer

SHERMCO INDUSTRIES, USA

"The things I appreciated about the last HiFLEX™ coil order was the responsiveness from the point of ordering all the way to shipment. The coil construction was consistent. The slot section of the coil was spot on.

The package/crate was secure as well. I have seen many sets of coils have damage during shipment but I see no damage incurred during shipment. The delivery time was excellent."

Billy Higgs, MSD Shop Manager

BRUSH AFTERMARKET, UK

"Brush Aftermarket would like to confirm that Houghton International have manufactured and supplied more than 12 sets of half bar coils for generator sets above 40 MVA and 13.8KV."

Loyd Perkins, Project Manager

AVONMORE ELECTRICAL, IRELAND

"Avonmore have being rewinding high voltage machines for over 20 years with no failure. The reliability of the coils is non-negotiable – they must be right.

We came across Houghton International through our membership of EASA .We recently moved from a long standing supplier based on price, but more importantly, reassurance that quality would be right.

We have now used 3 sets of HiVAX™ preformed coils for a Siemens 600Kw motor rated at 6.6Kv and the feedback from the winders is excellent. The coil fits are excellent, with technical back-up to match. Paperwork is thorough, and delivery times have been on time. We congratulate Michael and his team on a great service."

Derry Sheehan, Managing Director

LANNE ELEKTRISKE VERKSTED, NORWAY

"Following our latest order, I am writing to express my praise for the sets of HiFLEX™ coils manufactured for us by Houghton International. The quality of the coils was of the highest standard and they were delivered on time within secure packaging.

We highly value the support from their engineers who are willing to visit us at short notice to help us view or rewind jobs on-site here in Norway when we require additional labour to meet our customer's urgent delivery requirements."

Terje Lanne, Owner

Houghton International
High Voltage Coils

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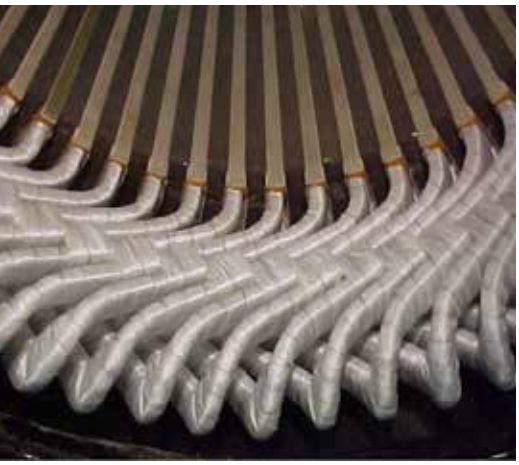
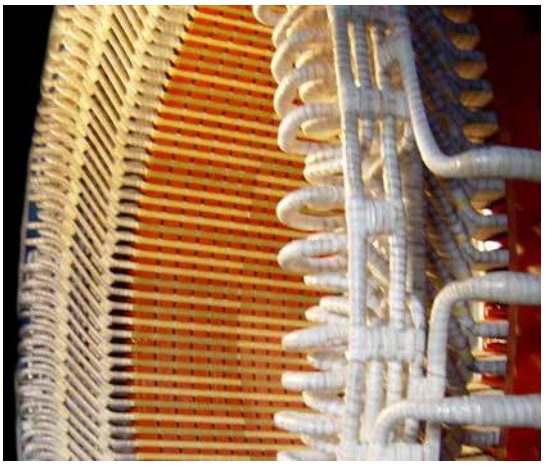


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