



# Insulating Systems for Traction Motors

**vonRoll**

# We Enable Energy

As one of the oldest industrial companies in Switzerland, founded in 1803, we focus on products and systems for power generation, transmission and distribution, rotating machines and mechanical engineering. Von Roll is the global market leader for insulation products and the only company to offer the complete range of insulation products, composites, consulting, tests and services for the electrotechnical industry.

For more than 100 years, we have been making outstanding contributions to this market, developing a number of highly innovative products that have enabled both steady increases in power output and smaller and more compact machines.

## Customers enjoy the following benefits:

- » One single source for all insulating materials
- » Thorough expertise from power generation and transmission to its efficient utilization
- » Proven compatibility for system components
- » Testing at Von Roll of both materials and systems
- » Consulting for applications and technologies
- » Training in insulation materials and systems

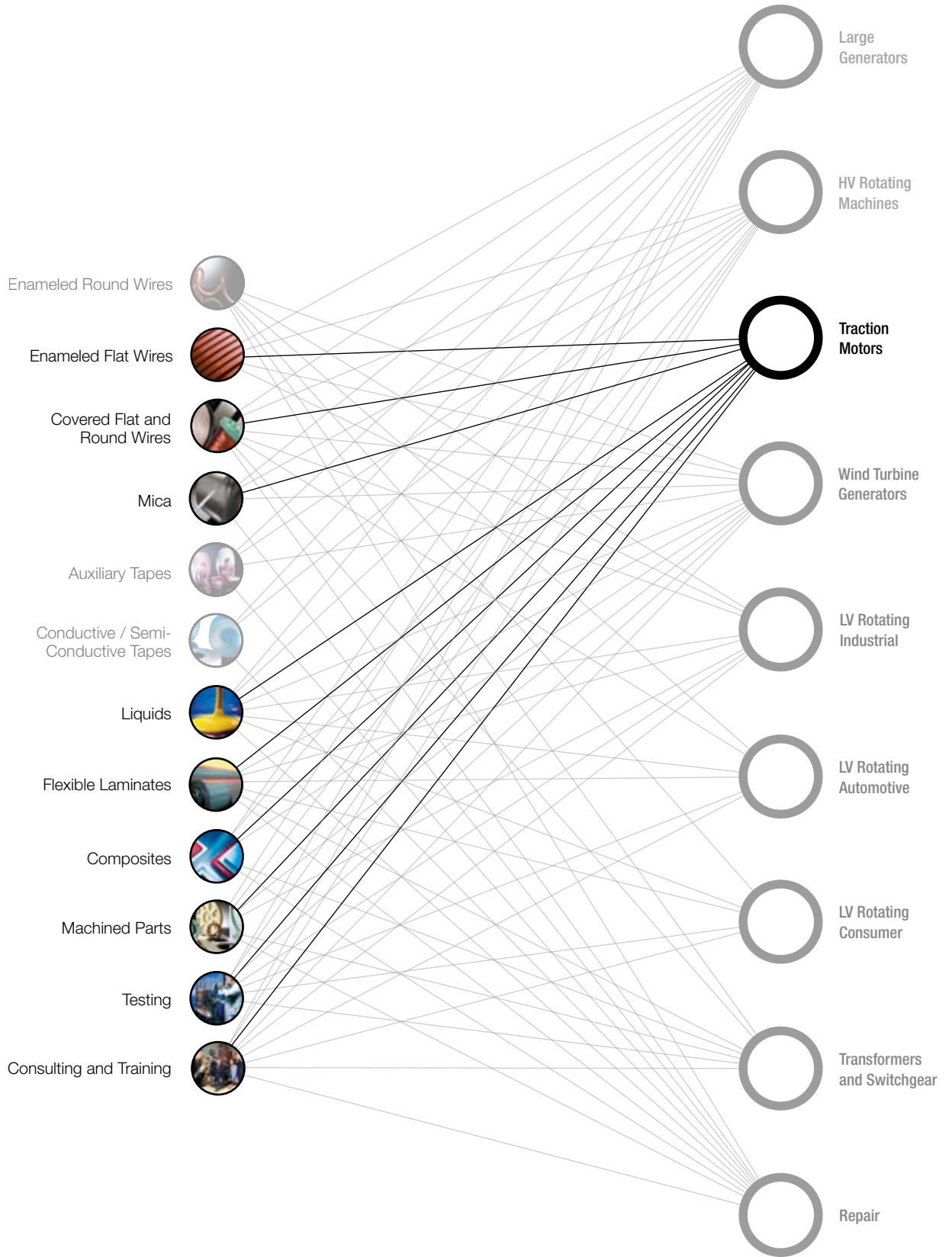
Von Roll continues to be actively involved in helping manufacturers to reduce costs and to meet the continuing demand for increased efficiency and power-to-weight ratio of traction motors. As the original material manufacturer for your particular insulation system, we have materials to meet all of your insulation requirements, for both resin-rich (RR) and vacuum pressure impregnation (VPI) technologies.

These motors power railway locomotives, multi-unit trains, trams and metros, and smaller vehicles such as automobiles, operating at voltages as high as 3.3 kV with power output up to 1800 kW. The need to minimize weight leads to highly compact designs, necessitating extreme operating temperatures and elevated electric stress, all under varying loads in harsh environments. In addition to carrying the full range of specialized insulation products, Von Roll has developed key materials to help manufacturers meet these trends:

- » Enamel and glass conductor insulation as a competitive alternative to polyesterimide film
- » Polyesterimide impregnation resins to bridge the gap between silicone and other resins
- » Kevlar-reinforced banding tapes



# Our Products for Traction Motors



Von Roll offers full system solutions for every market shown in this application tree. Please contact us or visit our website [www.vonroll.com](http://www.vonroll.com) for further information.

## A Variety of Insulation Systems

Von Roll has been continuously involved in the multiple insulation changes that have taken place in the last decades. The increasing availability of reliable and efficient power electronics created a strong trend in certain regions toward converter-driven AC induction motors. From a global view, both DC machines and inverter-driven AC induction machines are in production.

The insulation systems preferred by various manufacturers of traction motors may be categorized based on the machine type and on the design of the main-wall insulation:

- » The armature windings may be located on the rotor, as in DC machines, or on the stator, as in AC machines
- » The insulation may employ vacuum-pressure impregnation (VPI) or resin-rich (RR) technology
- » The main-wall insulating resin may be based on silicone, unsaturated polyesterimide, epoxy or polyester.

There is a considerable diversity of insulating materials available to fill the many requirements of the variety of traction-motor designs.

Application	Insulating material	DC motors	AC motors
Conductor insulation	Enamel + glass, enamel + glass & polyester, or polyimide film	•	•
Main insulation	Mica tapes, polyimide film	•	•
	Woven glass tapes	•	•
	Impregnating resin	•	•
Slot wedging	Slot liner	•	•
	Slot wedges rotor	•	
	Slot wedges stator		•
Overhang bracing	Overhang rings		•
	Ropes		•
	Filler between coils	•	
Commutator	Segment plates	•	
	V-rings	•	
Armature reinforcement	Banding tapes	•	

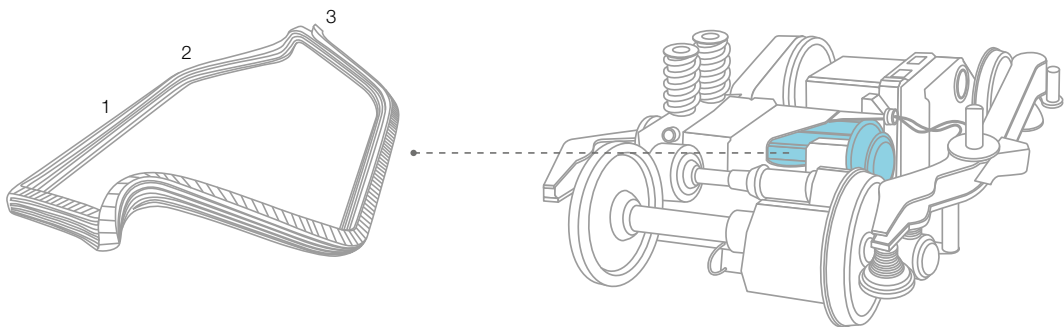




## Winding Wires

The high-stress operation of traction motors means that the winding-wire insulation is anything but trivial. The choice is affected by increase due to insulation, thermal performance, mechanical robustness, dielectric strength, ability to bind with the impregnation resin and in some cases resistance to partial discharge. Whatever your decision, Von Roll can provide the quality you require.

	Increase due to insulation (mm)	TI, °C	Mechanical properties	Corona resistance
Enamel + glass (Silix)	0.23–0.32	155 180 200	medium	medium
VS 220 VF	0.15–0.19	220	very good	medium
FEP-coated polyimide film (1 layer half-lapped)	0.15–0.19	240	low	low
FEP-coated polyimide CR film (1 layer half-lapped)	0.15–0.19	240	low	good
VS 240 VF	0.15–0.19	240	very good	medium
VS 240 V (P)	0.20–0.25	240	very good	medium
FEP-coated polyimide film (1 layer half-lapped + glass)	0.30–0.35	240	good	medium



1. Enamel + glass VS240 V; 2. Samicapor® 366.86; 3. Damisol® 3551



## VPI Tapes

Von Roll is highly committed to mica. Our added value is visible throughout the complete manufacturing chain. It starts by mining, preparation of the mica scrap, preparation of the mica paper pulp, production of mica paper and finally production of mica tapes that can be used to the highest standards to make mainwall insulation.

Von Roll has the right solution to improve the quality and cost-effectiveness of the mainwall insulation needed for your traction applications.

With Samicapor®, Von Roll has designed a range of outstanding VPI mica tapes that fulfill the requirements of mainwall and endwinding insulation, namely:

- » High dielectric strength
- » High thermal performance
- » Corona discharge resistance
- » Fast and easy impregnation
- » Resin retention without draining
- » Smooth application without creasing
- » Both manual and fast-running machine application
- » Full compatibility with predefined resin systems



Von Roll's commitment to mica starts with mining and stops with the production of mica-taped wires.



## VPI Resins

The resin is essential in determining the thermal performance of traction motors, but the choice of resin is complex and depends on a number of factors. There are several critical parameters, including:

- » Temperature resistance up to 220°C and above
- » Thermal shock
- » High reliability linked to the high thermal class needed
- » Weather conditions
- » Chemical resistance

We offer a variety of high-performance resins to cover your selective needs, whose performance can be optimized through selection of the compatible Von Roll mica tape, as previously described.



## Mainwall Insulation Systems for VPI

Present main-wall insulation in terms of systems – integrating tapes and resins – organized by thermal class: VPI epoxy and polyester, polyesterimide (Samicabond) and silicone (plus RR silicone in next section).

### Epoxy and polyester systems for class 155 designs

	Thickness mm	Total weight g/m <sup>2</sup>	Samica® g/m <sup>2</sup>	Resin compatibility and thermal class	
				Epoxy	Polyester
Samicapor® 366.53-01	0.12	153	120	F	F

Resin reference	DC motors	AC motors	Thermal class	Description
Permafil® 74041	•		155	highly thixotropic epoxy resin (high film build) with good thermal properties; no volatile organic compounds (VOC)
Damiso® 3412-1	•		155	extremely reactive, two-component epoxy resin system; no VOC
Damiso® 3500 LoV	•		155	low-viscosity, one-component epoxy resin with good thermal properties; no VOC

### Polyesterimide systems for class 180 designs

#### Damisol® 3340, Permafil® 707/747

	Thickness mm	Total weight g/m <sup>2</sup>	Samica® g/m <sup>2</sup>	Resin compatibility and thermal class
				Polyesterimide
Samicapor® 366.53	0.12	153	120	H
Samicapor® 366.53-10	0.12	153	120	H
Samicapor® 366.58	0.15	195	160	H
Samicapor® 315.45	0.14	214	160	H

Resin reference	DC motors	AC motors	Thermal class	Description
Permafil® 707, 747	•	•	H	polyester resin with high thermal-shock and temperature resistance
Damisol® 2053 HFP	•		180	solvent-borne polyesterimide varnish with high flexibility and temperature resistance
Damisol® 3032 300 mPa.s	•	•	180	solventless polyesterimide resin with high electrical insulating properties and temperature resistance; Samicabond® system
Damisol® 3340 500 mPa.s	•	•	180	solventless polyesterimide resin with high electrical insulating properties, flexibility and temperature resistance; Samicabond® system
Damisol® 3630 HTP 600 mPa.s	•	•	180	solvent-free polyesterimide resin with high electrical insulating properties and temperature resistance; no VOC

### Silicone systems for class C designs with Damisol® 3551

	Thickness mm	Total weight g/m <sup>2</sup>	Samica® g/m <sup>2</sup>	PI film 25 µm g/m <sup>2</sup>	Resin compatibility and thermal class
					Silicone
Samicapor® 366.53	0.12	153	120		220 (C)
Samicapor® 326.40	0.13	169	80	37	220 (C)
Samicapor® 366.85	0.12	164	120		220 (C)
Samicapor® 366.86	0.12	155	120		220 (C)
Samicapor® 366.87	0.14	170	120		220 (C)
Samicapor® 366.88	0.11	155	120		220 (C)

Resin reference	DC motors	AC motors	Thermal class	Description
Damisol® 3551		•	220	solvent-free silicone resin with high electrical insulating properties and temperature resistance; class C, no VOC



High-temperature-resistant impregnating resin



Von Roll's commitment is extensive, including all steps in the manufacturing process, in particular the production of mica tapes and mica-taped wires.



Mica tapes for VPI applications



## Mainwall Insulation for the RR System

Insulation systems employing resin-rich (RR) technology can assure optimum quality through careful selection of the micaceous tape and detailed attention to the way the tape is applied and processed. Von Roll offers RR tapes well suited to high-temperature operation. The solutions we have devised to get you the best possible results include a complete range of RR mainwall insulation tapes and systems under the name of Samicatherm® for both conventional and hydrostatic pressing and under the names of Filosam and Samicaflex for the overhang areas.

The advantages of these tapes are that they:

- » Have high dielectric strength
- » Provide high thermal performance
- » Resist corona discharge
- » Can be applied smoothly without creasing
- » Can be applied by fast-running
- » Have short cutting times

### Mainwall tapes for conventional hot pressing

	Thickness mm	Total weight g/m <sup>2</sup>	Samica® g/m <sup>2</sup>	PI film 25 µm g/m <sup>2</sup>	Resin content g/m <sup>2</sup>	Resin compatibility and thermal class
Samicatherm® 315.51	0.09	117	60	37	20	220 (C)

### Overhang tapes for conventional hot pressing

	Thickness mm	Total weight g/m <sup>2</sup>	Samica® g/m <sup>2</sup>	Resin content g/m <sup>2</sup>	Resin compatibility and thermal class
Samicaflex® 366.18	0.12	150	75	52	220 (C)
Samicaflex® 366.19	0.18	215	120	72	220 (C)



## Flexible Materials

The characteristics required of flexible materials used as slot liners in any type of motor is their endurance at high operating temperatures. This is driven by the the need to withstand harsh thermomechanical conditions. Laminates for these applications are based on some combination of polyimide film, glass fabric and aramide paper.

Von Roll's laminates have an outstanding record of heat-shock resistance; excellent bonding properties furnish the high-performance materials with the means to fulfill demanding traction-motor requirements. These materials are known under the Von Roll trade names Myoflex® and Acuflex®. We provide a wide range of constructions to satisfy any particular slot-liner thickness and to maximize mechanical and thermal characteristics, as well as to optimize processed fitting.

	Thickness mm	Layer thickness, $\mu\text{m}$		Tensile strength	Breakdown voltage
		Glass	PI film		
Glass/PI film	0.08–0.12	25–50	25–75	high	medium
Glass/PI film/Glass	0.15–0.21	50–80	25–50	very high	medium
		Nomex	PI film		
Nomex® <sup>1)</sup> /PI film	0.09–0.29	50–250	25	low	medium
	0.11–0.32	50–250	50	medium	high
	0.14–0.34	80–180	75	high	very high
Nomex® <sup>1)</sup> /PI film/Nomex®	0.21–0.41	80–180	25	low	medium
	0.24–0.43	80–180	50	medium	high
	0.25–0.45	80–180	75	high	very high



## Adhesive Tapes

Von Roll offers a wide range of high-quality adhesive tapes for a variety of applications. The following are examples used for traction motors:

Product	Backing	Adhesive	Total thickness	Insulation class	Properties
Intertape® 4118	Kapton® <sup>1)</sup>	SI	0.063	H 180°C	Ultimate insulation tape. Conformable, tear-, puncture-resistant and extreme high-temperature-resistant. Used for ground insulation, repair and reinforcement of enameled or covering wires, insulation of soldering joint.
Isotape® 4428PV3	Polyimide	SI	0.064	H 180°C	
Isotape® 51202PV3	Teflon® <sup>1)</sup>	SI	0.095	H 180°C	Innovative backing makes it unique to fulfill requirements for high-voltage applications.
Intertape® 4618	glass cloth	SI	0.18	C 200°C	High-temperature-resistant glass cloth for extreme insulation application. Remains conformable and stable in insulation even after a long time period over 180°C. Recommended for outer and interinsulation for heat-resistant transformers and bundling of coils. Also used as high-temperature masking tape.
Isotape® 4638PV3	glass cloth	SI	0.19	H 180°C	

<sup>1)</sup> Registered Trade names of DuPont de Nemours



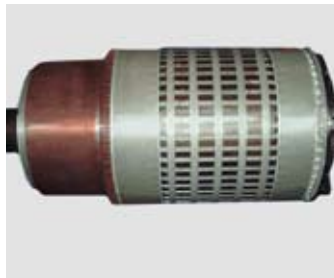
## Banding Tapes

Banding tapes act as a bracing composite to enable the commutator and unsupported windings in DC motors to withstand high rotational forces. In addition to possessing thermomechanical endurance, the material must be able to withstand fatigue trends and variable loads due to highly varying working conditions. Von Roll supplies a number of high-temperature banding tapes with a high retention of flexural strength under exposure to moisture and extreme temperature, including premium performance in class C with a Kevlar-reinforced tape to maintain high safety factors for motors with little space and low creepage. This is also optimal in guaranteeing a constant air gap at high speeds in AC inverter-driven applications using permanent-magnet rotors.

		H200	H220	K220
Thickness	mm	0.30 ± 0.03	0.30 ± 0.03	0.33 ± 0.04
Resin content	%	26 ± 2	26 ± 2	26 ± 2
Minimal tensile strength referred to one cured tape layer at 20°C	N/cm	2500	2500	3500
Thermal class		200 (H+)	220 (C)	220 (C)



4-pole railway motor assembly view



3.3 KV railway DC rotor banded with H220



Kevlar banding tape K220



## Composite Materials for Traction Motors

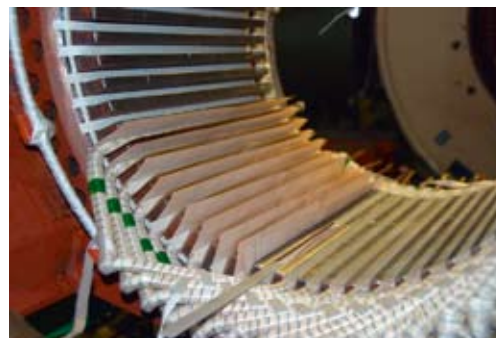
Von Roll offers a variety of high-quality composite materials that can be delivered as wedges, strips and sheets, machined parts or special components for use in different areas of traction motors. The following are just a selection. Please ask our specialists about additional products.

Product name	Form	Application	AC		DC	
			stator	rotor	stator	rotor
Commutator Samicanite® 41120	sheets and machined parts	copper segment insulation				•
Delmat® Epoxy 68660, Vetronite® G11, Vetronite® Polyimide, Delmat® Polyester 68420, Delmat® Polyester 68030	sheets and machined parts	slot wedges	•	•	•	•
U and L channels	U and L shaped	slot insulation		•		•
Vetroferrit®	sheets and machined parts	slot wedges	•		•	
Delbond® products	rolls, sheets and machined parts	interturn insulation		•		•
Prepreg Nomex® <sup>1)</sup>	sheets and machined parts	coil insulation	•		•	
Delmat® Epoxy 68660, Vetronite® G11	sheets and machined parts	blocking parts, support	external fixing elements			

<sup>1)</sup> Registered Trade names of DuPont de Nemours



High-voltage rotor for DC machines



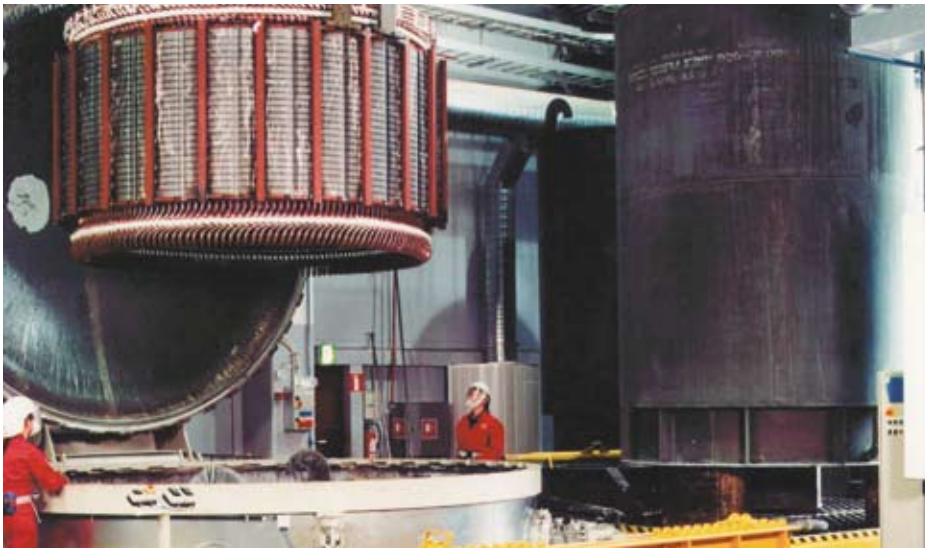
Machined parts tailored to customer-specific drawing

## Drying and Impregnation

The principles of air drying, controlled-rate impregnation, pressuring and curing resin are well understood by VPI process users or potential users.

For new equipment or upgrading existing plants, we consult on state-of-the-art VPI technology to increase our customers' efficiency.

Instrumentation for measuring capacitance, temperature, pressure and time are vital for in-line quality control of impregnation and can be built into the systems.



Large Vacuum Pressure Impregnation (VPI) unit



## Finishing Coating

The Damicoat® range of finishing and overcoat varnishes includes air-drying and oven-curing solutions. They are all single components for easy processing by spray, brush, and even dipping and dip-rolling processes.

Selection table	Color*	Thermal class	Drying time	Comments on products and use
Damicoat® 2405-01	N/RB/G	B/F	40 min	quick dry; highly chemically resistant overcoat varnish
Damicoat® 2404	RB/G	F	15–20 h	highly chemically and temperature resistant overcoat varnish
Damicoat® 2407	RB	F/H	1–2 h	high-temperature-resistant overcoat varnish, used for up to class H high-voltage and traction machines

\*B: Black; G: Grey; N: Natural; RB: Red/Brown



## Testing

Materials and systems have to be tested in order to ensure the requested specifications concerning mechanical, electrical and thermal characteristics.

At Von Roll laboratories we are able to test our customers' materials and systems according to IEC, UL and other specifications.

- » Thermal, electrical and mechanical aging tests
- »  $\tan \delta$  measurements at different temperatures
- » Partial discharge measurements with different voltage ranges



Testing in the Von Roll laboratory



## Training

For a number of years we have been offering a unique program of high-voltage insulation training within our Von Roll Corporate University. The objectives of this program are:

- » Better understanding of high-voltage insulation technology for rotating machines and up-to-date knowledge on insulating materials and systems
- » Practical experience in the application of electrical insulating materials



Our training courses are attended by customers and partners from around the globe.

# We Enable Energy

Von Roll is the sole full-range supplier of materials and systems for the insulation of electrical machines as well as high-performance products for various high-tech industries.



## Mica

Materials related to high-voltage insulation. Von Roll's commitment is extensive, including all the steps in the manufacturing process.



## Flexibles

Insulating flexible materials for low-voltage applications such as flexible laminates and adhesive tapes.



## Wires

Insulated round, flat and litz wires for high-voltage, low-voltage and electronic applications.



## Transformers

High-performance transformers for power transmission and distribution, solutions tailored to all applications of today's energy supply companies.



## Cables

Mica tapes for fire-resistant cables. Von Roll provides a wide range of products that are ideally suited to all commonly used standards.



## Testing

Von Roll provides electrical, thermal and mechanical testing of individual materials as well as complete insulating systems. We are UL-certified.



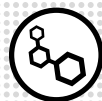
## Liquids

Impregnation resins for high and low-voltage, potting resins, casting resins, as well as encapsulating and conformal coatings.



## Training

Von Roll Corporate University provides a training program in high- and low-voltage insulation for its customers.



## Composites

Engineered materials made from a resin and a support structure with distinct physical, thermal and electrical properties. They can be molded, machined or semi-finished.

Please contact us or visit our website [www.vonroll.com](http://www.vonroll.com) for further information:

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## About Von Roll

As one of the longest established industrial companies in Switzerland, founded in 1803, we focus on products and systems for power generation, transmission and distribution, rotating machines and mechanical engineering. Von Roll is the global market leader in insulation products, systems and services and is represented at more than 32 locations in 19 countries with around 3,400 employees.