



# Winding Wires and Litz Wires

## 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

Electric motors, generators, transformers and relays have something in common: the winding wires. These wires are conductors, mainly based on electrolytically refined, tough pitch copper, which may be insulated using a wide variety of different materials. The resulting high-quality conductors are used in the electrical industry to make coils and compact windings.

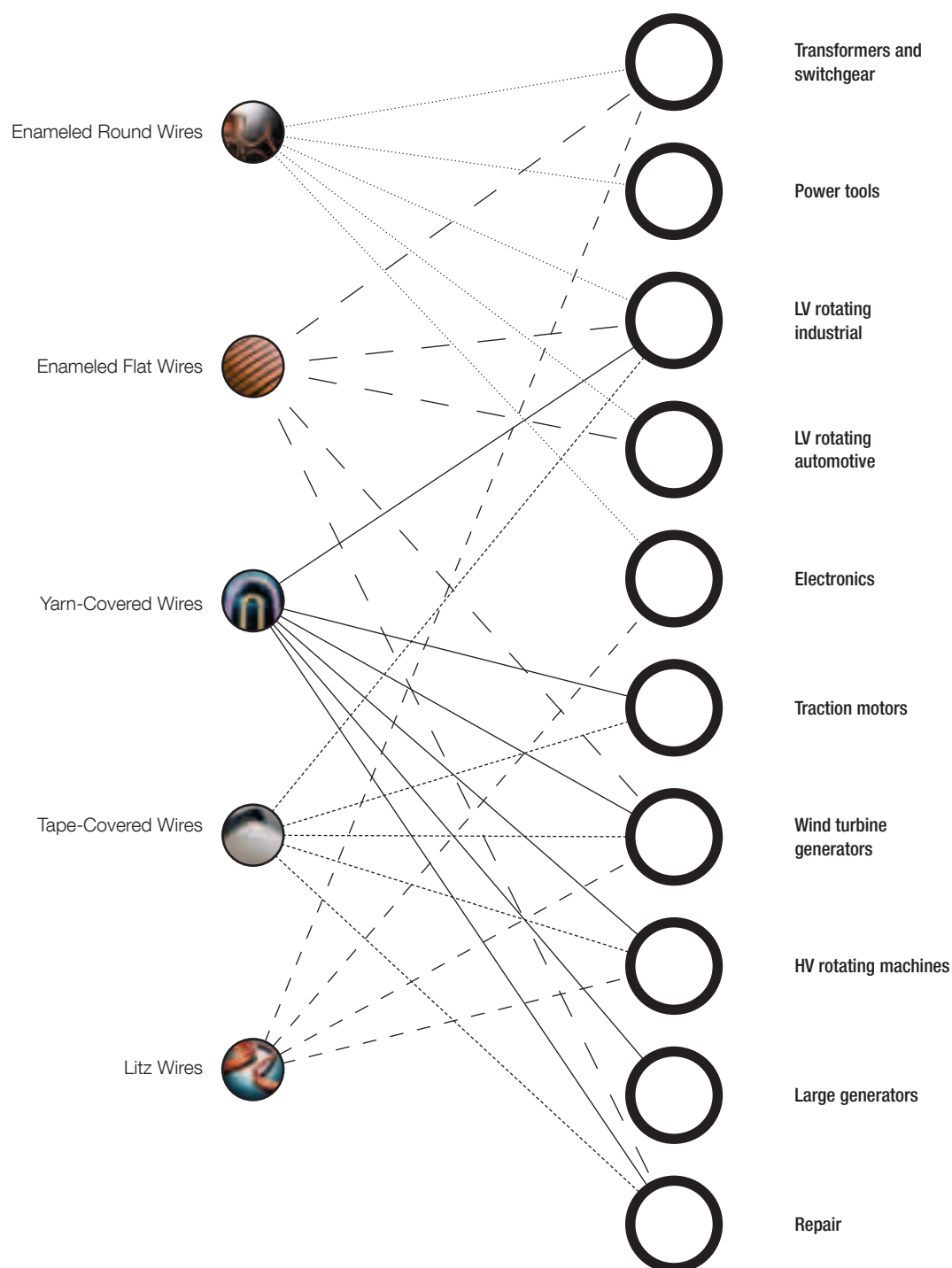
Von Roll's winding wires are at the leading edge of technology. The consistent high quality of our products and our customized insulations, adapted to every application, guarantees safety and reliability of electrical machines. Von Roll manufactures a complete range of winding wires using different types of insulation coverings, such as enamels, yarns and tapes.

Von Roll completes its offer for electrical systems with litz wires. The bare or enamelled versions are available with the same insulation coverings as for winding wires. We can supply a wide range of litz wire constructions to suit customers' special applications (e.g. transformers, converters, filters, induction hot plates, contactless power transmission, high-frequency applications).



## Wires Worldwide

Most of our products and the associated services can be offered to manufacturers and repairers of motors, power generators, transmission and distribution equipment all over the world thanks to Von Roll's global presence<sup>1)</sup>, with dedicated wire-production sites located in Europe, the USA, India and Asia.



<sup>1)</sup> The information and data presented in this document are for typical materials produced by the affiliated companies of Von Roll Holding AG. Some variation in product names and properties is to be expected for products manufactured in different locations.

## Enamelled Copper Wires, Round

Von Roll offers a complete range of enamelled round wires for a large range of applications:

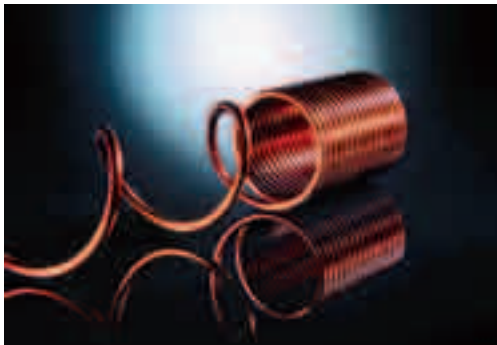
- » Duroflex®: Enamelled wire with outstanding mechanical coating properties for windings in transformers.
- » Thermex®: High-temperature wires with temperature indexes up to 240°C for use in electrical and magnet coils, transformers, motors and small generators.
- » Thermibond®: Self-bonding wires that allow the motor or generator manufacturer to avoid using impregnation varnishes and thus to reduce manufacturing time cycles.

Von Roll's round enamelled copper wires are manufactured in the dimension range from 0.355 to 5.00mm.

Conductor materials other than copper are also available with enamelled insulation on request: e.g. nickel-plated copper, special copper-based alloys or superconductors.

### The Advantage to You

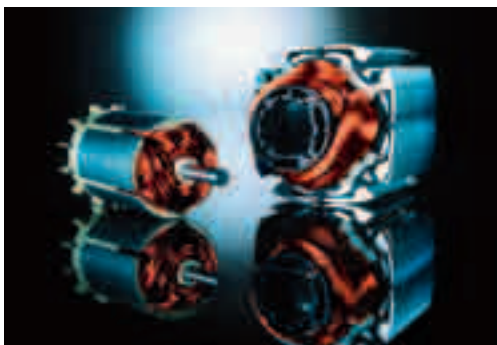
- » Own production of a large range of different qualities and diameters of enamelled wires
- » Original Pyre-ML® enamel<sup>1)</sup> used for the highest-temperature-class enamelled wire, Thermex® 240



Self-bonding wire Thermibond®



Various enamelled round wires



Thermex® and Thermibond® in low-voltage motors



<sup>1)</sup> Pyre-ML® is a registered trademark of Industrial Summit Technology Co.

**Grad 0:**

Special Coating Class for Standard Enamelled Copper Wires, round (not according to IEC)

Nominal bare diameter d (mm)	Min. increase due to insulation d, -d (mm)	Max. overall diameter mm	Weight/ 1000 m kg	Length/kg m
0.355*	0.013	0.375	0.896	1116
0.375	0.013	0.396	0.999	1001
0.400*	0.013	0.422	1.137	880
0.425	0.014	0.447	1.282	780
0.450*	0.014	0.473	1.437	696
0.475	0.014	0.498	1.600	625
0.500*	0.014	0.524	1.772	564
0.530	0.015	0.555	1.990	503
0.560*	0.015	0.585	2.220	450
0.600	0.015	0.626	2.550	392
0.630*	0.015	0.657	2.810	356
0.670	0.016	0.697	3.180	314
0.710*	0.016	0.738	3.570	280
0.750	0.016	0.779	3.980	251
0.800*	0.016	0.830	4.530	221
0.850	0.017	0.881	5.110	196
0.900*	0.017	0.932	5.720	175
0.950	0.017	0.983	6.370	157
1.00*	0.017	1.034	7.060	142

**Grad 0B:**

Special Coating Class for Self-Bonding Wires, round (not according to IEC)

Nominal bare diameter d (mm)	Min. increase due to insulation d, -d (mm)	Max. overall diameter mm	Weight/1000 m kg	Length/kg m
0.355*	0.020	0.392	0.909	1100
0.375	0.021	0.414	1.014	986
0.400*	0.021	0.439	1.152	868
0.425	0.022	0.466	1.300	769
0.450*	0.022	0.491	1.455	687
0.475	0.024	0.519	1.621	617
0.500*	0.024	0.544	1.790	559
0.530	0.025	0.576	2.015	496
0.560*	0.025	0.606	2.247	445
0.600	0.027	0.649	2.578	388
0.630*	0.027	0.679	2.840	352
0.670	0.028	0.722	3.210	312
0.710*	0.028	0.762	3.600	278
0.750	0.030	0.805	4.019	249
0.800*	0.030	0.855	4.566	219
0.850	0.032	0.909	5.156	194
0.900*	0.032	0.959	5.773	173
0.950	0.034	1.012	6.432	155
1.00*	0.034	1.062	7.120	140

\*standard dimensions

**Grade 1:**

Coating Class for Standard Enamelled Copper Wires, Round, according to IEC 60317-0-1r

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
0.355*	0.020	0.392	0.907	1100
0.375	0.021	0.414	1.01	990
0.400*	0.021	0.439	1.15	870
0.425	0.022	0.466	1.30	769
0.450*	0.022	0.491	1.45	690
0.475	0.024	0.519	1.62	617
0.500*	0.024	0.544	1.79	559
0.530	0.025	0.576	2.01	498
0.560*	0.025	0.606	2.24	446
0.600	0.027	0.649	2.57	389
0.630*	0.027	0.679	2.83	353
0.670	0.028	0.722	3.21	312
0.710*	0.028	0.762	3.60	278
0.750	0.030	0.805	4.01	249
0.800*	0.030	0.855	4.56	219
0.850	0.032	0.909	5.15	194
0.900*	0.032	0.959	5.77	173
0.950	0.034	1.012	6.42	156
1.00*	0.034	1.062	7.11	141
1.06	0.034	1.124	7.99	125
1.12*	0.034	1.184	8.91	112
1.18	0.035	1.246	9.88	101
1.25*	0.035	1.316	11.1	90.1
1.32	0.036	1.388	12.4	80.7
1.40*	0.036	1.468	13.9	71.9
1.50	0.038	1.570	15.9	62.9
1.60*	0.038	1.670	18.1	55.2
1.70	0.039	1.772	20.4	49.0
1.80*	0.039	1.872	22.9	43.7
1.90	0.040	1.974	25.5	39.2
2.00*	0.040	2.074	28.2	35.5
2.12	0.041	2.196	31.7	31.5
2.24*	0.041	2.316	35.4	28.2
2.36	0.042	2.438	39.3	25.4
2.50*	0.042	2.578	44.1	22.7
2.65	0.043	2.730	49.5	20.2
2.80*	0.043	2.880	55.2	18.1
3.00	0.045	3.083	63.4	15.8
3.15*	0.045	3.233	69.9	14.3
3.35	0.046	3.435	79.0	12.7
3.55*	0.046	3.635	88.7	11.3
3.75	0.047	3.838	98.9	10.1
4.00*	0.047	4.088	113	8.85
4.25	0.049	4.341	127	7.87

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
4.50*	0.049	4.591	142	7.04
4.75	0.050	4.843	159	6.29
5.00*	0.050	5.093	176	5.68

**Grade 1B:**

Coating Class for Self-Bonding Wires, round, according to IEC 60317-0-1

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
0.355*	0.035	0.413	0.926	1080
0.375	0.037	0.436	1.03	968
0.400*	0.037	0.461	1.17	853
0.425	0.038	0.489	1.32	756
0.450*	0.038	0.514	1.48	677
0.475	0.041	0.543	1.65	607
0.500*	0.041	0.568	1.82	549
0.530	0.042	0.600	2.04	489
0.560*	0.042	0.630	2.28	439
0.600	0.045	0.674	2.61	383
0.630*	0.045	0.704	2.88	348
0.670	0.047	0.748	3.25	308
0.710*	0.047	0.788	3.64	274
0.750	0.050	0.832	4.06	246
0.800*	0.050	0.882	4.61	217
0.850	0.052	0.937	5.21	192
0.900*	0.052	0.987	5.83	172
0.950	0.055	1.041	6.49	154
1.00*	0.055	1.091	7.18	139
1.06	0.056	1.154	8.06	124
1.12*	0.056	1.214	8.99	111
1.18	0.057	1.276	9.97	100
1.25*	0.057	1.346	11.2	89.4
1.32	0.059	1.419	12.5	80.3
1.40*	0.059	1.499	13.0	77.0
1.50	0.061	1.602	16.1	62.3
1.60*	0.061	1.702	18.2	54.8
1.70	0.063	1.805	20.6	48.6
1.80*	0.063	1.905	23.0	43.4
1.90	0.065	2.008	25.7	39.0
2.00*	0.065	2.108	28.4	35.2

\*standard dimensions

**Grade 2:**

Coating Class for Standard Enamelled Copper Wires, Round, according to IEC 60317-0-1

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
0.355*	0.038	0.411	0.921	1090
0.375	0.040	0.434	1.03	971
0.400*	0.040	0.459	1.17	854
0.425	0.042	0.488	1.32	758
0.450*	0.042	0.513	1.47	680
0.475	0.045	0.541	1.64	610
0.500*	0.045	0.566	1.81	552
0.530	0.047	0.600	2.04	490
0.560*	0.047	0.630	2.27	441
0.600	0.050	0.674	2.61	383
0.630*	0.050	0.704	2.87	348
0.670	0.053	0.749	3.24	309
0.710*	0.053	0.789	3.64	275
0.750	0.056	0.834	4.06	246
0.800*	0.056	0.884	4.61	217
0.850	0.060	0.939	5.20	192
0.900*	0.060	0.989	5.82	172
0.950	0.063	1.044	6.49	154
1.00*	0.063	1.094	7.18	139
1.06	0.065	1.157	8.06	124
1.12*	0.065	1.217	8.98	111
1.18	0.067	1.279	9.96	100
1.25*	0.067	1.349	11.2	89.3
1.32	0.069	1.422	12.4	80.6
1.40*	0.069	1.502	14.0	71.4
1.50	0.071	1.606	16.0	62.5
1.60*	0.071	1.706	18.2	54.9
1.70	0.073	1.809	20.6	48.5
1.80*	0.073	1.909	23.0	43.5
1.90	0.075	2.012	25.6	39.1
2.00*	0.075	2.112	28.4	35.2
2.12	0.077	2.235	31.9	31.3
2.24*	0.077	2.355	35.6	28.1
2.36	0.079	2.478	39.5	25.3
2.50*	0.079	2.618	44.3	22.5
2.65	0.081	2.772	49.7	20.1
2.80*	0.081	2.920	55.5	18.0
3.00	0.084	3.126	63.6	15.7
3.15*	0.084	3.276	70.1	14.3
3.35	0.086	3.479	79.3	12.6
3.55*	0.086	3.679	89.0	11.2
3.75	0.089	3.883	99.3	10.1
4.00*	0.089	4.133	113	8.85
4.25	0.092	4.387	127	7.87


\*standard dimensions

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
4.50*	0.092	4.637	143	6.99
4.75	0.094	4.891	159	6.29
5.00*	0.094	5.141	176	5.68

**Grade 2B:**

Coating Class for Self-Bonding Wires, round, according to IEC 60317-0-1

Nominal bare diameter	Min. increase due to insulation	Max. overall diameter	Weight/1000m	Length/kg
d (mm)	mm	mm	kg	m
0.355*	0.053	0.432	0.942	1062
0.375	0.056	0.456	1.05	951
0.400*	0.056	0.481	1.19	540
0.425	0.058	0.511	1.35	743
0.450*	0.058	0.536	1.50	666
0.475	0.062	0.565	1.67	598
0.500*	0.062	0.590	1.85	541
0.530	0.064	0.624	2.07	482
0.560*	0.064	0.654	2.31	433
0.600	0.068	0.699	2.65	378
0.630*	0.068	0.729	2.91	344
0.670	0.072	0.755	3.29	304
0.710*	0.072	0.815	3.69	271
0.750	0.076	0.861	4.11	243
0.800*	0.076	0.911	4.67	214
0.850	0.080	0.967	5.27	190
0.900*	0.080	1.017	5.89	170
0.950	0.084	1.073	6.56	152
1.00*	0.084	1.123	7.26	138
1.06	0.087	1.187	8.15	123
1.12*	0.087	1.247	9.08	110
1.18	0.089	1.309	10.1	99.4
1.25*	0.089	1.379	11.3	88.7
1.32	0.092	1.453	12.6	79.6
1.40*	0.092	1.533	14.1	70.9
1.50	0.094	1.638	16.2	61.8
1.60*	0.094	1.738	18.4	54.5
1.70	0.097	1.842	20.7	48.3
1.80*	0.097	1.942	23.2	43.1
1.90	0.100	2.046	25.8	38.7
2.00*	0.100	2.146	28.6	35.0

Designation	DUROFLEX® 120	THERMEX® 200 	THERMEX® 220	
Temperature index <sup>1)</sup>	120	200	220	
Norms	IEC 60317-12 EN 60317-12 DIN 46416 Part 1 (M) BS 4516 Part 1 NEMA MW 1000/15C NFC 31-601	IEC 60317-13 DIN 46416 Part 7 (W210) BS 6811 Section 3.3 NEMA MW 1000/35C	IEC 60317-26* EN 60317-26 BS 4665 Part 1** NEMA MW 1000/81C	
Chemical base of the insulation	modified polyvinyl formal	THEIC-modified polyester imide base coat with a polyamide-imide overcoat	polyamide-imide	
Range of dimensions	IEC 60317-0-1	IEC 60317-0-1	IEC 60317-0-1	
Standard wires <sup>2)</sup>				
Grade 0 / Grade 0B	–	0.355 – 1.00 mm	0.355 – 1.00 mm	
Grade 1 / Grade 1B	1.25 – 5.00 mm	0.355 – 3.15 mm	0.355 – 5.00 mm	
Grade 2 / Grade 2B	1.25 – 5.00 mm	0.355 – 3.15 mm	0.355 – 5.00 mm	
Highlights	<ul style="list-style-type: none"> <li>» high mechanical properties</li> <li>» good stripping properties</li> <li>» excellent flexibility of the insulation</li> <li>» good impact strength and resistance to abrasion</li> <li>» hydrolysis-resistant</li> <li>» transformer oil-resistant</li> </ul>	<ul style="list-style-type: none"> <li>» excellent thermal and chemical properties</li> <li>» suitable for windings that are subjected to constantly high temperatures and mechanical stress</li> <li>» suitable for use with high-speed automatic winders</li> </ul>	<ul style="list-style-type: none"> <li>» outstanding mechanical, chemical and thermal properties</li> </ul>	
Applications	<ul style="list-style-type: none"> <li>» dry and oil-filled transformers up to highest performance</li> <li>» electrical equipment</li> </ul>	<ul style="list-style-type: none"> <li>» windings for class H... 200 AC and DC motors</li> <li>» dry and oil-filled transformers</li> <li>» contactor coils</li> <li>» magnet coils</li> <li>» motors for hermetic compressors, washing machines etc.</li> </ul>	<ul style="list-style-type: none"> <li>» windings for class H... 200 AC and DC machines</li> <li>» contactor and magnet coils subjected to extreme conditions</li> <li>» special motors</li> <li>» motors for hermetic compressors, washing machines etc.</li> </ul>	
Comparable properties <sup>3)</sup>				
Pencil hardness - as received - after solvent test	5H / 6H 4H	5H / 6H 4H	5H / 6H 4H	
Heat shock	175°C	220°C	240°C	
Cut-through	200°C	350°C	390°C	
Specific dielectric strength	150V/µm	150V/µm	150V/µm	
Soldering temperature	–	–	–	
Bonding temperature	–	–	–	

<sup>1)</sup> The Temperature Index is derived from the test carried out according to IEC Publication 60172 or NEMA MW 1000. It gives an indication of the behaviour of the wires when exposed to heat, but it does not necessarily equal the service temperature at which the wires can be used.


<sup>2)</sup> Round wires are usually lubricated up to and incl. 2.00 mm. For the manufacture of layer windings, wires without lubricant are possible.

<sup>3)</sup> Most properties are subjected to coating classes and dimensions. The listed properties are not or only limited affected by these factors.

<sup>4)</sup> For round self-bonding wires, all norms, except IEC, refer to the base coat only.





	THERMEX® 240	THERMIBOND® 158 	THERMIBOND® 168
	240	200	220
	IEC 60317-46 EN 60317-46 NEMA MW 1000/16C	IEC 60317-38 <sup>4)</sup> DIN 46416 Part 7 (W210) BS 6811 Section 3.3 NEMA MW 1000/35C	
	aromatic polyimide	THEIC-modified polyesterimide base coat with a polyamide-imide overcoat and a thermosetting duroplastic adhesive from aromatic polyamide	modified polyamide-imide base coat with a thermosetting duroplastic adhesive from aromatic polyamide
	IEC 60317-0-1	IEC 60317-0-1	IEC 60317-0-1
	–	0.355 – 1.00 mm	–
	0.355 – 2.65 mm	0.355 – 1.32 mm	1.40 – 2.80 mm
	0.355 – 2.65 mm	0.355 – 1.32 mm	1.40 – 2.80 mm
	<ul style="list-style-type: none"> <li>» highest thermal properties</li> <li>» outstanding chemical and mechanical properties</li> <li>» good behavior when exposed to gamma rays</li> <li>» excellent behavior in the cryo-technique</li> </ul>	<ul style="list-style-type: none"> <li>» the wires are self-bonding preferably by means of a current surge</li> <li>» the bond coat solidifies the windings without any impregnation</li> <li>» resistant to refrigerants</li> <li>» suitable for use with high-speed automatic winders</li> </ul>	<ul style="list-style-type: none"> <li>» the wires are self-bonding preferably by means of a current surge</li> <li>» the bond coat solidifies the windings without any impregnation</li> <li>» resistant to refrigerants</li> <li>» suitable for use with high-speed automatic winders</li> </ul>
	<ul style="list-style-type: none"> <li>» all types of windings with service temperatures up to 220°C</li> <li>» motors and generators for the aviation and marine industries</li> <li>» motors and equipment in the nuclear field and very- low-temperature technique</li> <li>» for all windings requiring a high degree of reliability</li> </ul>	<ul style="list-style-type: none"> <li>» stator windings of asynchronous and universal motors</li> <li>» field coils</li> <li>» magnet coils</li> <li>» reactance coils</li> <li>» relay coils</li> <li>» self-supporting coils</li> </ul>	<ul style="list-style-type: none"> <li>» stator windings of asynchronous and universal motors</li> <li>» field coils</li> <li>» magnet coils</li> <li>» reactance coils</li> <li>» relay coils</li> <li>» self-supporting coils</li> </ul>
	5H 5H	– –	– –
	250°C	220°C	220°C
	410°C	350°C	350°C
	150V/μm	150V/μm	150V/μm
	–	–	–
	–	190°C / 230°C	190°C / 230°C

\* with TI 200

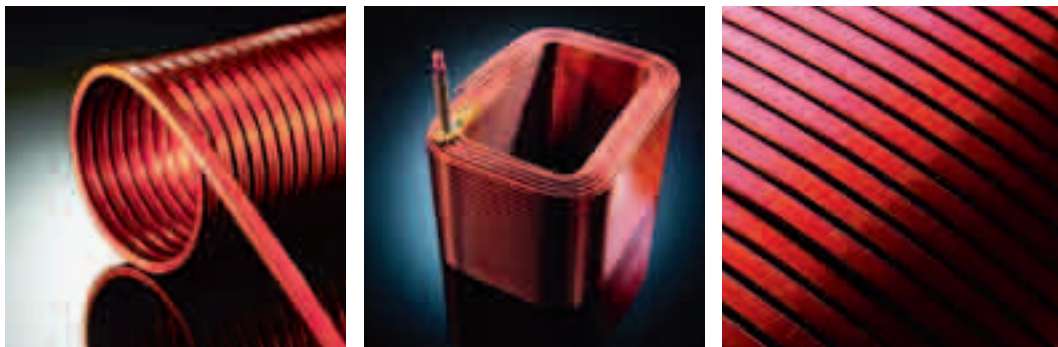
\*\* with TI 180

## Enamelled Copper Wires, Flat

Among its high-tech winding-wire products, Von Roll offers a complete range of flat enamelled copper wires:

- » Duroflex®: Enamelled wire with outstanding mechanical coating properties mainly for windings in transformers.
- » Thermex®: High-temperature wires with temperature indexes up to 240°C for electrical and magnet coils, transformers, motors, small industrial and wind turbine generators.
- » Thermibond®: Self-bonding wires that enable the motor or generator manufacturer to avoid using impregnation varnishes and thus to reduce manufacturing time cycles.

Von Roll's rectangular copper wires typically can be supplied in the wire cross-section range from 1.50mm<sup>2</sup> up to 80mm<sup>2</sup>.



Ultra-thin enamelled rectangular wire

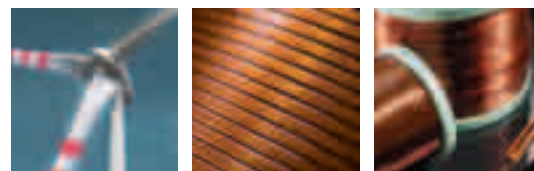
Application example for Thermex® 220

Thermex® 240

### The Advantage to You

- » Different types of enamel with very good mechanical strength and bonding properties
- » Very consistent quality and dimension tolerances per industry standards
- » Wide range of dimensions (very small to very large flat-wire cross-sections)
- » Original Pyre-ML® enamel<sup>1)</sup> used for the highest-temperature-class enamelled wire, Thermex 240

<sup>1)</sup> Pyre-ML® is a registered trademark of Industrial Summit Technology Co.



Designation	DUROFLEX® 120	THERMEX® 200	THERMEX® 220	THERMEX® 240	THERMIBOND® TS
Temperature index <sup>1)</sup>	120	200	220	240	>2010
Norms	IEC 60317-18 DIN 46417 Part 1 (M) BS 4516 Part 2 NEMA MW 1000/18C	IEC 60317-29 BS 6811 Section 4.2 NEMA MW 1000/36C	IEC 60317-58	IEC 60317-47 NEMA MW 1000/20C	
Chemical base of the insulation	modified polyvinyl formal	modified polyester imide with polyamide-imide base coat	polyamide-imide	aromatic polyimide	modified polyamide imide base coat with a thermosetting duroplastic adhesive from aromatic polyamide
Range of dimensions	IEC 60317-0-2 <sup>2)</sup> Grade 1 Grade 2	IEC 60317-0-2 <sup>2)</sup> Grade 1 Grade 2	IEC 60317-0-2 <sup>2)</sup> Grade 1 Grade 2	IEC 60317-0-2 <sup>2)</sup> Grade 1 Grade 2	IEC 60317-0-2 <sup>2)</sup> Grade 2
Highlights	<ul style="list-style-type: none"> <li>» excellent bending properties</li> <li>» high flexibility of the insulation</li> <li>» good impact strength and resistance to abrasion</li> <li>» hydrolysis-resistant</li> <li>» high mechanical properties</li> <li>» good stripping properties</li> </ul>	<ul style="list-style-type: none"> <li>» excellent thermal and chemical properties</li> <li>» suitable for windings that are subjected to constantly high temperatures and mechanical stress</li> </ul>	<ul style="list-style-type: none"> <li>» outstanding mechanical, chemical and thermal properties</li> <li>» suitable for windings that are subjected to constantly high temperatures and mechanical stress</li> </ul>	<ul style="list-style-type: none"> <li>» highest thermal properties</li> <li>» outstanding chemical and mechanical properties</li> <li>» good behavior when exposed to gamma rays</li> <li>» excellent behavior in the cryo-technique</li> </ul>	<ul style="list-style-type: none"> <li>» the wires are self-bonding by means of a current surge or by being cured in an oven</li> <li>» the bond coat solidifies the windings without any impregnation</li> </ul>
Applications	<ul style="list-style-type: none"> <li>» dry and oil-filled transformers up to highest performance</li> <li>» electrical equipment</li> </ul>	<ul style="list-style-type: none"> <li>» windings of AC and DC motors of class H... 200</li> <li>» contactor coils</li> <li>» magnet coils</li> <li>» dry and oil-filled transformers</li> </ul>	<ul style="list-style-type: none"> <li>» windings in highly stressed AC and DC motors of class H... 200</li> <li>» contactor coils</li> <li>» magnet coils</li> <li>» dry and oil-filled transformers</li> </ul>	<ul style="list-style-type: none"> <li>» all types of windings with service temperatures up to 220°C</li> <li>» motors and generators for the aviation and marine industries</li> <li>» motors and equipment in the nuclear field and very-low-temperature techniques</li> <li>» for all types of windings requiring a high degree of reliability</li> </ul>	<ul style="list-style-type: none"> <li>» field coils of AC and DC machines</li> <li>» special applications</li> </ul>
Comparable properties <sup>3)</sup>					
Pencil hardness as received after solvent test	5H 3H	5H 4H	5H / 6H 4H	5H 5H	– –
Heat shock	150°C	220°C	240°C	260°C	240°C
Specific dielectric strength	150V/μm	150V/μm	150V/μm	150V/μm	150V/μm
Bonding temperature	–	–	–	–	180°C – 220°C

<sup>1)</sup> The temperature index is derived from tests carried out according to IEC Publication 60172 or NEMA MW 1000. It gives an indication of how the wires behave when exposed to heat, but it does not necessarily equal the service temperature at which the wires can be used.

<sup>2)</sup> In addition to the dimensions according to IEC 60317-0-2, any size up to a maximum cross-section of 80.00mm<sup>2</sup> can be manufactured, provided a suitable ratio of the sides is chosen.

<sup>3)</sup> Most properties are subjected to coating classes and dimensions. The listed properties are not or only limited affected by these factors.

## Yarn-Covered Winding Wires

One of Von Roll's best-known specialities worldwide is the development and production of fiber-covered and taped wires that meet the most demanding requirements of the electrotechnical industry. Our fiber-covered wires are lapped with glass or with a combination of mixed glass/polyester fibers:

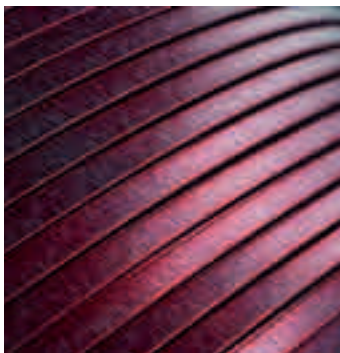
- » **Silix®** are glass-yarn-covered and varnish-impregnated round or flat wires.
- » **Daglas®** are round or flat wires covered with a thermally fused yarn combination of glass and polyester fibers, available both unvarnished and varnished.
- » **VTV** are round or flat wires that are insulated with a combination of mixed glass/polyester fibers and impregnated glass yarn.
- » **VS** are yarn-covered round or flat wires with outstanding thermal and mechanical properties, based on polyamide-imide or polyimide enamel for the conductor insulation and the covering impregnation.

Von Roll's yarn-covered wires are ideal for applications where the wire insulation requires improved mechanical properties, for example in:

- » rotors and stator windings of electrical motors (low- and high-voltage)
- » rotors and stator windings of traction motors
- » rotors and stator windings of wind turbine generators
- » conductor strands or Roebel bars for large power generators (hydro, turbo)

### The Advantage to You

- » Wires with improved mechanical strength
- » High-performance yarns and impregnation varnishes
- » Wide range of builds possible (standard, very thin or reinforced)
- » Own means of production for a broad range of round and flat enamelled wires



Rectangular wire covered with glass/polyester yarn blend (Daglas®)



Conductor stack with thermosetting-varnish-coated Daglas® wire



Special wires for traction motors (VS 220 / VS 240)

Product range	SILIX®	DAGLAS	VTV	VS	
Temperature index <sup>1)</sup>	155, 180 or 200	155, 180 or 200	155 or 180	220 or 240	
Type of insulation	E-Glass, alkali-free, varnish-impregnated	glass/polyester-fiber blend, varnish-impregnated or not	glass/polyester-fiber blend and varnish-impregnated glass fibers	varnish-impregnated yarns	
Insulation options	1 or 2 lapped layers 2 cross-lapped layers in general	1 or 2 lapped layers 2 cross-lapped layers in general	2 cross-lapped layers	1 or 2 lapped layers 2 cross-lapped layers in general	
Type of impregnation	epoxy (TI 155), B-stage epoxy (TI 155), polyester-imide (TI 180), silicone (TI 200)	epoxy (TI 155), B-stage epoxy (TI 155), polyester-imide (TI 180), silicone (TI 200)	epoxy (TI 155), B-stage epoxy (TI 155), polyester-imide (TI 180)	polyamide-imide (TI 220), polyimide (TI 240)	
Standards	IEC 60317-0-4, IEC 60317-0-6 IEC 60317-31, IEC 60317-49 (TI 180) IEC 60317-32, IEC 60317-48 (TI 155) IEC 60317-33, IEC 60317-50 (TI 200)				
Conductor material <sup>2)</sup>	» bare copper, soft » enamelled copper  Thermex® 200, Thermex® 220, Thermex®240	» bare copper, soft » enamelled copper  Thermex® 200, Thermex® 220	» bare copper, soft » enamelled copper  Thermex® 200, Thermex® 220	» enamelled copper  Thermex® 220, Thermex® 240	
<b>Standard range of dimensions</b>					
round <sup>3)</sup>	diameters (mm)	0.45 to 6.00	0.45 to 6.00	0.90 to 6.00	0.90 to 6.00
rectangular	cross-section (mm <sup>2</sup> )	2 to 80 subject to thick vs. width ratio	2 to 80 subject to thick vs. width ratio	2 to 80 subject to thick vs. width ratio	2 to 80 subject to thick vs. width ratio
	width (mm)	2 to 22	2 to 22	2 to 22	2 to 22
	thickness (mm)	1 to 6	1 to 6	1 to 6	1 to 6
Highlights	» thermal resistance at constantly high temperatures » mechanical resistance » great resistance to abrasion and scraping » chemical resistance	» covering with high bonding strength » great resistance to abrasion and scraping	» excellent thermal bonding properties » excellent mechanical properties (adhesion, flexibility)	» outstanding thermal resistance » covering with high mechanical strength	
Applications	» Roebel bars in power generators » HV rotating electro-machines » industrial LV motors	» Roebel bars in power generators » HV rotating electro-machines » industrial LV motors	» HV rotating electro-machines » Roebel bars in power generators	» traction motors » heavy-duty motors	

<sup>1)</sup> The temperature index is derived from tests carried out according to IEC Publication 60172 or NEMA MW 1000. It gives an indication of how wires behave when exposed to heat, but it does not necessarily equal the service temperature at which the wires can be used.

<sup>2)</sup> Besides copper, other conducting materials, such as oxygen-free copper, nickel-plated copper, nickel, superconductors and special alloys are possible on request.

<sup>3)</sup> Instead of round or rectangular wires, other types, such as litz wires and hollow conductors, can be insulated as well.

## Tape-Covered Winding Wires

Von Roll's taped wires are widely known for their use as winding wires in rotating machines, which can be subjected to high-voltage working conditions, partial discharges and high thermal stress. Our taped wires are particularly adapted to the windings and coils in the following applications:

- » Inverter-driven industrial motors
- » High-voltage rotating machines
- » Traction motors
- » Mining motors etc.

By using special lapping or taping operations, we can insulate conductors in round or rectangular cross-sections (i.e. round and flat wires).

In addition to electrolytically refined, tough pitch copper, on request other conductor types can be covered with yarns or tapes as well, such as oxygen-free copper, nickel-plated copper, nickel, hollow conductors, litz wires, superconductors and special alloys.

### The Advantage to You

- » Wires with high dielectric strength
- » High-performance tapes
- » Own production of mica paper, mica tapes and mica-taped wires
- » Wide range of dimensions and builds possible



Tape-lapped wire with two layers of polyimide foil



Bobbin of a tape-lapped wire with polyimide foil



Reel of wire tape-lapped with Samicafilm



Reels of wire tape-lapped with Samicafilm



Product range	SAMICAFILM®	POLYIMIDE	POLYIMIDE + Glass or DAGLAS	POLYESTER
Temperature index (acc. to IEC 60172) <sup>1)</sup>	155 or 180	240	240	180
Type of insulation	mica/polyester tape with epoxy resin as binder and with or without thermo-setting bonding layer	polyimide foil coated on one or both sides with an FEP (Teflon®) adhesive, e.g. Kapton FN, FCR or FWR	polyimide foil coated on one or both sides with an FEP (Teflon®) adhesive with an additional glass/polyester or varnish impregnated glass lapping	polyester PET films
Insulation options	<ul style="list-style-type: none"> <li>» 1 to 4 lapped tape layers</li> <li>» possibility to lap in combination with polyester film</li> <li>» butt-lapped or overlapped tape layers</li> <li>» overlap up to 66%</li> </ul>	<ul style="list-style-type: none"> <li>» 1 or 2 lapped fused tape layers</li> <li>» lapped tape layers in same direction or cross-lapped</li> <li>» overlap up to 66%</li> </ul>	<ul style="list-style-type: none"> <li>» 1 or 2 lapped fused tape layers</li> <li>» lapped tape layers in same direction or cross-lapped</li> <li>» overlap up to 66%</li> <li>» 1 or 2 lapped layers of glass or glass/polyester-fiber blend</li> </ul>	<ul style="list-style-type: none"> <li>» 1 or 2 lapped tape layers with overlap up to 66%</li> </ul>
Standards		IEC 60317-43 (round) IEC 60317-44 (rectangular)		
Conductor material <sup>2)</sup>	<ul style="list-style-type: none"> <li>» bare copper, soft</li> <li>» enamelled copper Thermex® 200 or Thermex® 220</li> </ul>	<ul style="list-style-type: none"> <li>» bare copper, soft</li> <li>» enamelled copper (on request)</li> </ul>	<ul style="list-style-type: none"> <li>» bare copper, soft</li> </ul>	<ul style="list-style-type: none"> <li>» enamelled copper Thermex® 200 or Thermex® 220</li> </ul>
<b>Standard range of dimensions</b>				
round <sup>3)</sup> diameters (mm)	0.80 to 3.50	0.45 to 3.50	0.45 to 3.50	0.80 to 3.50
rectangular cross-section (mm <sup>2</sup> )	up to 100	up to 80	up to 80	on request
width (mm)	2.00 to 20.00	2.00 to 20.00	2.00 to 20.00	
thickness (mm)	0.80 to 6.00	0.50 to 6.00	0.50 to 6.00	
Highlights	<ul style="list-style-type: none"> <li>» very good dielectric strength</li> <li>» outstanding resistance to corona discharges</li> <li>» reduced consolidation times of the straight bar sections with the hot-melt-adhesive-coated grades</li> </ul>	<ul style="list-style-type: none"> <li>» very good dielectric strength</li> <li>» outstanding thermal performance</li> </ul>	<ul style="list-style-type: none"> <li>» very good dielectric strength</li> <li>» outstanding thermal performance</li> <li>» mechanical resistance</li> </ul>	<ul style="list-style-type: none"> <li>» very good dielectric properties</li> </ul>
Applications	<ul style="list-style-type: none"> <li>» high-voltage motors</li> <li>» wind turbine generators</li> <li>» inverter-driven industrial motors</li> </ul>	<ul style="list-style-type: none"> <li>» traction motors</li> <li>» motors for heavy-duty applications (rolling mills, mining machines, oil pumps etc.)</li> <li>» aircraft generators and marine engines</li> </ul>	<ul style="list-style-type: none"> <li>» high-temperature coils</li> <li>» traction motors</li> <li>» stirring coils</li> </ul>	<ul style="list-style-type: none"> <li>» motors of class H...200</li> <li>» special motors for cooling pumps, mining machines etc.</li> </ul>

<sup>1)</sup> The temperature index is derived from tests carried out according to IEC Publication 60172 or NEMA MW 1000. It gives an indication of how the wires behave when exposed to heat, but it does not necessarily equal the service temperature at which the wires can be used.

<sup>2)</sup> Besides copper, other conductor materials, such as oxygen-free copper, nickel plated copper, nickel, superconductors and special alloys are possible on request.

<sup>3)</sup> Instead of round or rectangular wires other types, such as litz wires and hollow conductors can be insulated as well.

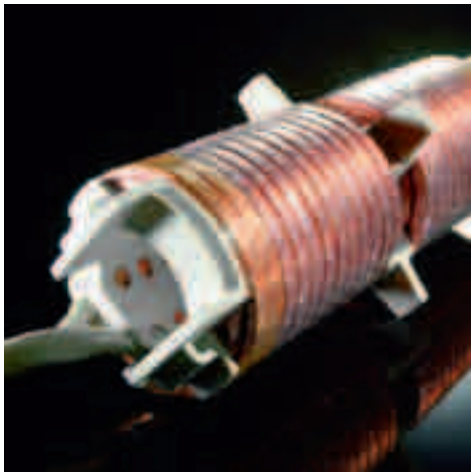
## Enabling Energy with Litz Wires

High-Frequency litz wires consist of bunched, solderable, enamelled Soldex® wires. The enamel insulation is based on modified polyurethane. The bunched strands can be covered with one or two layers of natural silk or polyamide yarn.

High-frequency litz wires are directly solderable with the lapping and enamel still in place. Individual solderable Soldex wires in temperature classes 155 or 180 and enamel application classes Grade 0, Grade 1 and Grade 2 are used in our standard high-frequency litz wires, depending on customer requirements. The standard filaments used for the covering are either natural silk or polyamide (Nylon) yarns, but high-frequency litz wires can also be taped with polyester foil.

All litz wires are also available without additional insulation.

### Applications



Primary coil high-frequency transformer



32 kW transformer for switched power supply  
© Vacuumschmelze GmbH



Toroid coil © Schaffner EMV



High-frequency transformers

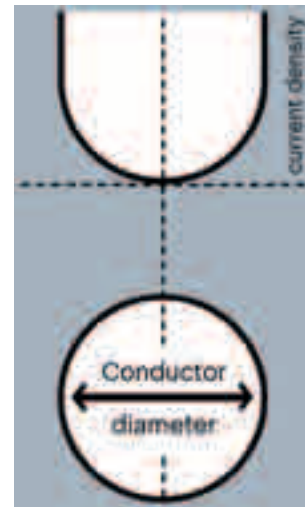


## Why High-Frequency Litz Wires?

High-frequency litz wires consist of bunched enamelled strands. They are used to counteract the increase in conductor resistance (impedance) at higher frequencies. The fields of an alternating current cause eddy currents in an electrical conductor, and these work against the flow of current. The effect of these eddy currents increases at higher frequencies. Accordingly, a frequency-dependent AC resistance is added to the DC resistance. The eddy losses are at their greatest inside the conductor and fall off toward the outside.

The greatest part of the current therefore flows at the surface of the conductor (what is known as the skin effect). It is also called the skin depth of the current. In the case of the proximity effect, the eddy losses are caused by the fields of adjacent conductors. In order to minimize these losses, the cross-sectional area of the single conductor is reduced (lower eddy losses), and several conductors are run "in parallel." To balance out the effects of the fields on the individual conductors, the conductors are twisted together. The twist must be chosen so that, from the viewpoint of the length of the litz wire, the position of one wire alternates regularly between the core and the outside of the package. High-frequency litz wires should be used only up to approximately 2MHz, because the capacitance effect of the conductor becomes too great at higher frequencies. Approximate diameters of individual strands as a function of frequency are listed below:

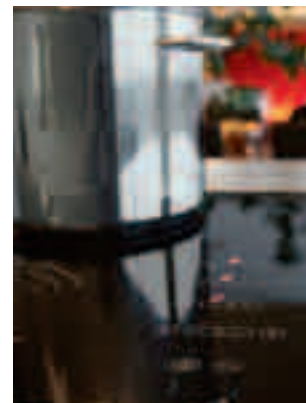
Frequency	Individual strand diameter
50 Hz – 1 kHz	0.400 mm
1 kHz – 10 kHz	0.250 mm
10 kHz – 20 kHz	0.200 mm
20 kHz – 50 kHz	0.125 mm
50 kHz – 100 kHz	0.100 mm
100 kHz – 250 kHz	0.071 mm
250 kHz – 500 kHz	0.063 mm
500 kHz – 850 kHz	0.050 mm
850 kHz – 1.5 MHz	0.040 mm
1.5 MHz – 2.8 MHz	0.032 mm



Transrapid train © Thyssen Krupp



Electric cars



Induction hot plate

## Standard High-Frequency Litz Wires

Von Roll standard high-frequency litz wires comply with IEC 60317-11 and DIN 46447 standards.

However, our product range includes a much wider range of structures.

Dimensions	
Single-wire diameter	0.03mm to 0.50mm
Number of strands	from 2 to several thousand

### Pitch (length of lay)

Pitch is a major factor in the construction of an high-frequency litz wire. It determines the flexibility, form stability, electrical resistance and winding characteristics of the litz wire.

A **short pitch** produces a litz wire with good form stability, fairly high resistance and a rounder profile.

A **long pitch** produces a more flexible and more economical litz wire.

Our standard pitches are:

Litz wires without covering	
≤ 1.50mm external Ø	approx. 10 to 25mm
> 1.50mm outer Ø	approx. 12 to 16 x outer Ø
Covered litz wires with braiding	
≤ 1.50mm external Ø	approx. 20 to 45mm
> 1.50mm outer Ø	approx. 16 to 26 x outer Ø

## Additional Insulation

Lapping/taping	Increase due to insulation		Characteristics
	1 layer	2 layers	
Without additional insulation			<ul style="list-style-type: none"> <li>» high copper fill factor</li> <li>» directly solderable without prior removal of the insulation</li> </ul>
Natural silk	30–40 µm	60–80 µm	<ul style="list-style-type: none"> <li>» thermal stability up to 110°C</li> <li>» directly solderable without prior removal of the insulation</li> <li>» small increase of insulation</li> <li>» suitable for honeycombed coils</li> </ul>
Polyamide yarn	40–50 µm	80–100 µm	<ul style="list-style-type: none"> <li>» thermal stability up to 130°C</li> <li>» no decomposition, only a buildup of molten pearls</li> <li>» heat-treated, therefore no unravelling when cut to length</li> </ul>
Polyester tape Thickness 12 to 23 µm	Depending on tape thickness and type of foil		<ul style="list-style-type: none"> <li>» high dielectric strength</li> </ul>

## Special Designs

We can supply a wide range of litz wire structures to suit customers' special applications. Depending on the application, bunching, stranding, pitch and twisting direction can be chosen individually.

### Round Litz Wires

Dimensions	
Single wire Ø	0.03mm up to 1.00mm
Number of strands	from 2 to several thousand
External Ø	up to 20mm

### Selection of Single Wire

Bare or enamelled to Grade 0, Grade 1, Grade 2 or Grade 3

Wire type	Base	Temperature class	Characteristics
Soldex®	PU	155, 180	solderable at approx. 375°C
Thermex® S180	PEI, modified	180	tinnable enamel at approx. 470°C / resistant to transformer oil
Thermex® 200	PEI + PA	200	good thermal stability
Thermibond® 158	PEI + PAI + thermosetting adhesive	200	self-bonding
Thermofix®	PU + thermoplastic adhesive	130, 155	solderable, self-bonding

### Additional Types of Insulations

- » One or more layers of lapping/braiding made of a range of yarns, e.g. polyamide, cotton, glass, polyester, aramide etc.
- » One or more layers made of polyester foil, polyimide foil, aramide paper, glass tape or Samica® with up to 75% overlap.
- » Insulation consisting of adhesive-coated foils such as polyester tape and polyimide is heat-treated to obtain good bonding. Various combinations are possible.
- » Extruded litz wires (PUR, PVC, PE/XLPE, HFFR, silicone).



High-frequency litz wire



Various types of litz wire

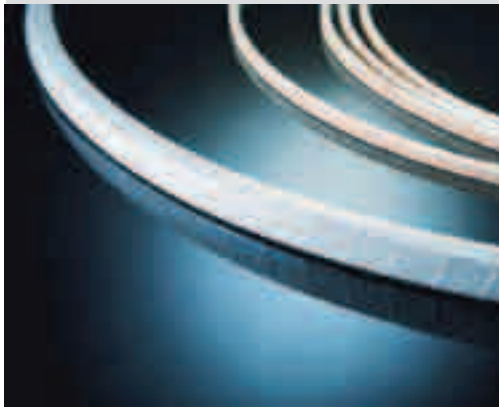
## Rectangular Litz Wires

To optimize the fill factor, it is preferable to use bare or HV-litz wires with a rectangular profile.

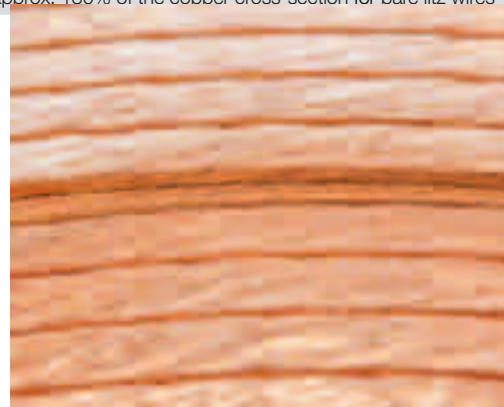
The filling factor is increased by:

- » compressing the litz wire
- » better filling of the winding space thanks to the rectangular geometry

Dimensions	
Single-wire diameter	from Ø 0.10mm to 1.00mm
Standard diameters enamelled wire	0.10, 0.25, 0.40, 0.50, 1.00mm
Standard diameters bare wire	0.30, 0.50, 1.00mm
Total copper cross-section	1.0 to >100mm <sup>2</sup>
Section ratio	1.25 : 1 to 3 : 1
Cross-section of the rectangular litz wire	approx. 160% of the copper cross-section for HF-litz wires approx. 130% of the copper cross-section for bare litz wires



Rectangular litz wire taped with aramide paper



Rectangular litz wire without tape insulation

## Selection of Single Wire

Bare or enamelled to Grade 0, Grade 1 or Grade 2

Wire type	Base	Temperature class	Characteristics
Thermex® S180	PEI, modified	180	tinnable enamel at approx. 470°C / resistant to transformer oil
Thermex® 200	PEI + PA	200	good thermal stability
Thermibond® 158	PEI + PAI + thermosetting adhesive	200	self-bonding

## Additional Types of Insulations

- » One or more layers made of polyester foil, polyimide foil, aramide paper, glass tape or Samica® with up to 75% overlap.
- » Insulation consisting of adhesive-coated foils such as polyester tape and polyimide is heat-treated to obtain good bonding. Various combinations are possible.

## Overview of bare and enamelled litz wires

Bare litz wires	Enamelled litz wires
High flexibility - especially for rectangular litz wires	Mainly for high-frequency application
Flat rolled litz wires: Filling factor 76 to 80%	Flat rolled litz wires: Filling factor 66 to 78% (depending on cross-section and the insulation increase of the enamel, Grade 2, Grade 1, Grade 0)
	Avoid losses caused by skin effect, proximity effect
Easy connection	
Cheaper design	
Typical application examples	
Transformers	Contactless power transmission
Converters	Induction heating, induction hot plates
Uninterruptible power supplies	Low-voltage, high-voltage rotating machines
Filter	High-frequency transformers
Ballasts	Switched power supply



High-frequency litz wire



Various types of litz wire

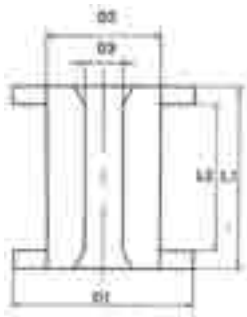
### The Advantage to You

- » Leading manufacturer of electrical insulation systems
- » Own production of a large range of enamelled wires
- » Wide range of machines for lapping, braiding and taping litz wires
- » A large range of yarns (polyamide, polyester, natural silk, glass) and tapes (polyester PET, polyester PEN, polyimide, aramide paper, Samica®)
- » Worldwide service through our own sales offices and agents
- » Competent, customer-focused partners

## Packaging of Litz and Winding Wires

Cylindrical reels acc. to IEC 60264-2, DIN 46399

Type	D1	D2	D3	D4	D5	L1	L2	Wire capacity	
								Round	Rectangular
160	160	100	22	–	–	160	128	6kg	–
200	200	125	22	–	–	200	160	12kg	–
250	250	160	22	–	–	200	160	20kg	–
355	355	224	36	–	–	200	160	40kg	45kg
500	500	315	36	–	–	250	180	80kg	100kg

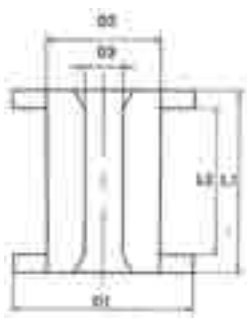


Cylindrical reels acc. to DIN 46395 and others

Type	D1	D2	D3	D4	D5	L1	L2	Wire capacity	
								Round (covered)	Rectangular
D710	710	500	41/51	–	–	250	180	180kg	200kg
D8p	800	400	40	–	–	270	200	320kg	350kg
VM 630	630	315	40	–	–	230	180	–	150kg
VM 800	800	380	42	–	–	270	195	–	350kg
E5*	500	250	127	–	–	250	200	–	120kg
T500**	500	360	40	–	–	235	200	–	80kg

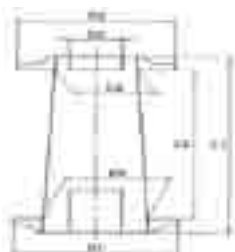
\*one-way plastic reel

\*\* one-way wooden reel



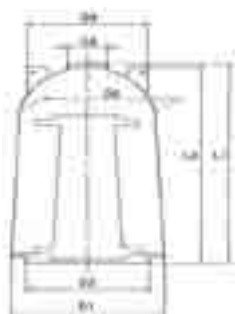
Conical reels acc. to IEC 60263-3, DIN 46383

Type	D1	D2	D3	D4	D5	L1	L2	Wire capacity
								Round
250/400	250	160	100	140	236	400	335	45kg
315/500	315	200	100	180	300	500	425	90kg
400/630	400	250	100	224	375	630	530	180kg



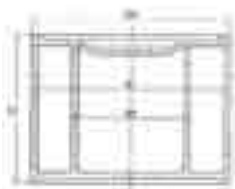
Covers for conical reels

Type	D1	D2	D3	D4	D5	L1	L2
250/400	310	255	250	100	270	475	470
315/500	388	315	305	100	338	607	595
400/630	490	400	390	100	428	763	748



Cardboard draw-packs acc. to IEC 60264-1, DIN 43396

Type	D1	D2	D3	H	Wire capacity
315	315	200	340	355	50kg
500	500	315	530	400	200kg



# 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

All materials related to high-voltage insulation. Von Roll's commitment to mica starts with mining and ends with finished tapes.



## Wires

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



## Cables

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



## Liquids

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



## 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.



## Flexibles

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



## Ballistic Protection

High-quality systems for armored defense based on thermoset / thermoplastic products in single-use or tailored combinations.



## Transformers

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



## Testing

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



## Training

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

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

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### About Von Roll

We Enable Energy – As one of Switzerland's longest established industrial companies, Von Roll focuses on products and systems for power generation, transmission and distribution. Von Roll's business portfolio is divided into five business segments: **Von Roll Insulation** is the global market leader in insulation products, systems and services. **Von Roll Composites** produces composite materials and parts for assorted industry appliances. **Von Roll Transformers** offers complete solutions for the fast expanding market of high performance transformers. **Von Roll Water** provides solutions for process engineering tasks in the field of water and waste water management. **Von Roll Solar** is developing a third-generation solar cell.