

Insulation That Can Take It

3M™ ThermaVolt AR Electrical Insulating Paper

3M™ ThermaVolt AR (TVAR) Electrical Insulating Paper combines the best of two technologies – inorganic and aramid. The result is the excellent thermal conductivity and voltage endurance of inorganic insulation plus the strong mechanical and thermal properties you expect of aramid insulation. With good mechanical strength – particularly tensile and tear strength – TVAR insulating paper maintains its integrity while remaining conformable.

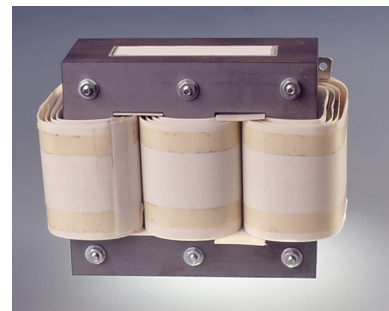
Made with inorganic material, TVAR insulating paper has higher thermal conductivity than meta-aramid fiber insulation, which can enable coil performance improvement. As an example, an existing coil design may have a lower temperature rise at the same power level or the coil load may be increased while the temperature rise is held constant. If the coil design is optimized for higher thermal conductivity, this may result in smaller conductor size and lower overall material cost, and potentially higher efficiency, depending upon the coil design.

TVAR insulating paper can meet some of the most demanding applications with minimal environmental and human impact. TVAR insulating paper is RoHS & REACH compliant. It also has earned the HL3 rating, the most stringent in EN 45545-2, which is the standard for fire safety requirements for electrical equipment on railway vehicles.

Applications

Open-ventilated dry-type transformers, motors and generators rated through Class 220(R)

- Major and minor ground insulation
- Core wrap
- High-low barrier
- Inter-winding and turn insulation
- Phase insulation



Features	Advantages	Benefits
High thermal conductivity	May lower coil temperature rise Can decrease coil size for the same power rating and temperature rise	Potentially longer transformer life and greater overload capability Reduced conductor size and reduced or eliminated air gaps result in lower cost for same power rating
Good mechanical strength	Resists damage during handling	Excellent conformability for assembly
Long-term voltage endurance	Resists partial discharge damage	Longer insulation life during partial discharge
Low moisture absorption	Can improve dimensional stability	Coil assembly with reduced humidity control concerns
EN 45545-2 HL3 Rating	Meets highest standard for fire safety requirements for electrical equipment on railway vehicles	Ensures railway industry compliance
RoHS & REACH Compliant	Meets global environmental, health and safety standards	Reduced human and environmental impact

3M™ ThermaVolt AR Electrical Insulating Paper Typical Mechanical and Electrical Properties

Not for specifications. Values are typical, not to be considered minimum or maximum.
Properties measured at room temperature 73°F (~23°C) unless otherwise stated.

3M™ ThermaVolt AR Insulating Paper is qualified for use as major ground insulation in electrical insulation systems rated through Class 220(R) per UL 1446 and IEC Std. 61857.



		ASTM Test Method	3 mil	4 mil	5 mil	5.5 mil	7 mil	10 mil	11.5 mil	15 mil	20 mil	30 mil
Nominal Thickness	mm	D-645	0.08	0.10	0.13	0.14	0.18	0.25	0.29	0.38	0.51	0.71
	mil		3	4	5	5.5	7	10	11.5	15	20	30
Basis Weight	g/m ²	D-202	87	105	168	186	244	326	429	501	668	1032
	lb/yd ²		0.16	0.19	0.31	0.34	0.45	0.60	0.79	0.94	1.2	1.9
Density	g/cc		1.1	1.1	1.3	1.3	1.4	1.3	1.5	1.3	1.3	1.3
Tensile Strength, MD	lb/inch	D-828	25	52	72	70	81	98	135	190	234	319
	N/cm		44	91	126	123	142	172	236	333	410	559
Tensile Strength, CD	lb/inch	D-828	10	20	30	26	34	36	65	82	102	152
	N/cm		18	35	53	46	60	63	114	144	179	266
Elongation to Break, MD	%	D-828	1.9	2.5	3.5	2.0	2.9	2.5	3.0	4.7	4.5	3.9
Elongation to Break, CD	%	D-828	1.4	3.2	4.1	2.9	2.6	2.0	2.5	3.8	3.7	3.6
Elmendorf Tear, MD	g	D-689	146	173	312	245	416	537	505	824	1276	1718
	N		1.4	1.7	3.1	2.4	4.1	5.3	4.9	8.1	12.5	16.8
Elmendorf Tear, CD	g	D-689	362	530	780	775	1050	1448	1110	2184	2752	>3200
	N		3.5	5.2	7.7	7.6	10.3	14.2	10.9	21.4	27.0	>31.4
Dielectric Breakdown Strength	kV		0.85	0.98	1.5	2.4	2.8	3.8	6.5	7.4	8.6	14.8
	V/mil	D-149	280	245	300	435	400	380	570	490	430	490
	kV/mm		11	10	12	17	16	15	22	19	17	19
Moisture Absorption	%	D-644	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Available Roll Sizes*	Sq yd		1090	815	650	595	465	325	285	220	160	110
	Sq m		910	680	545	495	390	270	240	185	135	92

*Roll width: 36 inches (914 mm). Roll thickness, size and weight are for guideline purposes only, as they can vary by +/- 15%.

Product is also available in 8.5" x 11", 24" x 36" or 36" x 36" sheets.

Thermal Conductivity

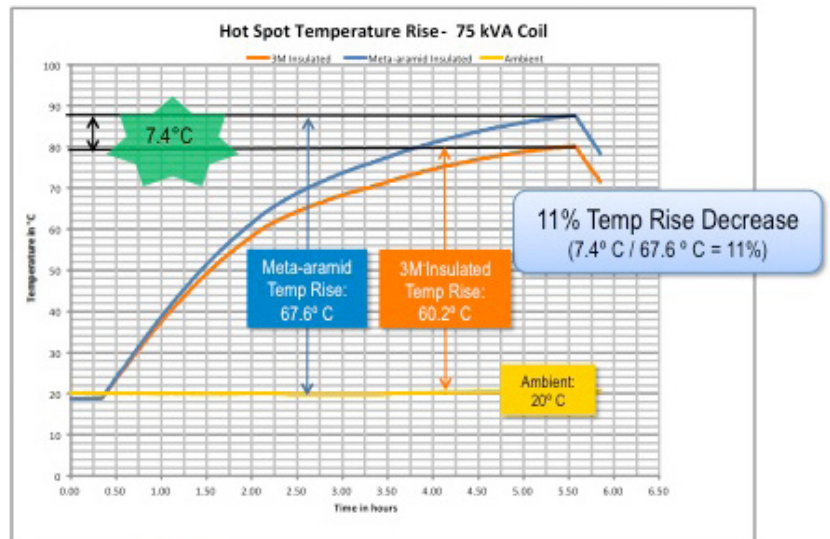
3M™ ThermaVolt AR (TVAR) Electrical Insulating Paper has excellent thermal conductivity performance, which can increase the heat dissipation required in today's high-efficiency electrical apparatus. Its high thermal conductivity helps enable a transformer that has been designed with calendered meta-aramid to run cooler, or if the transformer is redesigned, to potentially reduce size, utilizing less conductor, resulting in lower total transformer cost.

		ASTM Test Method	3 mil	4 mil	5 mil	7 mil	11.5 mil
Thermal Conductivity (180°C)	W/m-K	E-1530	0.10	0.13	0.16	0.17	0.23

For a 75 kVA coil that was designed with minimal cooling ducts, the coil fabricated with a combination of TVAR insulating paper and 3M ThermaVolt Calendered Inorganic Insulating Products had a maximum temperature rise that was 11% less than the same coil insulated with calendered meta-aramid. In this case, the 3M-insulated coil runs cooler, which results in the insulation having more overload capability and longer life.



Two identical 75 kVA coils;
One with 3M™ Insulation and
one with calendared meta-aramid



Another option is to optimize the coil design for smaller size and lower cost using TVAR insulating paper.

- Reduction in conductor cross sectional area
 - As conductor size decreases, electrical resistance increases, which increases the heat generated. Designs with reduced conductor size and high thermal conductivity insulation may achieve temperature rise equal to designs with larger conductor and lower thermal conductivity insulation.
- Reducing or eliminating air gaps
 - Decreases overall size of coil
 - Decreased circumference results in shorter conductor length

Example: 75 kVA Transformer Coil

- Material cost
 - 23% core
 - 73% conductor
 - 4% insulation
- Reduce conductor size by 11% since decrease in temperature rise was 11%
- Result: 8% decrease in total material cost

Conductor % of material cost	73%
Reduction in conductor material	x11%
Material cost savings	8%

Total System Cost Savings: 8%
Exceeds cost of the insulation
(Calculated cost of savings can vary depending on transformer design.)

Resistance to Partial Discharge

Most equipment is designed to avoid partial discharge or corona attack that may lead to premature failure. However, there are cases where it is not practical to do so or there are external factors that substantially increase the dielectric stress so materials must be used that are resistant to damage caused by partial discharge.

Made with inorganic material content, 3M™ ThermaVolt AR (TVAR) Electrical Insulating Paper exhibits excellent resistance to partial discharge and enables long-term voltage endurance.

To understand the level of performance, TVAR insulating paper and calendered meta-aramid insulation were tested through a procedure developed for variable-frequency drives. With a voltage of 180 volts per mil to ensure corona, a 20-kilohertz square wave and a temperature of 150°C, the test is more severe with an expected shorter time to failure relative to a traditional 60-hertz frequency test. This is due to the voltage cycles being more than 300 times faster, the square wave being more destructive than a sine wave and the increased temperature decreasing insulation life.

The average time to failure for the three calendered, meta-aramid 7-mil insulation samples was less than an hour. Three samples of 7-mil TVAR insulating paper completed more than nine days of testing before the first failure.

Inorganic-based materials can enable:

- Long-term Voltage Endurance
 - Resists partial discharge/corona
 - Greater electrical insulation reliability



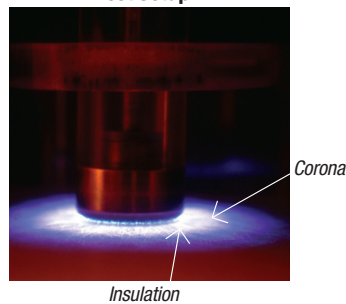
Voltage Endurance

Dielectric stress, v/mil (kV/mm): 180 (7.0)
 Frequency: 20-kHz/temperature: 150°C
 3 samples each insulation

Mean Time to Failure (in minutes)

Meta-aramid Insulation	22
3M™ TVAR Insulation	>13,200

Voltage Endurance Test Setup



	Calendered Meta-aramid Insulation 7-mil	3M™ TVAR Insulation 7-mil
Sample 1**	24	13,200
Sample 2**	20	17,760
Sample 3**	22	*60,660
AVERAGE (minutes)	22	>13,200

*Test terminated (no failure)

**Test conducted by third party, 2013

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