

## Thermal Conductivity

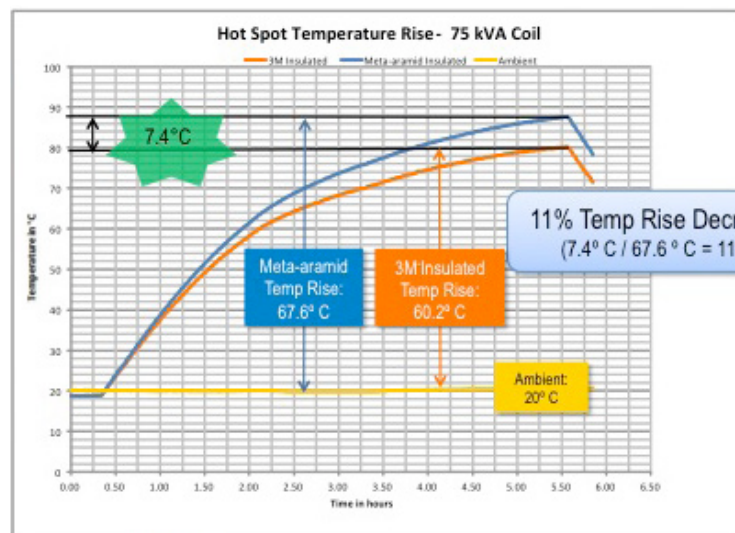
3M™ ThermoVolt Calendered Inorganic Insulating Products have excellent thermal conductivity performance, which can increase the heat dissipation required in today's high-efficiency electrical apparatus. The high thermal conductivity helps enable a transformer that has been designed with calendered meta-aramid to run cooler, or if the transformer is redesigned, to potentially reduce size, utilizing less conductor, resulting in a lower total transformer cost.

ASTM Test Method		3 mil	5 mil	7 mil	10 mil	15 mil	
Thermal Conductivity (180°C)	W/m-K	E-1530	0.15	0.17	0.18	0.21	0.25

For a 75 kVA coil that was designed with minimal cooling ducts, the coil fabricated with a combination of ThermoVolt insulating paper and 3M ThermoVolt AR Electrical Insulating Paper 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 calendered meta-aramid



Another option is to optimize the coil design for smaller size and lower cost using ThermoVolt 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, 3M™ ThermoVolt Calendered Inorganic Insulating Products exhibit excellent resistance to partial discharge and enable long-term voltage endurance.

To understand the level of performance, ThermoVolt 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 thick insulation samples was less than an hour. Three samples of 7-mil ThermoVolt insulating paper were tested for more than two months without failure, at which time the test was stopped.

### 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)**

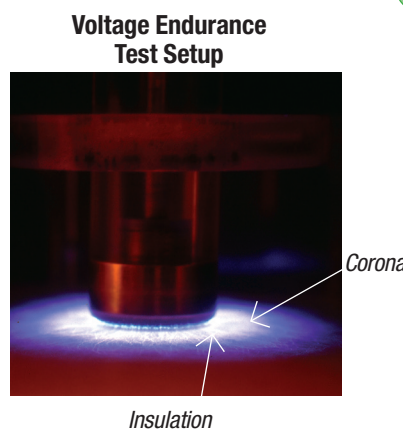
Meta-aramid Insulation	22
3M™ ThermoVolt Insulation	>98,940*

\*No failures, stopped test

	Calendered Meta-aramid Insulation 7-mil	3M™ ThermoVolt Insulation 7-mil
Sample 1**	24	*98,940
Sample 2**	20	*98,940
Sample 3**	22	*98,940
AVERAGE (minutes)	22	>98,940

\*Test terminated (no failure)

\*\*Test conducted by third party, 2013



3M is a trademark of 3M company.

### Important Notice

All statements, technical information, and recommendations related to 3M's products are based on information believed to be reliable, but the accuracy or completeness is not guaranteed. Before using this product, you must evaluate it and determine if it is suitable for your intended application. You assume all risks and liability associated with such use. Any statements related to the product which are not contained in 3M's current publications, or any contrary statements contained on your purchase order shall have no force or effect unless expressly agreed upon, in writing, by an authorized officer of 3M.

### Warranty; Limited Remedy; Limited Liability.

This product will be free from defects in material and manufacture at time of manufacture. **3M MAKES NO OTHER WARRANTIES INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.** If this product is defective within the warranty period stated above, your exclusive remedy shall be, at 3M's option, to replace or repair the 3M product or refund the purchase price of the 3M product. **Except where prohibited by law, 3M will not be liable for any indirect, special, incidental or consequential loss or damage arising from this 3M product, regardless of the legal theory asserted.**



### Electrical Markets Division

6801 River Place Blvd.  
Austin, TX 78726-9000  
855 293 6018  
Fax 800 245 0329  
electricaloem@3m.com  
www.3m.com/flexibleinsulation

Please recycle. Printed in USA.  
© 3M 2014. All rights reserved.  
80-6016-0767-6



## 3M™ ThermoVolt Calendered Inorganic Insulating Paper

3M™ ThermoVolt Insulating Paper meets the high performance requirements for high-temperature, dry-type transformers as major ground insulation in electrical systems rated through Class 220(R). ThermoVolt paper offers good dielectric characteristics, excellent partial discharge resistance and high thermal conductivity – making it especially suitable for use as interwinding insulation in strip-wound coils.

ThermoVolt paper also is available bonded with polyester (PET) film for applications that require enhanced stiffness and formability, such as ground and layer insulation.

ThermoVolt insulating paper, made with inorganic material, has higher thermal conductivity than meta-aramid fiber insulation and 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.

ThermoVolt insulating paper and laminates are RoHS & REACH Compliant.

### Applications

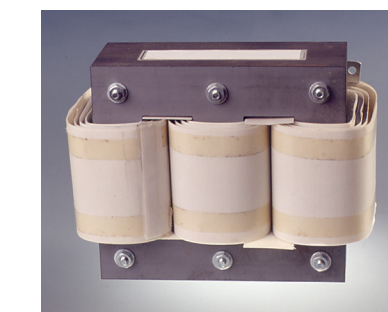
Open ventilated dry-type transformers rated through Class 220(R)

#### Major Insulation

- Ground insulation
- Core and outer wrap
- Interwinding (or high-low) insulation
- Turn insulation

#### Minor Insulation

- Layer 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
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
RoHS & REACH Compliant	Meets global environmental, health and safety standards	Reduced human and environmental impact
UL 94 V0 Rating*	Ensures resistance to ignition and flame spread	Excellent flammability performance

\*ThermoVolt insulating paper only. Does not include ThermoVolt Laminates.

### 3M™ ThermaVolt Calendered Inorganic 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 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.



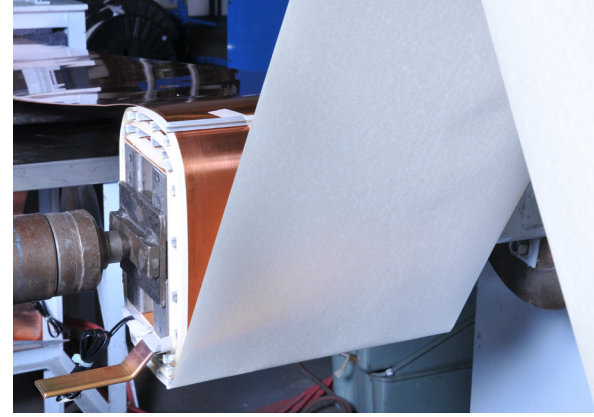
		ASTM Test Method	3 mil	5 mil	7 mil	10 mil	15 mil
Nominal Thickness	mm	D-645	0.08	0.13	0.18	0.25	0.38
	mil		3	5	7	10	15
Basis Weight	g/m <sup>2</sup>	D-202	103	195	274	366	561
	lb/yd <sup>2</sup>		0.19	0.36	0.49	0.67	1.04
Density	g/cc		1.4	1.5	1.5	1.5	
Tensile Strength, MD	lb/inch	D-828	17	31	41	53	100
	N/cm		30	54	72	93	175
Tensile Strength, CD	lb/inch	D-828	8	16	22	34	58
	N/cm		14	28	39	60	102
Elongation to Break, MD	%	D-828	1.5	1.5	1.5	2.0	
Elongation to Break, CD	%	D-828	1.1	1.1	1.1	2.0	
Elmendorf Tear, MD	g	D-689	40	108	172	280	534
	N		0.4	1.1	1.7	2.7	5.2
Elmendorf Tear, CD	g	D-689	60	142	302	354	734
	N		0.6	1.4	3.0	3.5	7.2
Dielectric Breakdown Strength	kV	D-149	1.1	3.0	3.3	5.0	8.0
	V/mil		365	590	470	500	530
	kV/mm		14.4	23.2	18.5	20.9	
Dielectric Constant 23°C, 50% RH, 50 Hz		D-150	3.5	3.9	4.0	4.0	
Dissipation Facor 23°C, 50% RH, 50Hz	%	D-150	7	7	7	7	
Moisture Absorption	%	D-644	<1	<1	<1	<1	
Flame Rating	UL File	UL94	V-0, 5VA	V-0, 5VA	V-0, 5VA	V-0, 5VA	V-0, 5VA
	E65069						
Available Roll Sizes*	Sq yd		1090 & 2960	650 & 1775	465 & 1270	325 & 890	220 & 590
	Sq m		910 & 2475	545 & 1485	390 & 1060	270 & 745	185 & 495

\*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.

### 3M™ ThermaVolt Calendered Inorganic Insulating Paper and TvF Laminates 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 TvF Laminate is ThermaVolt Inorganic Calendered Insulating Paper bonded to one layer of polyester (PET) film. This laminate exhibits superior mechanical and dielectric strength while maintaining excellent long-term performance and low moisture absorption. It 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	TvF 3+1	TvF 3+2	TvF 4+1	TvF 4+2	TvF 5+1	TvF 5+2	TvF 7+1	TvF 7+2
Nominal Thickness	mm	D-645	0.10	0.13	0.13	0.15	0.15	0.18	0.20	0.23
	mil		4	5	5	6	6	7	8	9
Basis Weight	g/m <sup>2</sup>	D-202	143	180	196	233	235	272	314	351
	lb/yd <sup>2</sup>		0.264	0.33	0.36	0.43	0.43	0.50	0.58	0.65
Density	g/cc		1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.5
Tensile Strength, MD	lb/inch	D-828	31	53	39	61	44	63	60	68
	N/cm		54	93	68	107	77	285	105	119
Tensile Strength, CD	lb/inch	D-828	30	60	27	58	30	55	42	56
	N/cm		53	105	47	102	53	96	74	98
Elongation to Break, MD	%	D-828	2	9	4	3	4	3	4	4
Elongation to Break, CD	%	D-828	7	6	6	4	6	4	6	8
Elmendorf Tear, MD	g	D-689	76	120	92	150	108	172	160	224
	N		0.7	1.2	0.9	1.5	1.0	1.7	1.6	2.2
Elmendorf Tear, CD	g	D-689	98	157	119	220	140	232	232	256
	N		0.9	1.5	1.2	2.2	1.4	1.9	2.3	2.5
Dielectric Breakdown Strength	kV		6	8	6	8	6	9	6	9
	V/mil	D-149	1500	1600	1200	1300	1000	1300	750	1000
	kV/mm		59	63	47	51	39	51	30	39
Moisture Absorption	%	D-644	<1	<1	<1	<1	<1	<1	<1	<1
Available Roll Sizes*	Sq yd		815 & 2220	650 & 1775	650 & 1775	545 & 1480	545 & 1480	465 & 1270	410 & 1100	360 & 990
	Sq m		680 & 1860	545 & 1485	545 & 1485	455 & 1235	455 & 1235	390 & 1060	345 & 930	300 & 830

\*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.

### 3M™ ThermaVolt Calendered Inorganic Insulating Paper and TvFTv Laminates 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 TvFTv Laminates have ThermaVolt paper bonded to both sides of the polyester (PET) film, which maximizes the amount of ThermaVolt material exposed in a laminate configuration. This laminate exhibits very high mechanical and dielectric strength while maintaining excellent long-term performance and low moisture absorption. It 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	TvFTv 3+1+3	TvFTv 3+3+3	TvFTv 3+5+3	TvFTv 4+2+4	TvFTv 5+1+5	TvFTv 5+2+5	TvFTv 5+5+5	TvFTv 5+7.5+5	TvFTv 7+1+7	TvFTv 7+2+7	TvFTv 7+14+7
Nominal Thickness	mm	D-645	0.18	0.23	0.28	0.25	0.28	0.30	0.38	0.45	0.38	0.41	0.71
	mil		7	9	11	10	11	12	15	17.5	15	16	28
Basis Weight	g/m <sup>2</sup>	D-202	254	327	391	388	430	454	570	664	600	627	1050
	lb/yd <sup>2</sup>		0.47	0.60	0.72	0.71	0.79	0.84	1.05	1.22	1.11	1.16	1.94
Density	g/cc		1.4	1.4	1.4	1.6	1.5	1.5	1.5	1.5	1.5	1.5	
Tensile Strength, MD	lb/inch	D-828	52	101	120	87	60	97	142	195	95	149	327
	N/cm		91	178	210	152	105	170	249	341	166	261	572
Tensile Strength, CD	lb/inch	D-828	33	77	143	63	40	67	118	220	62	100	269
	N/cm		58	135	250	110	70	117	207	385	109	175	471
Elongation to Break, MD	%	D-828	2	3	4	3	3	3	3	4	2	2	4
Elongation to Break, CD	%	D-828	3	3	4	3	4	4	4	4	2	2	4
Elmendorf Tear, MD	g	D-689	170	480	484	400	250	350	552	740	380	800	1270
	N		1.7	4.7	4.8	3.9	2.5	3.4	5.4	7.3	3.7	7.8	12.4
Elmendorf Tear, CD	g	D-689	200	588	676	498	300	464	648	896	540	1000	2050
	N		1.9	5.8	6.7	4.9	2.9	4.6	6.4	8.9	5.3	9.8	20.1
Dielectric Breakdown Strength	kV		7.6	11	15	11	9.5	12	15	18	11	12	
	V/mil	D-149	1100	1200	1400	1100	860	1000	1000	1000	730	750	NA
	kV/mm		43	47	55	43	34	39	39	39	29	30	
Moisture Absorption	%	D-644	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Available Roll Sizes*	Sq yd		465 & 1270	360 & 990	300 & 805	325 & 890	300 & 805	270 & 740	220 & 590	185 & 510	220 & 590	205 & 555	115 & 315
	Sq m		390 & 1060	300 & 830	250 & 875	270 & 745	250 & 875	225 & 620	185 & 495	155 & 425	185 & 495	170 & 465	95 & 265

\*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.