# 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.

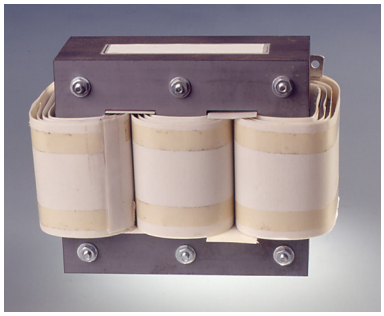
Made with inorganic material, TVAR insulating paper has higher thermal conductivity than meta-aramid fiber insulation, which can enable coil performance improvement. As an example, an existing coil design may have a lower temperature rise at the same power level or the coil load may be increased while 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 | Potentially longer transformer life and greater overload capability |
| | Can decrease coil size for the same power rating and temperature rise | 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 73ºF (~23ºC) 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 | D-149 | 0.85 | 0.98 | 1.5 | 2.4 | 2.8 | 3.8 | 6.5 | 7.4 | 8.6 | 14.8 |
| | V/mil | | 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.

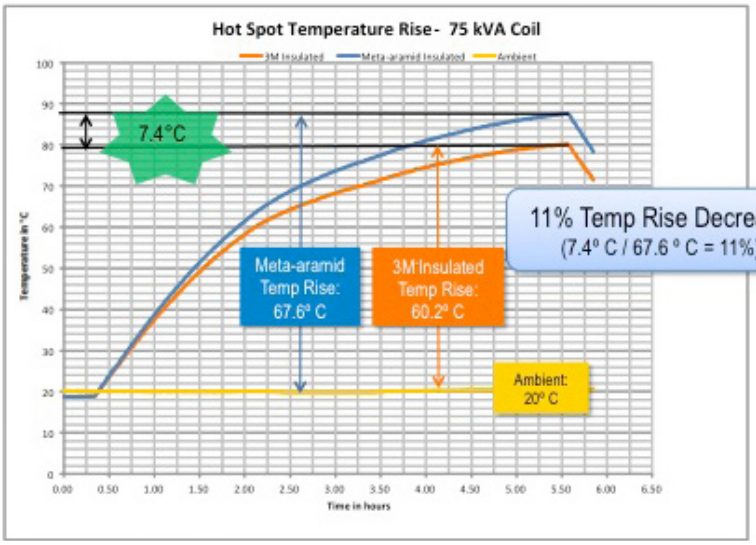
## Thermal Conductivity

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 (180ºC) | 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 150ºC, 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.

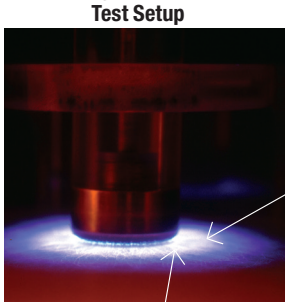
### Inorganic-based materials can enable:

- 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: 150ºC
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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