

APPLICATION GUIDELINE #38

(Medium Voltage Motor Insulation System)

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Features of a Quality Medium Voltage Insulation System:

- **Mechanical rigidity for elimination of movement:** Each time a motor starts (or sees an abrupt load variation), the stator-coil ends try to move as the magnetic forces inside the windings react to oppose one another. Whenever a stator winding flexes from any movements such as mechanical shocks during starting, pinch-stresses and cracks appear in the insulation and become a weak point for moisture and chemical contaminants. The portions of the windings in the stator slots are also subjected to tremendous forces that are equal to the force that moves the rotor. If the windings move, the ground wall insulation can be mechanically damaged. The hardness of the winding also serves as armor protection from any damaging impacts that could occur at the time of any disassembly.
- **Void-free encapsulation for maximum heat transfer:** One of the most damaging contributors in the breakdown of insulation is heat. The higher the temperature a winding is subjected to, the faster the degradation of dielectric and mechanical properties and the sooner the insulation will fail. The heat from the copper-loss inside the winding must pass through the insulation to either the cooling air or to the iron and then to the outer cooling air. Since air is a good insulator of heat, the elimination of all air pockets within the winding maximizes the flow of heat. The VPI not only provides the best heat transfer between the copper to the outside of the coil but also between the coil to the iron core. The coil-to-iron transfer is most important with the cooling path of a TEFC type of motor enclosure.
- **Chemical Inertness:** Another process in the degradation of insulation is from chemical decomposition of the materials. A motor can be located in areas where destructive elements such as petroleum, caustic vapors or abrasive, conductive dirt, or moisture can attack a winding over time. Epoxy, such as is used in a quality driven VPI process, is well known for being chemically stable against decomposition by environmental agents. Additionally, extensive life testing with chemical exposures to confirm the chemical resistance of the insulation system also provides good assurance.
- **Prevention of partial discharge:** [Partial discharge](#) (sometimes referred to as corona) cannot occur if there are no air gaps or voids in the insulation. A well controlled VPI process is very effective in eliminating voids in the insulation and between the winding and the stator steel.

Value-added features of the TOSHIBA Medium Voltage Motor Insulation System

Wire Insulation: Toshiba uses wires that are insulated with Heavy-polyester coated strands covered with a layer of glass wrap. It is these two types of materials that give each individual strand both superior electrical and mechanical strengths. The bottom coatings provide a dielectric strength well in excess of the voltage stresses that are present. The outer glass wrap provides protection against scrapes as well as greater resin absorption on the surface of the wire for improved bonding and heat transfer.

Wire Size: The rectangular shape of the individual strands are dimensioned to facilitate ease of production. Design limits are well established that will result in superior wind-ability and minimum

insertion stress that could damage the wire insulation. The wire size is also selected to minimize the stray losses internal to the coil-turns that contribute to heating and lower efficiencies.

Forming: Toshiba uses a two stage forming process. First, the strands are looped. At this point in production Toshiba takes an additional step to insure strand alignment with a dip and bake of the loops in hot presses. This rigidly cured alignment during the loop stage results in improved heat transfer and dimensional control. The loop is then formed into coils that are shaped by an expanding machine for insertion into the stator. This process forms the loops into a diamond shaped configuration of exacting dimensions and tolerances.

Tape Application: Dry tape containing mica flakes is then wrapped around the coils. Mica is used because of the superior dielectric properties. Based on the voltage of the motor the appropriate number of layers is applied. Taping machines are used to optimize the quality of half-lap layering. This tape also contains an epoxy catalyst that coagulates the resin during the VPI process to eliminate draining prior to curing. An external layer of Glass Tape is also applied to the coil for external protection against damage that might occur to the mica ground-tape during the coil insertion (winding) process. Layers of Mica Tape are applied to individual turns when the turn-to-turn voltage of a design requires additional dielectric protection. Semi-conducting tape is applied (as required by the voltage of a rating) to provide control of the dielectric stresses so as to suppress destructive electrical discharges.

Insertion: Once the coils have been formed and their dimensions confirmed the dry coils are inserted into the slots of the stator core. Since the coil insulation is in a flexible state at this stage, the insulation is unaffected by the deformation and mechanical stresses imposed by the insertion process. Additionally, a combination of expert winders and the optimum geometry of the formed coils minimize any excessive forces that could damage the insulation.

Connections: Skilled professionals connect the coil leads by hand soldering each joint. Connections are insulated using the same number of layers of Mica groundwall tape and glass that was applied to the coil groundwall insulation. The beginnings and ends of the phase connections are terminated with leads. For enhanced equality TOSHIBA uses high temperature and chemically stable material for the leads. The leads are made of flexible copper strands coated with Silicon Rubber insulation rated 200 deg. C. For increased durability the leads also have an additional sheathing of braided glass over the Silicon insulation to protect from damage.

End-Turn Bracing: Every time a motor is started (or sees an abrupt load variation), the stator coil ends try to move as the magnetic forces inside the windings react to oppose one another. Whenever a stator winding flexes from any movements such as mechanical shocks during starting, pinch-stresses and cracks can appear in the insulation and become a weak point for fatigue or ingress of moisture and chemical contaminants. Depending on the predetermined design criteria, based on coil geometry and magnetic forces present, TOSHIBA applies the appropriate blocking and tying materials for additional bracing of the stator winding end-turns. Braided epoxy rope is tightly laced to the end-turns with glass tie-cords so that when cured during the VPI bake cycle, they become fully integrated with the resin impregnated end-turn encapsulation.

Magnetic Top-Sticks: Prior to the VPI process, the dry, insulated coils are held in place by a flat stick located at the top of the stator slot toward the air gap. Typically the industry uses nonmagnetic poly-glass laminate material for top-sticks. Toshiba however, uses precisely dimensioned top-sticks made from magnetic material. When magnetic material is used to cover the slot openings located around the stator ID, it smoothes out the turbulence of flux in the air gap (permeance ripple) by filling the non-metallic notch of the slot opening. Non-magnetic material does not accomplish this effect. The benefit from the smoothing of the air gap is that the core loss and stray-load losses are reduced which lowers the internal heating and improves efficiency.

Vacuum Pressure Impregnation: The key to the high reliability of Toshiba's insulation system is the application of the "Total Immersion System" sometimes referred to as Global VPI. In this system the fully wound, braced, and connected stator coils are immersed and cured solidly together with the stator core steel. The wound stator assembly is preheated and placed into a pressure tank. A high degree of vacuum is drawn removing the air from the stator coils. The tank is then flooded with an Epoxy resin. Once the stator assembly is completely covered, the tank is pressurized. The absence of air and the subsequent introduction of resin under pressure sets up a condition where all voids throughout the stator winding become completely filled (impregnated) with resin. The preheating of the stator aids in the absorption of the epoxy into the winding by reducing the viscosity of the resin. Additionally, so that the epoxy resin does not drain out prior to curing, there is a catalyst in the Mica Tape that reacts with the epoxy to immediately coagulate the resin to a jell-like state. The resin impregnated stator assembly is then baked in an oven. Baking finishes the curing process resulting in a solid glass-like hardness. For additional insurance of internal penetration and added mechanical strength, Toshiba repeats the complete VPI process a second time.

Heating and Curing: It is important in the process to have a controlled heating and cooling cycle. The thermal stresses are carefully controlled through the monitoring and verification of the cycles as a Quality Control check.

In-Process Inspections: Throughout each process of the manufacture of Medium Voltage motors, TOSHIBA conducts extensive quality verifications to prescribed standards and limits prior to being used in subsequent manufacturing steps. The following is a list of the in-process checks that are performed on the insulation system. TOSHIBA performs all tests on 100% of the Medium Voltage motors manufactured in Houston. All QC test operations are in conducted accordance with procedures under the certified TOSHIBA ISO 9001 Quality Assurance plan.

- Incoming checks are performed on all raw materials.
- Dimensional checks are performed after the coil looping and coil forming stages.
- Wire insulation is reconfirmed after forming. In a process unique to Toshiba, the wire insulation is checked after the mechanically stressful coil forming. It is during the forming of the coil that the wire insulation can become damaged. In this quality check the vulnerable knuckles (corners) of **every coil** are scanned with a conducting brush to detect any dielectric damage.
- Dimensional checks are performed on insulated coils after taping.
- Wound coils are subjected to an [AC voltage dielectric withstand test \(Hi-pot\)](#) prior to VPI.
- Wound coils are subjected to an impulse [voltage surge comparison test](#) prior to VPI.
- Heating and curing cycles are monitored and charted to obtain records of process compliance.
- The VPI process of each motor is checked after curing by a Power Factor "Tip-up" test. Continuous records are kept of the winding Tan and Capacitance tests, which are used to confirm the absence of voids throughout the encapsulation.
- An AC voltage dielectric withstand test is again applied to each phase after final assembly. The TOSHIBA Medium Voltage Insulation System is a Class F 155°C rated temperature system. The encapsulating features of the TOSHIBA Insulation System enable it to meet and exceed the requirements of the NEMA MG1-20.49 Immersion test.

SUMMARY:

Insulation systems are subjected to thermal, electrical, mechanical, and environmental factors acting independently or together. The characteristics of a quality Insulation System that provide effective countermeasures to these destructive factors are:

- 1) Strong, durable mechanical properties of a fully distributed epoxy encapsulation.
- 2) Excellent properties of thermal durability in the materials with heat transfer optimized.
- 3) Chemical stability and complete encapsulation for high resistance to severe environmental conditions.

The high level of reliability in Toshiba Medium Voltage Motors is obtained from the quality enhancing features of the insulation system as described previously.

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