STAMFORD | AvK ™

POWERING TOMORROW, TOGETHER

Application Guidance Notes: Technical Information from STAMFORD | AvK

# AGN040 – Winding Insulation System

The object of the following information is to assist with ensuring the STAMFORD | AvK alternator, incorporated into a well-designed Generating Set, will meet the performance and service expectations for the varied Generating Set applications.

## WINDING PROTECTION ON STAMFORD ALTERNATORS

In the past, STAMFORD | AvK offered a 'double dip' impregnation process on main stator windings for alternators intended for use in severe environments. STAMFORD | AvK has since conducted analysis into the insulation materials available, together with advanced impregnation processes, to determine the optimum winding insulation system for each alternator model. This brought about changes to impregnation processes for a number of models in the STAMFORD range.

The strengths and weaknesses of the different impregnation options were analysed for processes that would offer a cost effective solution for best alternator life expectancy. By considering the much revered 'Dip & Bake' through to Vacuum Pressure Impregnation (VPI) and the associated impregnation materials.

## Definitions.

### Dip.

The traditional method of getting a good fill. This method involves standing the wound component vertically in the 'Dip tank' and then slowly allowing the impregnant to flood the tank and so naturally push the air upwards and out of the winding slot as the flood level rises. This is a lengthy exercise of approximately 1 hour to flood and then about 45 minutes to drain, before placing the wound component - now with winding slot horizontal - in the oven for 'The Bake'.

### Vacuum Pressure Impregnation.

Vacuum Pressure Impregnation (VPI) is a process that has been introduced to ensure good penetration of the impregnation resin/varnish into the full length of the lamination pack's winding slot area. The modern hi-tech VPI system is conducted in an autoclave. The vacuum removes all the air from the winding slot. The slow chamber flood combined with the chamber vacuum and vacuum in the windings and slot area, ensures slots are completely filled with impregnant. Then, when the final part of the process occurs, which is the pressure applied to the surface of the impregnant in which the wound component is now fully submerged, the impregnant is forced into any winding area corner/ crevice that has not been fully filled by the initial vacuum in conjunction with the slow flood.

### Baking.

Having gone to so much trouble to get the impregnant into the slot, it is most important to do the baking process with the entire impregnant still filling the slot. With a modern two part resin impregnant, the chemistry of this material means that it includes polymers of materials with 'barbs' that expand in such a way that they will not allow the resin to run out of the slot. Even so, the most advanced manufacturing process of conducting VPI and then Bake / Cure must be controlled around handling gently and in a time scale that works in conjunction with the resins designed chemistry.

### Trickle.

This process offers some benefits over both the above, but then introduces vagaries concerning the achieved level of slot fill if the process is not very tightly controlled. The material used is a modern chemically advanced resin, but probably not an epoxy resin as is normally used for the VPI process. The trickle process involves a process of continually spinning the wound component so that the impregnant does not run off. Of warming the dry wound component to help the applied impregnant thin down and so, run into the winding slot area. Of tilting the wound component such that gravity works with the venturi effect of naturally drawing the impregnant into the slot. Finally, when sufficient impregnant has been applied the heat /cure process is started. All the above with the wound component still rotating to ensure absolutely minimal drain-out and run-off and an even build up on the overhang.

**Analysis of process benefits.**

For volume manufacturing of a product, then the tightest possible Process Control (PC) will result in the most consistent product performance and if the correct process is being used, then will give consistently good life expectancy. VPI or trickle processes have distinct benefits over the old dip & bake scheme conducted under the control of 'experienced' operators.

STAMFORD | AvK changed from the old 'dip and bake' impregnation process some time ago and replaced it with a trickle process for smaller alternators and a VPI process for the larger alternators.

The materials used for the trickle flow process are a durable polyester resin with an epoxy sealant. The material used in the VPI process is a modern chemically advanced epoxy resin. These impregnation materials can be compared with the chemical advances now available with modern engine lubricating oils, from the traditional mineral oil = varnishes, to a semi-synthetic = two part resins, to the hi-spec. fully synthetic oil = Epoxy resins.

These insulation materials and impregnation processes have been engineered by STAMFORD | AvK to offer the wound components within the alternator the best possible protection against everyday contaminants that an open ventilated rotating electrical machine may be subjected to. The modern electrical impregnation materials incorporate a chemical resistance to moisture, oil, acid, and mild abrasion, along with an excellent tolerance to thermal cycling and heat soak. They are designed to withstand harsh environmental conditions, including marine, off-shore and coastal, and condition with high relative humidity.

**STAMFORD Insulation Systems & Impregnation Procedure.**

**S0/S1, P0/P1:**

Stator: Dip and Trickle (polyester) or Vacuum Impregnation (VI) using epoxy resin*

Rotor: Single Dip (polyester) or Hot Roll Dipping (HRD) using polyester or epoxy resin*

Exciter Field [stator]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

Exciter Armature [rotor]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

PMG Stator: Dip and Bake process using a polyester resin.

**UC 224 and UC 274:**

Stator: Dip and Trickle (polyester), Vacuum Impregnation (VI), or Vacuum Pressure Impregnation (VPI) using epoxy resin*

Rotor: Single Dip (polyester) or Hot Roll Dipping (HRD) using polyester or epoxy resin*

Exciter Field [stator]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

Exciter Armature [rotor]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

PMG Stator: Dip and Bake process using a polyester resin.

**N200/N300 range**

Stator: Vacuum Impregnation (VI) process using polyester resin

Rotor: Hot rotation dipping (HRD) process using polyester resin

Exciter Field [stator]: Vacuum Impregnation (VI) process using polyester resin

Exciter Armature [rotor]: Vacuum Impregnation (VI) process using polyester resin

**S4, S5, S6 (HC6) and S7 (P7):**

Stator: Vacuum Pressure Impregnation (VPI) using epoxy or polyester resin*

Rotor: Hot Roll Dipping (HRD) using epoxy or polyester resin*

Exciter Field [stator]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

Exciter Armature [rotor]: Vacuum Impregnation (VI) using epoxy resin or Dip and Bake using polyester resin*

PMG Stator: Dip and Bake process using a polyester resin

**S7 HV**

Stator: Vacuum Pressure Impregnation process, epoxy anhydride

Rotor: HRD impregnation process, epoxy resin

Exciter Field [stator]: Vacuum Impregnation (VI), polyester resin

Exciter Armature [rotor]: Vacuum Impregnation (VI), polyester resin

PMG Stator: Vacuum Impregnation (VI), polyester resin

**S9, P80:**

Stator: Vacuum Pressure Impregnation process using epoxy resin.

It is possible to specify an extra treatment of the VPI process.

Rotor: Vacuum Pressure Impregnation process using epoxy resin.

It is possible to specify an extra treatment of the VPI process.

Exciter Field [stator]: Vacuum Impregnation (VI), epoxy resin

Exciter Armature [rotor]: Vacuum Impregnation (VI), epoxy resin

PMG Stator: Dip and Bake process using a polyester resin.

**S9, P80 HV:**

Stator: Vacuum Pressure Impregnation process, epoxy anhydride

Rotor: Vacuum Pressure Impregnation process using Epoxy Resin

Exciter Field [stator]: Vacuum Impregnation (VI), epoxy resin

Exciter Armature [rotor]: Vacuum Impregnation (VI), epoxy resin

PMG Stator: Vacuum Impregnation (VI), polyester resin

**Processing and materials may differ slightly depending on source plant.*

**Options and Alternatives.**

A Taped Exciter Stator option is available for UC, S4, S5, S6 and S7 (P7) alternators manufactured in the Europe. The epoxy resin impregnated design has fully taped overhangs and black epoxy is sprayed to provide additional benefits in harsh environments.

The addition of drip proof louvres is recommended for alternators intended for use in Marine and Coastal applications.

In applications where the relative humidity is likely to be above 60%, the option of an Anti-Condensation Heater is recommended.

Further information on Severe Environmental Impregnation (SEI) is available from Applications Engineering. Contact applications@cummins.com for advice.

## INSULATION RESISTANCE

The alternator's Insulation Resistance (IR), along with many other critical factors, will have been measured during the STAMFORD | AvK factory processes of manufacture, assembly and test. The alternator will have been transported with a packaging appropriate for the journey to the Generating Set assembler's works, where it is expected it will be stored within a weather protective building. However, absolute assurance that the alternator will arrive at the Generating Set builder's production line with IR values still at the factory test levels of above 100 MegOhms is not possible.

The alternator should arrive at the Generating Set assembler's works in a clean dry condition. If held in appropriate storage conditions, the alternator IR value should be, typically, 25 MegOhms. If the unused / new alternator's IR values fall below 10 MegOhm, then a drying out procedure should be implemented by one of the processes outlined below before being dispatched to the Customers site, and some investigation undertaken into the storage conditions the alternator had been subjected to.

Whilst it is known that an alternator will give reliable service with an IR value of just 1 MegOhm, but for a new alternator to be this low, it must have been subjected to inappropriate storage conditions.

Any temporarily reduced IR values can be restored to expected values by following the following explained drying out procedures. Then further operation on load will complete a thorough heating of the winding assemblies and will completely dry-off the IR reducing moisture. The following is offered as helpful guidance, but should be read in conjunction with the alternator's Owner's Manual.

### Insulation Resistance Value.

The IR value when measured on a new wound component will have values above 100MegOhm. When in service, various mechanisms will contribute to factors that will affect the IR value, and site measurements of just a few MegOhms become more typical.

Major factors, which affect and reduce the IR value, start with the winding outhang. Surface moisture, often present in conjunction with surface contamination, are typically the result of prevailing site conditions. Either will seriously reduce measured IR values, and if the root cause that allows this contaminant to be present is not addressed then the expected MTBF will be considerably reduced.

The Owner's Manual that is issued with every alternator, includes a section on Service and Maintenance, to provide guidance about measuring the IR value and expected typical values.

If the IR measurement is considered to be low, and further guidance and understanding about the risk of operation of the alternator's insulation system is required, then the next test would be a **P**olarization **I**ndex - PI Test.

**Maintaining Acceptable IR Values.**

Basically, keep the wound component clean and dry, and good values of IR are assured. But achieving the 'clean and dry' has to be engineered into the original Generating Set design, and then maintained by an effective on-site 'care regime'.

Considerations at the Engineering stage must include a way to combat moisture and contaminants carried airborne with the cooling air, especially when the Generating Set is operating in Rain, Fog, or Sea Mist etc.

Then also carefully consider the microclimate conditions that occur inside a typical Generating Set canopy/enclosure, especially just after the hot unit is taken out of service and is stopped. Within the canopy, the cooling down of the Generating Set promotes high humidity levels. As a result, surfaces become wet and this includes the alternator's windings.
It is necessary to find a way to combat this, and basically it requires engineered natural convection of airflow through the canopy, to counteract the dew point situation and so keep the levels of Relative Humidity (RH) low.

**Ways to Maintain High IR Values.**

A well-designed on-site 'care regime' should include:

- Anti-Condensation Heater. Fit the alternator with an anti-condensation heater and ensure that this is automatically switched on when the Generating Set is at rest. This will maintain a high value of IR for windings that are already in a clean and dry condition.

- Generating Set Canopy/Enclosure Space Heater. A heater or number of heaters of a power rating that is capable of maintaining low RH values within the Generating Set enclosure at the site environmental conditions.

- Regular Use as part of Planned Maintenance. Planned routine operation of the Generating Set at a rating that elevates the stator temperature to some 100degC T-total, for a period of say one hour will drive out any moisture that might otherwise begin a degradation process to the Insulation System.

**Ways to Improve IR Values.**

Consider a known good condition alternator that has not been run for some time but during which time, it has been standing in conditions of high RH. It is possible that simply running the Generating Set unexcited for a period of say 10 minutes will sufficiently dry the surface of the windings and so raise the IR sufficiently, to > 1 MegOhm - and so allow the unit to be put into service.

If the above unexcited 'blow-drying' does not raise the IR value sufficiently, then consider separately exciting the alternator with its output terminals connected by appropriately rated short circuit links.

By separately exciting at a level such that some 80% of rated current flows through the short circuit link, the alternator stator winding will start to heat up. This will drive off the embedded moisture, during a run period dependent upon the size of the alternator. For guidance, consider the following time periods:

1 hour for a S0/S1, P0/P1
2 hours for a UC 224, UC 274
3 hours for an S4 (HC4), S5 (HC5), S6 (HC6), S7 (P7), S8 (P80)

If the IR value remains below 1 megOhm, even after the above drying methods have been properly conducted, then a Polarization Index (PI) test should be carried out. This will offer some guidance about the characteristics and reason for the 'leakage current' that is causing the low IR value.

If surface contamination is the cause, therefore promoting surface tracking, then the alternator must be removed from the engine and stripped down to enable the stator winding to be thoroughly but carefully pressure washed, then baked in an oven to completely dry out. If now the value of IR is acceptable, then the stator should be treated with an over coating resin that is compatible with the original factory impregnation, before the alternator is reassembled onto the Generating Set.

For further information on IR and PI Testing, refer to AGN015 Testing Winding Insulation Systems.

## SUMMARY:

Life expectancy of a winding insulation system depends on its resistance to contamination and as the contamination is a very variable element in the longevity equation, the real answer of which impregnation process to use becomes a real 'risk assessment exercise' with not all the risks being known.

Such is the improvement in impregnation durability, that STAMFORD | AvK, now have just one standard winding impregnation process, for alternators manufactured in the UK, because they are confident the modern materials applied, using advanced methods, offer the optimum protection for the environments in which their alternators are likely to be installed.

The validated solution offerings described above for winding insulation protection on alternators manufactured by STAMFORD | AvK, are suitable for installation into harsh environment. There are alwavs technical considerations that must be initiated to address any environmental conditions that may challenge the continued serviceability of the alternator. The guidance in this AGN should be considered in conjunction with the guidance in AGN072 Environmental Conditions.

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