TECHNICAL ARTICLE

Alternator insulation & coating systems

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1. INTRODUCTION

This guide aims to present the criteria, processes, and materials used in the protection of WEG insulation and coating systems for different applications (environments). The scope of this guide comprises AC alternators, with open construction and low voltage with random windings.

2. CONCEPTS

It is important to highlight some definitions of terms that are presented in standards used by WEG and which are associated with insulating materials and insulation systems.

2.1. Thermal Index (IEC 60216-1): It is a numerical value of temperature in degrees Celsius arising from the thermal aging ratio at a time of 20,000 hours (or other specified time);

2.2. Thermal class (IEC 60034-18-1): Temperature to which an insulation system is applicable as defined by the thermal classes in IEC 60085 and as used in IEC 60505;

2.3. Electrical insulating material (IEC 60505): Material with negligible electrical conductivity, used to separate conductive parts into different electrical potentials;

2.4. Insulation system (IEC 60034-18-1): Insulation structure containing one or more electrical insulating materials applied on conductive parts used in rotating electrical machines.

In rotating electric machines, speaking of the active parts, it is not correct to apply the concept of insulating material or thermal index. The concept of thermal class and insulation system applies.
It is important to note that the insulation materials and systems used in WEG alternators are UL1446 - File E236096 certified.
The equipment used in the impregnation of the components has an automated process with time control of the resin bath cycles and temperature measurement through sensors. The use of these equipment guarantees the correct resin filling and protection of the coils.
WEG has several types of impregnation processes, highlighting the use of VPI (Vacuum Pressure Impregnation) impregnation technology and other processes, such as dip and/or drip impregnation.

3. DESCRIPTION OF POSSIBLE APPLICATION ENVIRONMENTS AND MATERIALS USED

WEG alternators are used in many applications. From the simplest, like power take-off drives, using tractors on small properties, even the most complex, such as parallel operation, ramp transfer systems and remote applications on ships, and oil rigs.
The main driving machines are diesel, gas, bio-gas, bio-diesel and ethanol internal combustion engines. They are also able to operate on steam, gas or hydraulic turbines. They operate in emergency service, rush hour or continuous service regimes, in various areas, such as: industrial, commercial, marine, construction,

telecommunications, mining, complexes, irrigation, hospitals, data center, rural, airports, among others.
Due to the wide range of applications in which WEG alternators are used, it is necessary to define the main characteristics of the possible environments used:

3.1. Normal Environment: It is characterized by having an average relative humidity of less than 60%, and consequently, does not have any aggravating element of corrosion thus allowing the use of metallic materials without restrictions to the application environment;

3.2. Humid Environment: It has an average relative humidity higher than 60%, where the slow process of corrosion of materials begins. When the average relative humidity exceeds 70%, the corrosion process becomes accelerated. This is due to the fact that this environment has humid particles (H_2O) suspended in the atmosphere, which can deposit on the surface of the material and accelerate the corrosion process. In this environment the use of uncoated carbon steel material is not indicated. The minimum recommendation for this environment is the application of metallic materials with galvanized or painted coating;

3.3. Maritime Environment: It presents more complex characteristics in relation to the previously presented environments, because besides the humidity there is also the presence of sea water, which presents a solution of salts containing living organic matter, dissolved gases and decomposing organic matter.
Seawater consists of sodium chloride (NaCl), magnesium chloride ($MgCl_2$), magnesium sulfate ($MgSO_4$) and calcium sulfate ($CaSO_4$). In this environment, the attacks are mainly performed by the action of sodium chloride (NaCl), which is a strong electrolyte, when deposited on the surface of the material, increases its conductivity accelerating the electrochemical mechanism of corrosion. The maritime environment can still be subdivided into 2 categories:

- **Onshore:** Located in the coastal zone where a cyclic condensation system occurs, with or little salinity and with a high level of corrosion.
- **Offshore:** Located open sea, where a cyclic condensation system occurs, combined with the strong presence of salinity and UV rays, and a high level of corrosion.

3.4. Contaminated environments: It is very common to apply products in environments contaminated by external agents and/or generated in the environment itself. Example of contaminants:

- **Ammonia (NH_3):** Often found in a chemical industry environment, in the nitric acid (HNO_3) and urea (CH_4N_2O) factories, which use ammonia as their raw material. The principle of attack is the combination of ammonia with sulfur oxide (SO_2), forming salts composed of strong electrolytes. It can be used in the industry for petroleum refining, pharmaceutical manufacturing inputs and as refrigerant in cooling chamber and air conditioning cooling processes. In agriculture, it is also used for the manufacture of fertilizers and can be produced naturally through the decomposition of organic materials (manure).
- **Sulfur Dioxide and Trioxide ($S0_2$ and $S0_3$):** Usually found in industrial environments, because industries use combustible oils containing plots of sulfur. $S0_2$ gas released into the atmosphere can be oxidized to $S0_3$. This reaction is catalyzed by metal oxides (such as Fe_2O_3) or by photochemical action, where light activates $S0_2$ allowing its oxidation to $S0_3$, they react with ambient humidity and form sulfuric acid and sulfuric acid, these being strong corrosion elements for the material. In the atmosphere, SO_2 binds to oxygen, producing SO_3, where such cloud-accumulated substances precipitate in the form of acid rain. SO_2 is still used in the food and beverage industry as an antibacterial, disinfectant, antiseptic, and product preservative.
- **Sulfuric acid (H_2SO_4):** It is a strong mineral acid, water soluble in any concentration. Sulfuric acid has many industrial applications and is produced in greater quantities than any other substance (it only loses in quantity to water). It can be used in the manufacture of other acids, fertilizers, medicines, ore and liquid effluent processing and in oil refining. Sulfuric acid reacts with most metals (iron, aluminum, zinc, manganese and nickel) with the formation of hydrogen gas and the corresponding metal sulfate. Tin and copper only react when in contact with concentrated hot acid. Lead and tungsten are inert to sulfuric acid.

- **Hydrogen Sulfide (H_2S):** Also known as hydrogen gas, it is a corrosive, poisonous and gaseous compound in its natural state. It is found in synthetic coal gas, natural gas and petroleum, paper, biogas sulfur-containing industry products. It has a rotten egg-like odor and its combination with air is explosive, they burn with a blue flame to form sulfur dioxide (SO_2) and water.
  When in aqueous solution it is called hydrogen sulfide, and becomes highly corrosive when in contact with the steel surface, forming a ferrous sulfide corrosion product (FeS). It also reacts with other metals such as copper, silver and lead.

For environments subject to metal contamination, the use of stainless steel fasteners is required.

Alternators can still be employed in sheltered and not sheltered environments:

- **Sheltered:** The condition in which the product is protected inside a housing or construction, free from direct contact with external agents (water, dust, contaminants, gases, and weathering from nature). Environments considered as sheltered generator sets, generator sets opened in engine rooms, etc. It is common in this environment to apply products with IP21 and IP23 degree of protection.
- **Not Sheltered:** Condition in which the product is partially or completely unprotected, usually in the open (weather), and may have direct contact with external agents (water, dust, contaminants, gases, and weathering from nature). The application of products with IP21 and IP23 protection degree environment is not recommended.

4. INSULATION SYSTEMS

WEG offers the market three degrees of product isolation. Following are descriptions, typical application locations and the specification of the protection for each degree of insulation.

4.1. Grade 1 - INDUSTRIAL

- **Description:** Used for industrial applications, in normal environment and where the average relative humidity does not exceed 95%, with ambient temperature below 40 °C, sheltered, free from contaminants to metallic materials, with salinity and moderate winds (annual average speed below 5 m/s).
- **Typical application locations:** Industries, hospitals, residences, commercial establishments, farms and events in coastal cities.
- **Protection specification:**
  VPI Impregnation for the main stator;
  Painting the main stator windings with a layer of polyamide epoxy gray paint;
  Immersion impregnation for main rotor;
  Painting of the exciter stator magnetic core with a layer of polyamide epoxy gray paint;
  Painting of the exciter stator and rotor windings with a layer of polyamide epoxy gray paint for line AG10;
  Inclined drip impregnation of the stator and exciter rotor;

4.2. Grade 2 - NAVAL

- **Description:** Used for marine (onshore or offshore) applications where average relative humidity may exceed 95%, ambient temperature below 40 °C, sheltered, free from metallic contaminants, salinity and high winds (annual average speed above 5 m/s).
- **Typical application locations:** Ports, vessels, and oil rigs.
- **Protection specification:**
  Painting of the stator magnetic core and main rotor with a layer of polyamide epoxy gray paint;
  Painting the main stator and rotor windings with a layer of polyamide epoxy gray paint;
  VPI Impregnation for main stator;
  Immersion impregnation for main rotor;
  Painting of the windings and magnetic core of the stator and exciter rotor with a layer of polyamide epoxy gray paint;
  Inclined drip impregnation of the stator and exciter rotor.

Note: The use of heating resistance is recommended.

4.3. Grade 3 - SPECIAL

- **Description:** Used for applications in marine (onshore or offshore) environments and contaminated environments (presence of corrosion and abrasion), where the average relative humidity can exceed 95%, with ambient temperature below 40 °C, sheltered or not sheltered, where there is salinity, contaminants to metallic materials and strong winds (annual average speed above 5 m/s).

- **Typical application locations:** Rainforests, crushers and mining in general, chemical industries, floodplains and islands with extreme sea air.
- **Protection specification:**
  Painting of the stator magnetic core and main rotor with a layer of polyamide epoxy gray paint;
  Painting of the windings and magnetic core of the stator and main rotor with a polyamide epoxy gray paint layer and a red anti-tracking paint layer;
  VPI Impregnation for main stator;
  Immersion impregnation at main rotor;
  Resin application between main rotor layers;
  Use of double insulation in the stator slots and main rotor;
  Use of wire end tool to close the main stator slots;
  Painting of the magnetic stator core and exciter rotor with a layer of polyamide epoxy gray paint;
  Painting of the windings and magnetic core of the stator and exciter rotor with a layer of polyamide epoxy gray paint and with a layer of red anti-tracking paint;
  Derating at alternator rated power.

Note: The use of heating resistance is recommended.

5. COATING OF EXTERNAL COMPONENTS

For WEG alternators, basically three types of specifications for painting the external components are used:

5.1. Painting Plan 207A: Used for sheltered industrial applications, in humid environments with average relative humidity below 95%, with salinity and free of contaminants harmful to metallic materials. Recommended for use on alternators applied with the Grade1 insulation system.

5.2. Painting Plan 212P: Used for applications in marine environments with an average relative humidity greater than 95%, exposed to salinity and free from contaminants that cause corrosion of metallic materials. Guarantees exposure to weather due to the high-resistance of Polyurethane paint in this environment, maintaining color and brightness. Recommended for use on alternators applied with the Grade2 insulation system.

5.3. Painting Plan 212E: Used for applications in marine environments with average relative humidity greater than 95%, exposed to salinity and in environments with high chemical concentration or containing contaminants that cause corrosion of metallic materials. Recommended for use on alternators applied with the Grade3 insulation system.

6. FASTENING ELEMENTS

WEG alternators can be used with two types of fastener materials:

6.1. Carbon steel: Galvanized coating materials, applied in environments with average relative humidity of less than 95%, free from salinity and contaminants that cause corrosion of metallic materials. Recommended for use on alternators applied with the Grade1 insulation system. In these cases, alternators are supplied with all painted external fasteners, ensuring longer material life.

6.2. Stainless steel: Used for applications in marine environments with average relative humidity greater than 95% and in environments containing contaminants that cause corrosion of metallic materials. Recommended for use on alternators applied with the Grade2 and Grade insulation system.

7. CHARACTERISTICS FOR EACH INSULATION SYSTEM

The main features of the protection systems are presented in the table below to help identify the environment and choose the most suitable process.

Table 1: *Use of alternators according to Degree of insulation.*

INSULATION	Grade1	Grade2	Grade3
Application	INDUSTRIAL	MARINE	SPECIAL
Place of installation	Sheltered Coastline	Boarded	Abrasion & Corrosion
Degree of protection	IP21 or IP23	IP21 or IP23	IP23
Reference standard	IEC 60721-3-3	IEC 60721-3-3	IEC 60721-3-3
Relative humidity	RH ≤ 95%	RH ≤ 100%	RH ≤ 100%
	Possible condensation	With condensation	Projection of water particles
Salinity	Salt presence	Salt fog	With salt spray
Salt settling	Up to 1g/m^3	Up to 10g/m^3	Up to 30g/m^3
Abrasiveness	Dust particles	Dirt particles	Sand particles
Lamination	Unpainted	Painted	Painted

8. POSSIBLE COMBINATION OF INSULATION SYSTEMS, FIXING ELEMENTS AND PAINTING PLAN

The possible combinations for selecting the insulation systems, fasteners and painting plans according to the applied environment can be visualized in Figure 1:

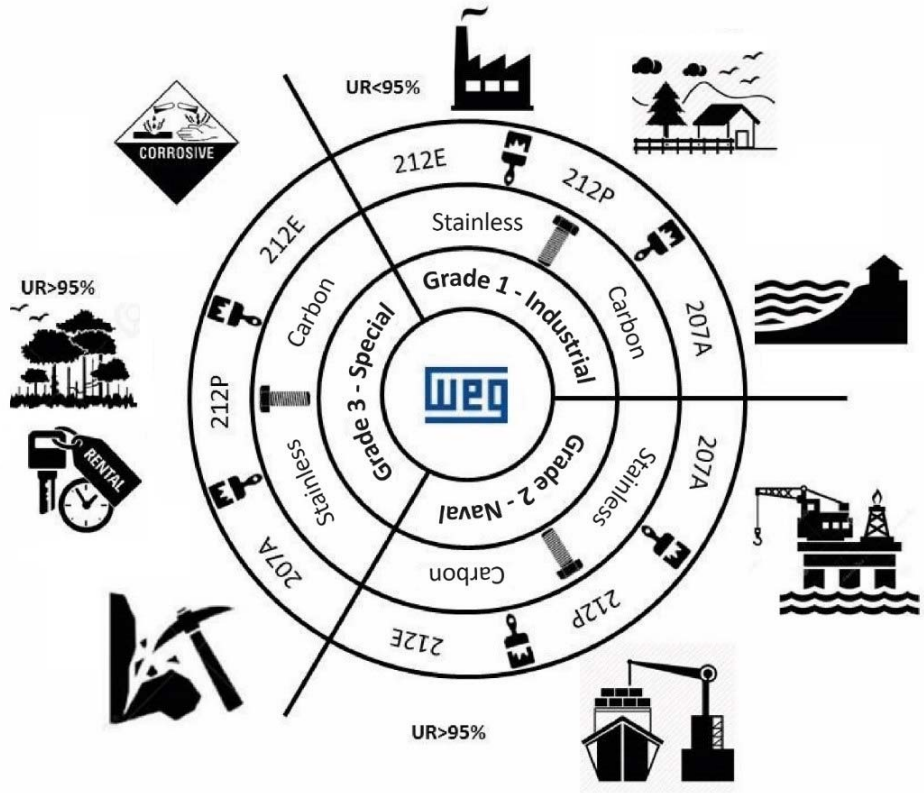

Figure 1: *Selection guide for the protection system, fastening elements and painting plan according to the environment.*

9. CONCLUSION

WEG offers three different insulation systems for its open-construction AC alternators, each for a particular application. Thus, knowing the application and materials used to protect each Grade of alternators provided by WEG is of utmost importance to the customer, who can make the best choice according to their needs. Therefore, this material seeks to cover this simplified view, suggesting the best application environment for each insulation system.