



# TECHNICAL PERSPECTIVE

## *Alternator Temperature Rise*

### INTRODUCTION

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Whenever a wire carries electrical current, its temperature will increase due to the resistance of the wire. One important factor of this temperature rise is the influence it has on the insulation system of an electrical machine, such as an alternator. The hotter the wire, the shorter the life expectancy of the insulation, and of course the machine itself. This article will explain some standards and considerations regarding alternator temperature rise.

### Scope

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The standard for designing generators relied on by the electrical generation industry is National Electrical Manufacturers Association (NEMA) Standard MG1, which encompasses the entire machine, and includes requirements for alternator temperature rise. (Other standards and definitions will be addressed in future articles in this series.)

### Generator Categories

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The MG1 standard defines two duty cycles: continuous, meaning 24 hours a day, 7 days a week under full load conditions, and standby, an emergency power source designed to back up a continuous source. While the standby category doesn't have any designated hour limits, the accepted standard of operation is much less per year.

### Insulation Classes

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MG1 recognizes four classes of electrical insulation materials used in alternators – A, B, F, and H. Each of these has different characteristics, but the common accepted feature is that they will have an expected minimum life of 30,000 hours under continuous operating conditions (actual insulation life would need to be determined in the end product). The primary

### KEY POINTS

- Scope
- Generator Categories
- Insulation Classes
- Generator Designs
- Temperature Rise Testing
- Derations
- Longevity Testing
- Applications & Other Considerations

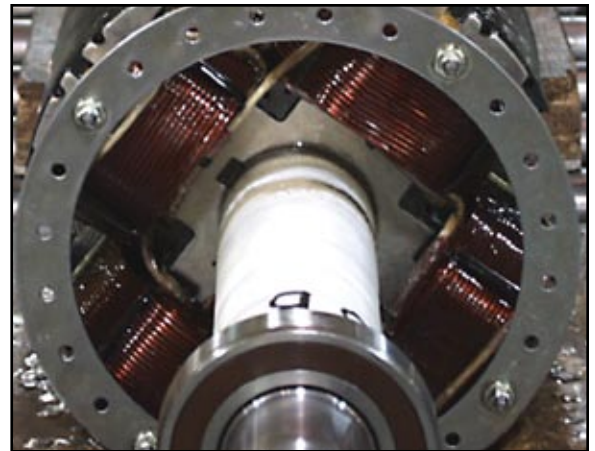


Figure 1

difference is the maximum allowable temperature at which the alternator windings can operate with these types of insulation, as shown in Table 1.

Table 1 - Maximum Operating Temperature - Continuous

	Class A	Class B	Class F	Class H
Max. Temp. °C	100	120	145	165
Max. Temp. °F	212	248	293	329

Since standby duty requires less operating hours than continuous use, MG1 allows the standby windings to operate at a temperature up to 25 °C warmer, as shown in Table 2.

Table 2 – Maximum Operating Temperature - Standby

	Class A	Class B	Class F	Class H
Max. Temp. °C	125	145	170	190
Max. Temp. °F	257	293	338	374

The additional operating temperature allows alternators of these types to generate more kilowatts, justifying the higher standby ratings found on most gensets.

Per UL 2200, Generac uses a Class H insulation system while designating its alternators to operate at a continuous temperature rating of 125°C, thus reducing thermal stress and building in a temperature margin that prolongs alternator life.

These maximum temperatures are actually made up of two parts – the ambient temperature of the environment and the heat, or temperature rise, created by the alternator windings. MG1 uses 40°C as its standard for ambient temperature. Subtracting 40°C from the maximum operating temperature gives us the temperature rise allowed for the heat generated by the resistance of the wire in the windings and other losses in the alternator, as shown in Table 3.

Table 3 – Maximum Temperature Rise (40 °C ambient)

<b>CONTINUOUS</b>				
	Class A	Class B	Class F	Class H
Temp. °C	60	80	105	125
Temp. °F	108	144	189	225
<b>STANDBY</b>				
	Class A	Class B	Class F	Class H
Temp. °C	85	105	130	150
Temp. °F	153	189	234	270

### Generator Design

Generator manufacturers have standard designs for alternators based on a number of physical and operating criteria. Some of the physical attributes that control the voltage and kilowatt rating of a design are: the size and material of the steel laminations, the length of the lamination stack, and the amount of copper wire. The frequency is controlled by the RPM of the rotating magnetic field. DC Current is supplied to create the magnetic field in the rotor through various designs categorized as brush-type, brushless or permanent magnet type. All these items, and the amount of cooling air driven through the alternator, affect the unit's output and temperature behavior.

### Temperature Rise Testing

Once a prototype alternator is constructed, it is tested to verify the design. One of the tests is to determine the temperature rise of the windings. There are two methods to obtain this data: 1) embed thermocouples into the windings during the winding process and measure this temperature directly or, 2) measure the resistance of the wire and calculate the temperature.

At first glance, method 1 may seem the most accurate. In actuality, it requires a number of thermocouples to get a good picture of what is happening throughout the alternator. The thermocouples themselves may cause some distortion, impacting temperature measurements. On the other hand, the resistance of copper wire per degree of temperature variance is a very consistent number. By accurately controlling all of the variables in a lab test (ambient temperature, load, frequency, etc.), the unit can be brought up to a stable, full

load operating temperature. After stopping and disassembling enough to attach instrument leads, recording equipment can take a number of readings over a known span of time and accurately construct an equation to extrapolate the true operating temperature of the winding.

### **Derations**

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NEMA does not allow any deviation from its maximum temperature constraints. If the ambient temperature is above their 40°C standard, the temperature rise must be reduced by the same number of degrees. This holds the maximum allowable operating temperature constant. Temperature rise is also influenced by altitude. The thinner air at higher altitudes has a decreased capacity to cool the alternator. NEMA's standard is 1000 meters (3,300 feet) before it requires a deration factor on the temperature rise, which amounts to 1% for every 100 meters above the 1000 meters.

### **Longevity Testing**

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The temperature class of an insulation system is typically determined using the test methods outlined in Underwriters Laboratory standard UL 1446 (Systems of Insulating Materials – General). The thermal aging test requires representative samples to be subjected to a series of test cycles to withstand heat aging, cold shock, mechanical stress, and moisture exposure. An electrical stress test is performed at the end of each cycle to determine if the sample is capable of continuing to cycle.

These tests are performed on the samples and are only intended for determination of the thermal class of the insulation system. It is important to note that the thermal ratings determined are for a complete system of insulating components, reflecting how the individual materials interact with each other. This helps build confidence that, when used properly, the group of materials in a UL recognized component electrical insulation system will help produce a quality product.

### **Applications & Other Considerations**

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Another thing to consider is that the temperature class of the insulation system established above is for a continuous duty application. NEMA MG1 recognizes the reduced amount of time a standby duty alternator runs (typically less than 200 hours per year). Typically, the allowable temperature rating is 25°C above the continuous duty temperature rating. Operating



Figure 2

the alternator insulation at the higher temperatures associated with a standby rating may shorten the insulation life by a factor of between 4 and 8. However, since standby units only run occasionally and don't amass long hours of operation, their alternators will still provide many years of service that are well within those parameters.

Based upon this logic, looking to extend the life of a standby alternator by specifying a unit with a lower maximum temperature rise than NEMA allows – say 105°C, or even 80°C – may not provide any added value to the customer.

There are, however, a number of other considerations that do require looking at the kW rating of the alternator. High starting currents, single phase loading on three phase units,

load imbalance, non-linear loading, load sensitivity to voltage variation, and high neutral currents are just a few of the reasons to look at upsizing the kilowatt rating of the alternator specified. These additional subjects will be covered in future articles in this series.

Most manufacturers supply generator specification sheets listing each unit's operating ambient temperature and the kW deration factor when elevated temperatures and / or altitudes are encountered. As long as your peak kW load is within the rated value, adjusted for elevated temperatures and / or altitudes as necessary, the genset under consideration will have an acceptable operating temperature.

#### **Additional Technical References**

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For additional technical information, refer to NEMA MG 1 - 1998 Sections 32.6 & 32.35



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