Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 012 – Environmental Rating Factors

There are certain environmental conditions that must be considered when determining the correct alternator and alternator's output rating for a particular application. It is often necessary to adjust the published output rating to achieve the expected life and performance of an alternator. The following factors must be applied to the selected published output rating.

AMBIENT TEMPERATURE

Ambient Temperature can be defined as the temperature of the surrounding air at a particular location. The internationally accepted standard value for all industrial applications is 40ºC. All design work and most ratings for alternators are based on this figure. The measured ambient temperature should be that of the cooling air at the air inlet openings of the alternator, with consideration that this may be higher than the Generating Set's surrounding temperature, due to heat being generated within the Generating Set housing.

Contact applications@cummins.com for rating multiplying factors for Marine applications.

The thermal heat transfer characteristic of the cooling air passing through an alternator is reduced as that cooling air's temperature increases. High ambient temperature results in excessive operating temperature. To maintain the thermal rating of the machine, it is necessary to de-rate the kVA rating by the appropriate rating multiplier from one of the following simple tables, as appropriate.

The maximum permissible ambient temperature is 60ºC. Contact applications@cummins.com for guidance if the cooling air temperature is above 60ºC.

Throughout the alternator manufacturing business, there are often references made to low voltage (LV), medium voltage (MV) and high voltage (HV) outputs. Generally, LV refers to nominal voltages less than 1000V (in alternators case less than 690V), MV refers to nominal voltages between 1000V and 4400V, and HV refers to nominal voltages between 4400V and 13800V.

The rating multiplying factors in the following table are for LV alternators at Base Continuous Ratings for Insulation Class H. These single multiplying factors are to be used for Class Temperature Rise Ratings for Class H, Class F and Class B. The table is based on a ratings adjustment of 3% for every 5ºC from 40ºC. The table may be used for **NEWAGE, STAMFORD S0/S1 to S7 LV Alternators**:

Temperature in °F	Temperature in °C	Rating multiplier
104	40	1.00
113	45	0.97
122	50	0.94
131	55	0.91
140	60	0.88

The rating multiplying factors in the following table are for LV/MV/HV alternators at Base Continuous Ratings for Insulation Classes; Class H and Class F. These multiplying factors are to be used for Class Temperature Rise Ratings for Class H, Class F and Class B. The table is based on a ratings adjustment of x% for every 5ºC from 40ºC. The table may be used for **STAMFORD S9, P80 and AvK Alternators.**

Utilisation T / °C	Utilisation T / °F	Class H V_{TC}	Class F V_{TC}	Class B V_{TC}
40	104	1.000	1.000	1.000
45	113	0.970	0.965	0.955
50	122	0.940	0.930	0.910
55	131	0.910	0.895	0.865
60	140	0.880	0.860	0.820

Further Information on Temperature Rise Changes with Increased Ambient Temperature.

A mathematical relationship has been established and is shown below as a general guide for considering changes to cooling air temperatures as measured at the alternator's air inlet. The following formula may be used if the alternator is to be relocated to a location with a different ambient temperature.

Formula;

Predicted temperature rise at a proposed new location where there is a higher ambient temperature.	=	Temperature rise measured under a known air inlet temperature	X	(160 + Ambient temp for new location) --- (160 + Ambient temp during test)

Example:

A Generating Set has been tested at its Class H temperature rise rating under a condition where the air inlet temperature is 26°C and the measured temperature rise is 112°C.

The Generating Set is now to be relocated to an area where the ambient temperature is 40°C.

Predicted Temperature rise at a proposed new location where there is a higher ambient temp	=	112°C	X	(160 + 40) ---------------- (160 + 26)	=	121°C

ALTITUDE

The density of air decreases at higher altitudes. Air at lower density decreases the heat transfer properties in an alternator, resulting in an increased temperature. To maintain the designed thermal rating of the machine, it is necessary to limit the alternator rating.

Up to 1000 metres above sea level (3300ft) the change in air density is insufficient to radically alter the thermal transfer properties of air. Above 1000masl, the effectiveness of the lower density air in cooling the internals of the alternator reduces sufficiently. To prevent excessive temperature rise due to reduced cooling, the output rating must be de-rated. The internationally accepted de-rating factor is based on a 3% de-rate for every 500m over 1000masl, up to an altitude of 4000masl for LV alternators.

For operating at altitudes above 4000masl (13123ft) contact applications@cummins.com for guidance.

No greater output is allowed from an alternator operating at an altitude below 1000masl.

Altitude in Feet	Altitude in metres	De-rate multiplier
3,380	1000	1.00
4,921	1500	0.97
6,562	2000	0.94
8,202	2500	0.91
9,842	3000	0.88
11,487	3500	0.85
13,123	4000	0.82
14,763	4500	0.79

When a Generating Set is operated at high altitude, one of the first considerations applied by a Generating Set manufacturer is the potential loss of mechanical power. This is a real consideration and a true phenomenon, due to the lower density atmosphere, resulting in less engine Horsepower capability and so less mechanical kilowatt output. In most cases, the power reduction, due to reduced engine power is a greater factor than the deration required on the alternator. Regardless; the alternator rating must always be verified.

It is important to understand; de-rates apply only to the alternator's Class temperature rise rating, not the complete Generating Set's rating. If the de-rated alternator kW capability remains equal to or greater than the Generating Set's de-rated kW capability, then there is no concern about operating at the Generating Set's capacity. If it is less, then the alternator will operate at a higher temperature rise and thus may require a change to a larger alternator. Note that this does not take into account, any other de-rate factors that need to be applied, such as for harmonic currents in non-linear loads.

Medium and High Voltage Generators at High Altitude

Despite the application of a de-rate factor, it is necessary to consider further, the use of MV/HV Generating Sets at high altitudes, between 1000 and 4000masl.

The reduced air density also means the dielectric strength of the air is reduced, which affects characteristics of the insulation materials in a winding insulation system. This effect can be particularly damaging on a high voltage alternator.

Specifically, on high voltage alternators operating at high altitude, there is the potential for a condition called Corona Discharge.

There is sometimes an option to manufacture the alternator with a special insulation system, designed for high altitude. The insulation system would normally have thicker main wall insulation. The isolation/sensing transformer on an alternator may also be adversely affected at high altitude, so a special design isolation/sensing transformer may be required. An additional de-rate will be required under these circumstances. Contact applications@cummins.com for further information.

Corona Discharge

The reduced atmospheric pressure at high altitude has the effect of increasing the potential for Visible Corona, in essence reducing air insulation characteristics. This phenomenon is described by Paschen's Law. It is not important to understand the all the details of Paschen's Law, but rather to realise that within the range of altitudes applicable for Generating Sets, there is a change in Visible Corona field characteristics. As altitude increases and so air density decreases, the potential for Visible Corona (purple glow) increases. Several factors influence the performance of insulation systems when operating at high altitudes. Invariably, however, they result in reduced insulation life and include:

Environment conditions - humidity, ambient temperature, air cleanliness, etc.
Application.
Temperature rise.
Manufacturing variance - inadequate space between phase coils, poor impregnation, loose fibres and/or poorly cut tape ends, poor insertion of the coils in the stator slots, etc.

The Partial Discharge problem occurs in air-cooled machines rated at 3kV or higher.

Since discharges usually occur in air, ozone is created. Apart from its ability to destroy tissues, ozone, in the presence of nitrogen from the atmosphere, and water, creates nitric acid - HNO3, causing further erosion of insulation materials.

The following criteria needs to be applied in regard to insulation systems to minimize corona discharge:

- Up to 1500m elevation: No change in insulation system requirement.
- 1500 to 3000m elevation: Only alternators of up to 11kV terminal voltage are permitted with insulation enhancement and additional de-rate.
- 3000 to 4000m elevation: Only alternators of up to 6.6kV terminal voltage are permitted with insulation enhancement and additional de-rate.
- Not an industry standard but derived from Paschen's curve and due to the compactness of our alternators design for satisfactory operation at normal elevations.
- Please refer to applications@cummins.com for guidance.

Environment.

Alternators are designed to provide trouble free operation in clean dry conditions. The installation of the Generating Set is to be such that contamination by airborne dust, dirt, debris, water or other contaminants is prevented from reaching the alternator cooling air inlets. This is accomplished through proper design of the room or housing, possibly requiring air inlet filtration or alternator air filters. If optional alternator air filters are fitted, there is a minimum 5% thermal de-rate required to the output rating, in addition to the altitude-derived thermal de-rate factor.