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 following simple table.

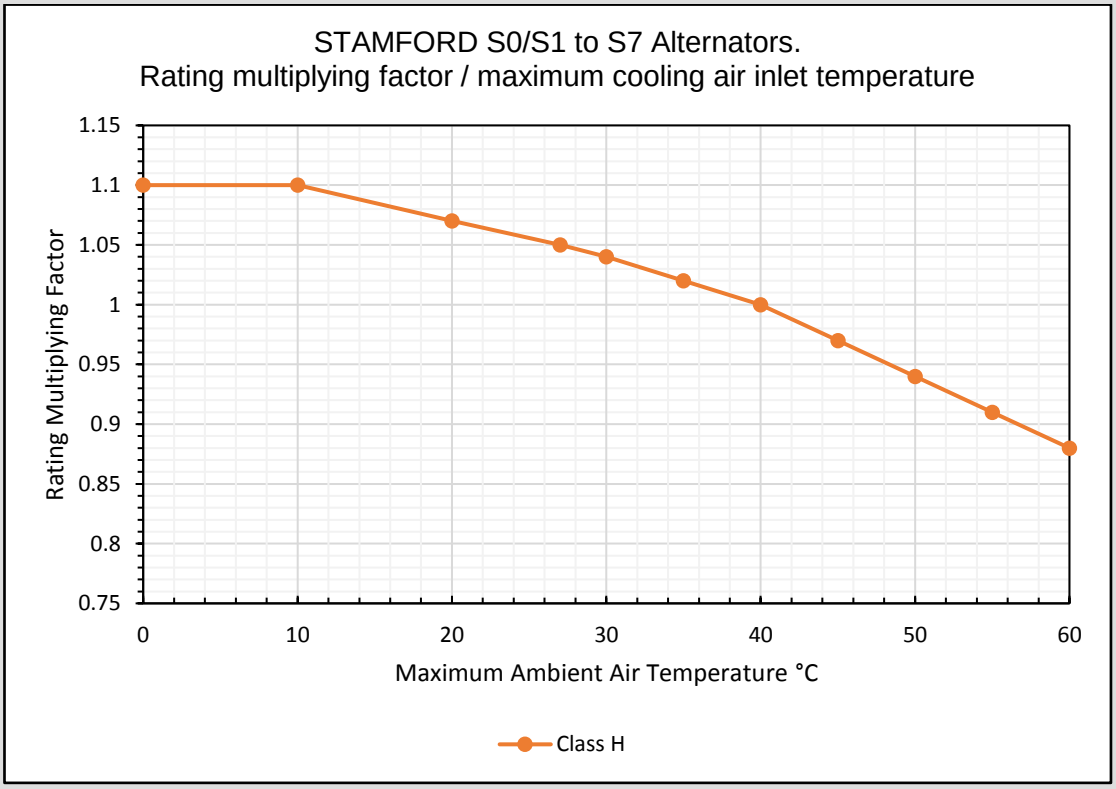
The maximum permissible ambient temperature is 60ºC. Contact applications@cummins.com for guidance if the cooling air temperature is above 60ºC.

For cooling air temperatures below 40ºC, International Standards allow the alternator's rating to be increased by an appropriate multiplying factor from the following simple table, but no further increase is allowed for temperatures below +10ºC.

The table over-page is based on a ratings adjustment of 3% for every 5ºC from 40ºC and is appropriate for STAMFORD low voltage alternators in range, S0/S1 to S7.

STAMFORD S0/S1 to S7 Alternators.

Temperature in °F	Temperature in °C	Rating Multiplier
50	10	1.09
64	18	1.06
80	27	1.03
104	40	1.00
113	45	0.97
122	50	0.94
131	55	0.91
140	60	0.88



The necessary ambient temperature rating multiplying factors for STAMFORD P80 (S8 and S9) alternators have been determined to take account of the wider operating voltage ranges and are different for the various Class temperature rise ratings. The multiplying factor are also appropriate for MV7 alternators.

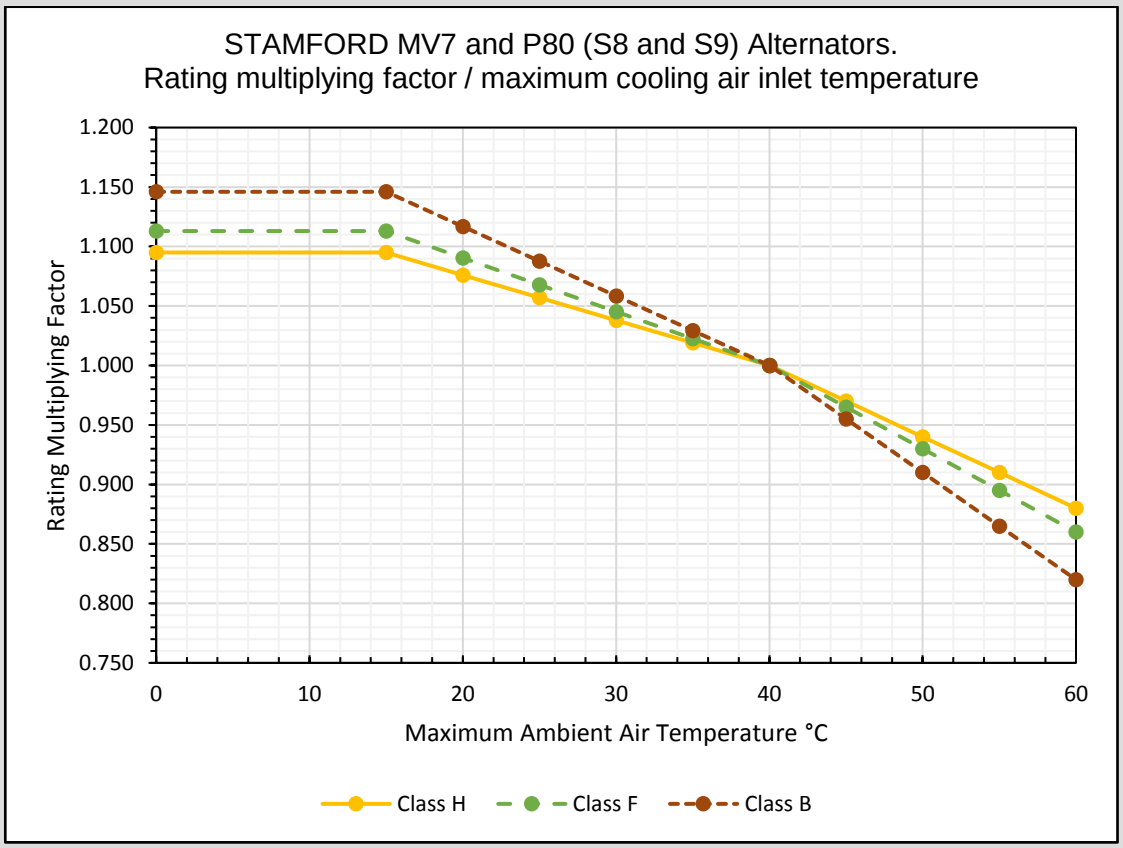
STAMFORD MV7, P80 (S8 and S9) Alternators.

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 690V, MV refers to nominal voltages between 1000V and 4400V and HV refers to nominal voltages between 4400V and 13800V.

Rating multiplying factors for LV and MV alternators at Base Continuous Ratings for Insulation Classes; Class H, Class F, Class B and Class E. These multiplying factors are also to be used for Class Temperature Rise Ratings for Class H, Class F, Class B and Class E.

Rating multiplying factors for HV alternators at Base Continuous Ratings for Insulation Classes; Class F, Class B and Class E. These multiplying factors are also to be used for Class Temperature Rise Ratings for Class F, Class B and Class E.

Utilisation T / °C	Class H V_{TC}	Class F V_{TC}	Class B V_{TC}	Class E V_{TC}
15	1.095	1.113	1.146	1.155
20	1.076	1.090	1.117	1.124
25	1.057	1.068	1.088	1.093
30	1.038	1.045	1.058	1.062
35	1.019	1.023	1.029	1.031
40	1.000	1.000	1.000	1.000
45	0.970	0.965	0.955	0.952
50	0.940	0.930	0.910	0.905
55	0.910	0.895	0.865	0.857
60	0.880	0.860	0.820	0.809



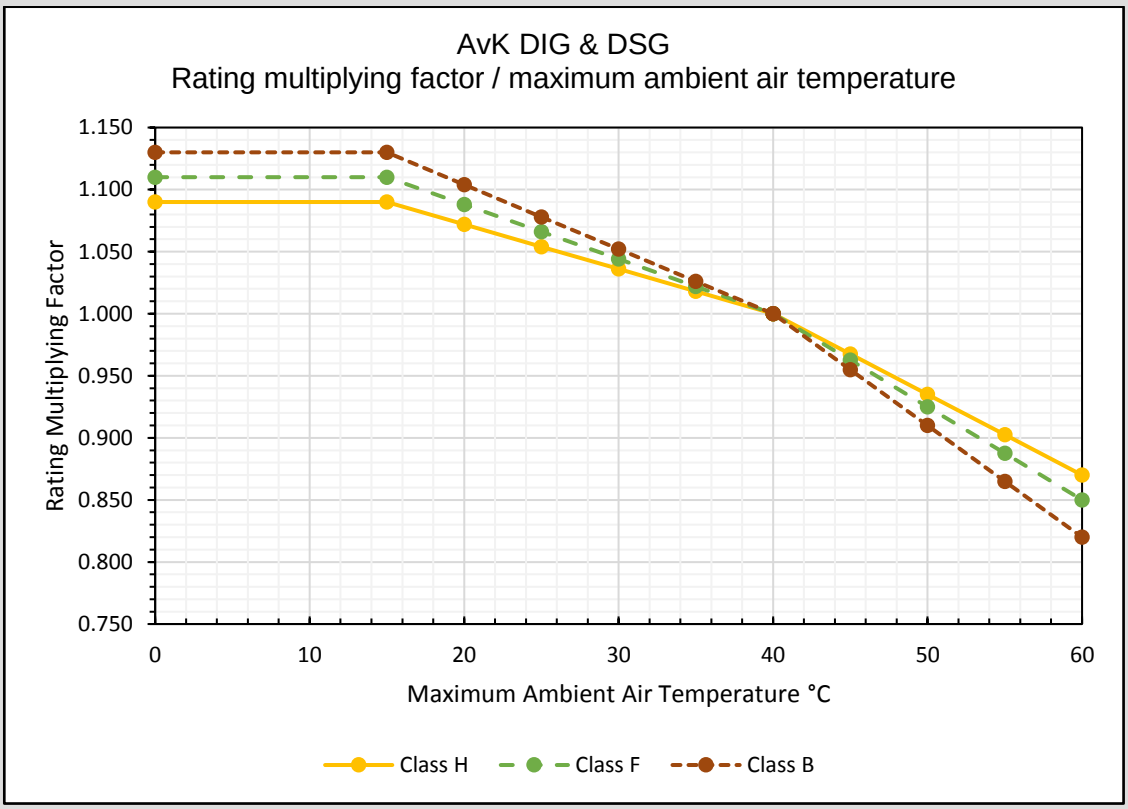
AvK Alternators.

If the alternator has been configured through the CAMOS tool, to the appropriate application specification, then all environmental rating factors that are applicable to that application for cooling air inlet temperature, will have already been applied. Therefore no further rating adjustment is necessary.

Rating multiplying factors for AvK DSG (LV) alternators at Base Continuous Ratings for Insulation Classes; Class H, Class F and Class B. These multiplying factors are also to be used for Class Temperature Rise Ratings for Class H, Class F and Class B.

Rating multiplying factors for AvK DIG (MV & HV) alternators at Base Continuous Ratings for Insulation Classes; Class F and Class B. These multiplying factors are also to be used for Class Temperature Rise Ratings for Class F and Class B.

Utilisation T / °C	Class H V_{TC}	Class F V_{TC}	Class B V_{TC}
15	1.090	1.110	1.130
20	1.072	1.088	1.104
25	1.054	1.066	1.078
30	1.036	1.044	1.052
35	1.018	1.022	1.026
40	1.000	1.000	1.000
45	0.968	0.963	0.955
50	0.935	0.925	0.910
55	0.903	0.888	0.865
60	0.870	0.850	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-ration factor is based on a 3% de-rate for every 500m over 1000masl, up to an altitude of 4000masl.

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

Unlike ambient temperature, the converse is not permitted. 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.

High Voltage Generators at High Altitude

Despite the application of a de-rate factor, it is necessary to consider further, the use of 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. 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 6 kV 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 general rules must be applied for alternators at altitudes above 1000masl:

STAMFORD MV7 Alternators (1kV to 4.4 kV) – Up to 3000masl, the thermal de-rate factor only is to be applied: 3% de-rate for every 500m over 1000masl. No alternative insulation system is offered as an option. At 3000masl and above, the MV7 is not offered.

STAMFORD MV P80 (S8 and S9) Alternators (1kV to 4.4 kV) – Up to 3000masl,the thermal de-rate factor only is to be applied: 3% de-rate for every 500m over 1000masl. At 3000masl and above, refer to applications@cummins.com for guidance, as a special insulation system design may be available.

STAMFORD HV P80 (S8 and S9) Alternators (4.4 kV to 13.8kV) – Up to 1500masl, the thermal de-rate factor only is to be applied: 3% de-rate for every 500m over 1000masl.

At 1500masl to 3000masl elevation, only alternators with an output voltage of up to 11 kV are permitted, with the appropriate de-rate factor. Refer to applications@cummins.com as a special insulation system may be available.*****

At 3000masl to 4000masl elevation, only alternators with an output voltage of up to 6.6kV are permitted, with the appropriate de-rate factor. Refer to applications@cummins.com as a special insulation system may be available to increase the permitted output voltage to 7.2kV.*****

*These alternators will have special insulation needs and require special sensing transformers. This is not an industry standard, but derived from Paschen's Curve and the compactness of our design for satisfactory operation at normal elevations. The thermal rating of alternators with special insulation systems must be determined by design. Please refer to applications@cummins.com for thermal ratings.

AvK DSG (LV) and DIG (MV & HV) Alternators. Up to 4000masl, a de-rate of 1% for every 100m above 1000masl is to be applied to the alternator's output rating. At 4000masl and above, refer to applications@cummins.com for guidance, as a special insulation system design may be available.

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.