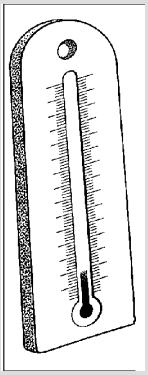
Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 113 - Application General Guidance and Rating Adjustments

To achieve the expected life and performance of an alternator, the many factors that affect the published base ratings must be considered. The following factors must be applied correctly to the published base rating to correctly select (nominate) the proper alternator for the application.

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.

AMBIENT TEMPERATURE ADJUSTMENTS



High ambient temperature results in excessive operating temperature in an alternator. To maintain the thermal rating of the machine, it is necessary to de-rate the kVA output rating. The standard temperature assumed for continuous rated industrial use alternators is 40°C. It may be possible to increase the rating if the ambient temperature is below 40°C.

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

Base Continuous Ratings

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, Class B and Class E.

The table below is based on a ratings adjustment of x% for every 5ºC from 40ºC and is applicable for all STAMFORD and AvK brand of alternators.

Utilisation T / °C	Utilisation T / °F	Class H V_{TC}	Class F V_{TC}	Class B V_{TC}	Class E V_{TC}
15	59	1.095	1.113	1.146	1.155
20	68	1.076	1.090	1.117	1.124
25	77	1.057	1.068	1.088	1.093
30	86	1.038	1.045	1.058	1.062
35	95	1.019	1.023	1.029	1.031
40	104	1.000	1.000	1.000	1.000
45	113	0.970	0.965	0.955	0.952
50	122	0.940	0.930	0.910	0.905
55	131	0.910	0.895	0.865	0.857
60	140	0.880	0.860	0.820	0.809

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.

Peak Standby Ratings

The rating multiplying factors in the following table are for LV/MV/HV alternators at Peak Standby Ratings for Insulation Classes; Class H and Class F. These multiplying factors are to be used for Standby Ratings at Class H at 40C and 27C ambient temperature, and Class F at 40C and 27C ambient temperature.

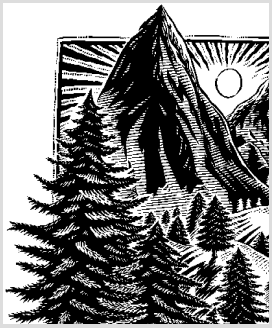
The table below is based on a ratings adjustment of x% for every 5ºC from 40ºC and is applicable for all STAMFORD and AvK brand of alternators.

Utilisation T / °C	Utilisation T / °F	Class H V_{TC}	Class F V_{TC}
15	59	1.080	1.095
20	68	1.064	1.076
25	77	1.048	1.057
30	86	1.032	1.038
35	95	1.016	1.019
40	104	1.000	1.000
45	113	0.975	0.970
50	122	0.949	0.940
55	131	0.924	0.910
60	140	0.898	0.880

ALTITUDE ADJUSTMENTS

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

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.

Refer to AGN012 Environmental Rating Factors. Alternatively, contact applications@cummins.com for further information.

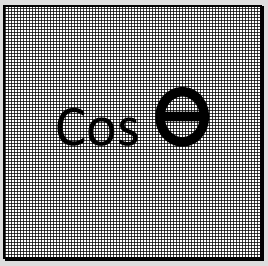
POWER FACTOR ADJUSTMENTS

The power factor is a way of identifying the electrical relationship between the active **real power** (kWe) required to do the job, and the consumed **apparent power** (kVA). The difference being due to the electrical characteristics of the electrical load applied to the alternator.

Power factor basically is a measurement of the timing - phase angle difference - of the current waveform relative to the voltage waveform. The idea being to identify how effectively the supplied power (kVA) is working in relation to the real work being done (kWe). The power is being used more effectively when the power factor is closer to unity.

Alternators are rated in line with industry standards and are designed to operate safely between 0.8pf lagging and 1.0pf (unity), because most electrical loads have these inductive power factor characteristics. This is an alternator's region of optimum working performance.

When supplying power to loads with power factors below 0.8 lagging, the alternator's windings will run hotter. There is; therefore, a need to de-rate the alternator's kVA output rating to maintain the correct working temperature in the windings. The following table provides the de-rate multiplying factors that must be applied to the alternator's kVA output rating for differing lagging power factors:



Lagging pf	De-rate multiplier
0.8	1.00
0.7	0.95
0.6	0.91
0.5	0.88
0.4	0.86
0.3	0.85
0.2	0.84
0.1	0.84
zero	0.84

Leading Power Factor

Leading (Capacitive) power factor loads can cause the alternator's output terminal voltage to rise. This effect is out of control of the AVR and may cause damage to connected loads. The capacitive load that can be supported by an alternator is limited and varies by design. Contact applications@cummins.com and the Application Engineering Department will provide the appropriate performance curve, called an **'Operating Chart'** or **'Capability Curve'** for the subject alternator. This chart or curve can be used to determine the alternator's maximum output for supplying loads with leading power factors.

For the above reason, any capacitor banks (Power Factor Correction capacitors) should, if at all possible, be disconnected when the system is being powered by a Generating Set, unless the true operating power factor of the load, under all conditions, has been considered.

Refer to **AGN004 Operating Charts**, for details of how to read the **'Operating Chart'** or **'Capability Curve'**.

Refer to **AGN087 Power Factor,** for further details of the effects of differing power factors.

GENERAL GUIDANCE ON INSULATION CLASSES AND TEMPERATURE RISE RATINGS

IEC60085 provides detail of the Insulation Class options that an alternator manufacturer may use to design an alternator's Insulation System. The table on the following page illustrates the allowed temperature rise for each Insulation System Class offered in the industry standard. The actual temperature of the copper stator windings is the maximum permissible temperature

in °C (Rise). This 'Rise' value is based on an ambient temperature of 40°C, which is the industry standard for all industrial use alternators. For base continuous ratings there is also an allowance or safety factor, referred to as 'hot spot', usually 10°C or 15°C. The three temperature values are added together give the alternator's 'total temperature' for that insulation system:

Temperature Rise + Ambient Temperature + Hot Spot Allowance = Total Temperature.

Insulation Class of machine	**A**	**E**	**B**	**F**	**H**
Maximum permissible temperature rise in °C based on an ambient temperature of 40°C plus hot spot allowance for the standard lifetime period of the Insulation System.	60	75	80	105	125

Note: The mathematically calculated 'half-life' figure for an Insulation System is 20,000 hours at the specified temperature rise value, used in continuous operation and at 40°C ambient. The actual life of the insulation materials in the Insulation System will be much longer if the site conditions are of an acceptable standard and the loads that are applied are within rating limits.

For further information, refer to **AGN013 Alternator Ratings and Overload.**

Insulation Life.

An alternator may be operated at different temperature rise ratings for Base Continuous Ratings and Standby Rating. Selecting the alternator's temperature rise rating can shorten or extend life of the alternator's Insulation System. The following table, for a Class H Insulation System, illustrates the calculated half-life - the actual life is dependent upon site and application conditions.

Note: these rating multiplying factors may be used as a general rule. For accurate temperature rise ratings, contact applications@cummins.com.

Class H Insulation System			
Temperature Rise Rating	**Rating Multiplier**	**Temperature Rise/Ambient °C**	**Calculated half-life in hours**
Peak Standby 27	1.09	163/27	3500
Peak Standby 40	1.06	150/40	3500
Class H (Base rate – continuous)	1.00	125/40	20000
Class F (Prime Power)	0.916	105/40	120000
Class B (Utility Parallel)	0.80	80/40	640000

For further information, refer to **AGN021 Alternator Life Expectancy.**

GENERAL GUIDANCE ON HUMIDITY

Excessive humidity that results in condensation on the windings will cause premature failure of the alternator's Insulation System. Catastrophic failure of the alternator's windings is probable if the alternator is switched on in these conditions. An Anti-Condensation Heater is

offered as an optional extra for high humidity conditions. The Anti-Condensation Heater needs a separate power supply. This heater should be used when the alternator is stationary, in conjunction with other measures such as a Space Heater in the Generating Set enclosure. As soon as the Generating Set is running, the Anti-Condensation Heater must be automatically disconnected.

The Anti-Condensation Heater is designed to keep a machine dry and it is not capable of drying out an alternator that is already saturated by condensation.

For further information, refer to **AGN227 Anti-Condensation Heaters.**

Refer to the **Owner's Manual** for the alternator, for instructions on how to conduct testing on the insulation. The manual also provides procedure on drying the insulation, if the result is below accepted resistance levels.

For further information, refer to **AGN072 Environmental Conditions.**

GENERAL GUIDANCE ON ENCLOSURE PROTECTION

Enclosure protection is identified as two numbers after the letters **IP**. For example **IP23** and indicates the degree of protection that a machine has against the **harmful ingress** of solid objects and liquids. The first number indicated the degree of protect against solids and the second against liquids. A third number gives the protection against mechanical shock, but this is not normally shown in the rotating machine industry.

The degree of protection does not imply, or mean, that a particular product is **Corrosion Resistant**. It simply indicates the level of protection against solids and liquid entering the machine.

For example, the most common codes used, or asked for, in the Generating Set industry are IP22, IP23, IP44 and IP54. To explain what each means, select a definition from the table below (simply match the two numbers to the code needed). For example, **IP23** is shown in **bold.**

First No.	Tests	Second No.	Tests
2	**Protected against solid objects up to 12mm e.g. fingers**	2	Protected against direct sprays of water up to 15º from the vertical
3	Protected against solid objects over 2.5mm e.g. tools and wires	**3**	**Protected against sprays to 60º from the vertical.**
4	Protected against solid objects over 1mm e.g. tools, wires and small wires	4	Protected against water sprayed from all directions - limited ingress permitted
5	Protected against dust - limited ingress with no harmful deposit	5	Protected against low pressure jets of water e.g. for use on ship decks - limited ingress permitted

This is part of an International Standard that conforms to BS EN 60529:1992 (2004) and IEC 60034-5.

For further information, refer to **AGN066 Alternator IP Protection.**

GENERAL GUIDANCE ON LOAD APPLICATION

The following information is for guidance only and is not to be taken as a set of rules for determining the type and size of alternator required for a particular application. For confirmation of the alternator required for an application, contact applications@cummins.com.

Alternator for supplying a Three-phase Motor.

Information required:

- Motor Rating
- Type of starter used
- Required Starting Current
- Existing base load
- Transient Voltage Dip (TVD) restriction.

If there is no TVD restriction, the following simple chart can be used and will result in approximately a 30% TVD with SX type AVRs and 23% with MX types:

TYPE OF STARTER	Starting Current in Amps	Generator kVA required with a standard AVR
Direct on Line (DoL)	7.0 x motor running current	3.33 x Motor kW.
Star Delta	2.5 x motor running current	1.40 x Motor kW.
Rotor Resistance	2.0 x motor running current	1.10 x Motor kW.
Autotransformer at 65% tapping	2.5 x motor running current	1.40 x Motor kW.
Autotransformer at 80% tapping	4.0 x motor running current	2.25 x Motor kW.

For specific alternator data, including TVD values, contact applications@cummins.com.

Alternator for supplying Non Linear Loads - Thyristor Loads, Switch-mode Power Supplies, UPS Systems, etc.

Non-linear loads generate harmonic distortion in their current waveform, which in turn distorts the alternator's output voltage waveform. The degree of harmonic voltage waveform distortion can lead to malfunction of the connected load equipment and may cause instability of the alternator's excitation system.

Most alternators produced today can be fitted with an excitation system that isolates the AVR from the effects of non-linear loads and have wound components that can cope with the high levels of waveform distortion without detrimental effect to themselves. However, there will be

a problem with electronic power devices and equipment trying to cope with the distorted waveform, if the levels are too high.

The following are common types of non-linear loads:

- Rectifier systems.
- **UPS** Systems (**U**ninterruptible **P**ower **S**upplies).
- Variable Speed Drives and Soft Start systems for motors.
- Switch mode power supplies.

Sizing for Non-Linear Loads.

To establish acceptable levels of waveform distortion it is important to know the type of non-linear load to be powered. The following details are required:

- Number of system pulses i.e. 4, 6 or 12 (4 is worst case, 12 is best)
- Current harmonic distortion produced by the load in %
- Are distortion filters fitted?
- Maximum voltage distortion level acceptable to the load in %
- Operating voltage and Frequency
- Operating power factor and efficiency.

Typical **Current** distortion figures, created by:

- 12 pulse system - 14%
- 6 pulse system - 30%
- 4 pulse system - 45%

Typical acceptable **Voltage** distortion figures:

- UPS System - 10%
- Inverter drive - 15%
- Soft Start System - 20%
- Rectifiers - 20%

Non-linear loads require the above information to be considered in terms of the proposed level of Non-linear load kVA, as well as its current Total Harmonic Distortion%, in conjunction with the identified number of pulses of the Non-linear load's converter stage.

This information then needs to be considered against the alternator's value of sub-transient reactance [X"d], calculated against a 'base level' for the Non-linear load's operating kVA. Refer to the '*Rules of Thumb'* below for some rough guidance.

If the Non-linear loads are likely to result in generating a level of harmonic voltage distortion above 5%, then the alternator will need to be fitted with an excitation system that is isolated

from the Generating Set's main output connections. In the case of a CGT alternator, this can be achieved by the fitting of a PMG and MX321 type AVR or digital AVR, as appropriate.

Rules of Thumb:
Consider a 6 pulse* Non-linear load *with 30% harmonic current distortion:
For a maximum level of harmonic voltage distortion of 10%, then X"d <3.4%
For a maximum level of harmonic voltage distortion of 15%, then X"d <5.3%

Consider a 12 pulse* Non-linear load *with 14% harmonic current distortion:
For a maximum level of harmonic voltage distortion of 10%, then X"d <13%
For a maximum level of harmonic voltage distortion of 15%, then X"d <20%

Input **filters** can be fitted to a load, to reduce the amount of Current distortion. Most Generating Sets can only tolerate low values of capacitive currents, usually in the order of 10-30%. The use of the filters, which include a combination of Inductive and Capacitive elements, means that at start up, when the active power is zero, the Generating Set only supplies the capacitive current for the filter.

If this value is known, then reference to the alternator's **Operating Chart** will ensure that the level is within manufacturer's recommendations.

Refer to **AGN004 Operating Charts**, for details of how to read the **'Operating Chart'.**

Due to the extra heat produced by the harmonics, it is recommended that the alternator rating for Non-linear loads is limited to the **Class 'F' temperature rise rating**.

For further information, refer to **AGN025 Non-Linear Loads.**