Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 021 – Alternator Life Expectancy

DEFINITION

Common Terms.

M.T.B.F.	-	**M**ean **T**ime **B**etween/**B**efore **F**ailures.
M.T.T.R.	-	**M**ean **T**ime **T**o **R**epair.

As an alternator manufacturer, Cummins Generator Technologies do not provide M.T.B.F. or M.T.T.R. data. With the alternator representing only a component part of a complete Generating Set equipment package, it is difficult for Cummins Generator Technologies to be specific with M.T.B.F. and M.T.T.R. figures. The resulting in-service longevity of all incorporated components will be directly related to the quality of the complete equipment package, the way in which that has been considered for the customer's application, the quality of the on-site installation and the prevailing operational service and care regime.

A Generating Set package designed and manufactured with due care and attention and thereby providing engineered incorporation of the Cummins Generator Technologies alternator, should provide acceptable environmental vibration levels and ambient temperature conditions. Even so, the package then must rely on the instructions sent out by the Generating Set manufacturer and the reader's comprehension of what constitutes safe operation and routine maintenance.

ALTERNATOR COMPONENTS AND ASSEMBLIES

Component parts and assemblies within the alternator can be categorised and some guidance regarding M.T.B.F. figures offered for each. As stated above, however; it must be assumed the alternator has been incorporated into a well-designed Generating Set, which will comply

with the expectations of the relevant national and international engineering standards for such an equipment package; an example of such a standard being ISO 8528.
There are, primarily, three assemblies within the alternator that affect life expectancy. Under each heading, guidance is offered for typical life assessment:

Windings.

We must thank **U**NDERWRITERS **L**ABORATORIES of the USA for specifying and determining through calculation, the expected life of an alternator's insulation system. UL1446 uses the Arrhenius Equation to model the relationship between time and temperature. The Arrhenius Equation, which describes the temperature dependence on the velocity coefficient of chemical reaction, can be used to model the relationship between system test life and temperature. The Arrhenius Equation was simplified by taking the natural logarithms to plot the relationship between time and temperature.

Alternator ratings for set maximum winding temperature levels are specified in accordance with IEC60034. U. L. have established operating temperatures and associated life expectancy levels for all electrical insulation materials and have grouped these materials into the various classes familiar to all those involved with electrical equipment, as determined in IEC60034.

The insulation materials used on STAMFORD and AvK DSG low voltage alternators are categorised as Class 'H', for which **U.L.** advise can be continuously operated at a temperature of 180'C and have a **'half life expectancy'** of some 20,000 hours, which calculates to about 2 years 4 months continuous running.

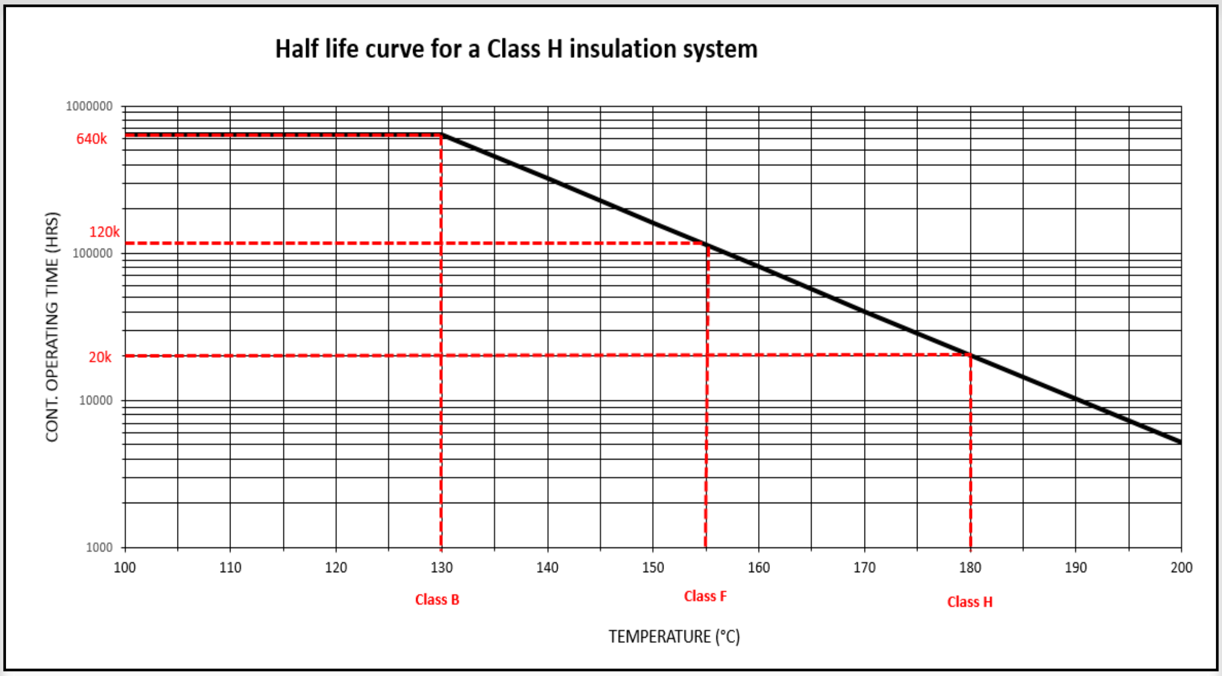
This **'half-life'** phrase means that after a period of 20,000 hours continuously operating at 180'C, the insulations 'ultimate electrical strength [which can be correlated to the insulation resistance], will have degraded to approximately half its original value when new. It does not mean that it will fail after 20,000 hours.

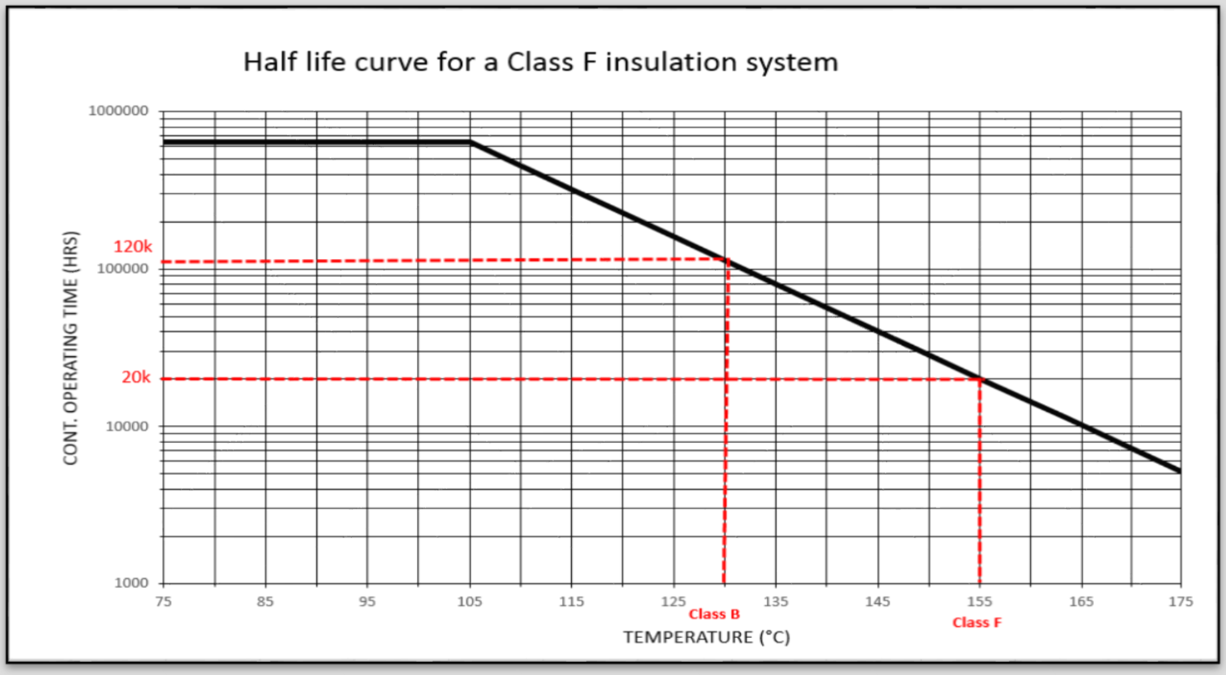
If the alternator is operated at thermal ratings below Class 'H', the 'half-life' periods are increased. For example; at Class 'F' temperatures the **'half-life'** is 120,000 hours (13 years, 8 months) and at Class 'B' temperatures the 'half-life' is 640,000 hours (about 73 years).

It is worth emphasizing the expected 'half-life' of the insulation materials at the different temperature rise ratings. The Class F temperature rise rating is typically around 9% less than the Class H temperature rise rating. The result being that the temperature inside the alternator is likely to be 155C (at Class F) rather than the maximum 180C (at Class H). This 9% reduction in the output rating significantly extends the expected life of the insulation system.

High voltage alternators manufactured by Cummins Generator Technologies have a Class F Insulation System. The life expectancy of a Class F insulation system, with a maximum temperature of 155^{0}C has similar operating properties and expectations to a Class H insulation system operating at a maximum temperature of 180^{0}C.

There follows; a 'half-life' graph for a Class H Insulation System and the 'half-life' graph for a Class F Insulation System:





Thermal Endurance.

The following information is offered to assist with understanding how the wound components are considered for thermal degradation.

The mistaken premise frequently made when assessing the half-life of an insulation system in order to determine its temperature rating, is that the half-life of a system is its failure point when related to temperature. This is academically correct but this will not result in machine failure. This statement can be elaborated thus:

In order to determine the half-life, the ultimate electric strength is ascertained and then the material is thermally aged until that figure is reduced by half – usually taken at 20,000 hours.

Taking a practical example the ultimate electric strength of Isopthalate Varnished Glass Cloth is about 1000 volts/mil – 40kV/mm. Ageing tests 130°C (Class B) would reduce this to half (i.e. 20kV/mm) in 20,000 hours, 10kV/mm in 40,000 hours, 5kV/mm in 80,000 hours, etc.

Since machine design is normally at voltage stress levels of between 1 and 3kV/mm depending on machine size and voltage, it follows that failure at these stress levels due to temperature alone would be in the order of 160,000 to 300,000 hours, which is 20 to 40 years.

It should be remembered that the above is based solely on voltage / temperature and in reality, failure due to voltage alone (apart from transient voltage spikes or corona discharge in HV machines) is most unusual – the majority of failures being associated with gross thermal abuse, or mechanical damage, water in some form or inter-turn faults resulting from combinations of the above.

As a result of the inter-dependence of the properties of materials, which themselves are subject to the service environment, it is impracticable (and unadvisable) to interpret the results of thermal endurance tests of individual materials in terms of performance of an insulation system.

The determination of temperature classification of materials based solely on thermal endurance, although desirable and useful as a guide, can be misleading.

In conclusion, whilst thermal degradation is an important factor, any winding assembly can be seriously weakened if subjected to a high voltage level. Such an occurrence could be the result of connected load switching activity, or connected system generated transient voltage spikes, or Non Linear Load harmonics, or fault conditions occurring within the connected electrical distribution system.

Bearings.

The expected life of a bearing is detailed in AGN009 – Bearing Life.

Typical life for an anti-friction bearing is stated at 30,000 to 40,000 hours, be that sealed for life or re-greasable but in-service, the alternator's environmental conditions inevitably affect this. AGN009 provides guidance on quantifiable life expectancy by the calculated performance of the lubricating grease.

Sleeve bearings theoretically could last forever if the alternator never stopped running. Stop-Start operation is the enemy here.

To determine bearing degradation on an alternator, we suggest the alternator's bearing(s) be monitored using commonly available bearing vibration monitoring equipment. With a well-maintained record of bearing vibration measurements, collected over a period of service life, degradation patterns can be plotted and so catastrophic bearing failure and resulting unnecessary additional component damage can be avoided.

Further details on life expectancy for anti-friction and sleeve bearings are published in the Owner's Manual for the alternator.

Bearing Currents that degrade bearings is a separate topic. Refer to AGN033 – Shaft Bearing Currents.

<u>Electronics.</u>

The Cummins Generator Technologies AVR design criteria ensures components are chosen to offer the AVR module with an MTBF figure calculated to be in the region of 100,000 hours (11½ years). The method is based on considering each component part against its specified capability and it's in AVR designed dynamic and steady state operating condition.