STAMFORD | AvK ™

POWERING TOMORROW, TOGETHER

Application Guidance Notes: Technical Information from STAMFORD | AvK

AGN 037 – Terminal Arrangements

INTRODUCTION

On-site electrical installation will generally involve only connecting up the site load to the Generating Set output terminals, installing the control wiring, temperature monitoring device, space heater and connecting batteries in compliance with relevant standards, such as **IEC60034, BS7671, National Electrical Code (NEC), UL2200, DIN 46200, VDE 0875, CSA22-2** and any other applicable standards.

The terminal box components within STAMFORD and AvK alternators include a variety of copper bars, which interconnect the stator winding electrical terminals. Each copper bar has been duly designed to meet engineering requirements for the prevailing operating levels with regard to current density and running temperatures, when considered against their designed location and functionality.

The conductors connected to the output terminals of an alternator must be carefully selected, ideally with a cable supplier's approval and compliant to International Standards for a Generating Set design that will offer resistance to heat and movement flexibility.

TERMINAL ASSEMBLY

The terminal box is designed to support the fitted terminal-bars or terminals, transformers, load cables and auxiliary terminal box. The frame of the Generating Set must be connected to an earth ground. Temperatures approaching 150^{o}C are expected to be generated within the alternator's windings and this heat will be conducted into the alternator's output terminals.

Note of clarification. The design of switchgear chamber Bus-Bars are controlled by engineering standards applicable to that application. Consequently, engineered control of the operating levels of current density, volt-drop considerations along with mechanical integrity under fault conditions combine and so result in stipulated levels of current density and Bus Bar chamber constructional designs. Such engineering standards should not be applied to alternator, motor, or transformer copper bars located within the confines of their equipment structure inherent terminal arrangement.

Output Terminal Connections

STAMFORD | AvK (Cummins Generator Technologies) recommend that cable suppliers should be consulted when selecting the output cable conductors that will be connected to the alternator's output terminals.

STAMFORD and AvK alternators are offered with an output termination arrangement of a construction that is considered to have - based on experience - sufficient surface area and appropriately sized holes for a bolted termination of each output conductor's connection-lug. This connection will have a high contact surface area and provision for the conductor to be clamped directly to the provided alternator terminal area.

The palm (flattened part) of load cable lugs must be clamped in direct contact with the main stator output terminals as shown in

Figure *1* so that the whole palm area conducts the output current.

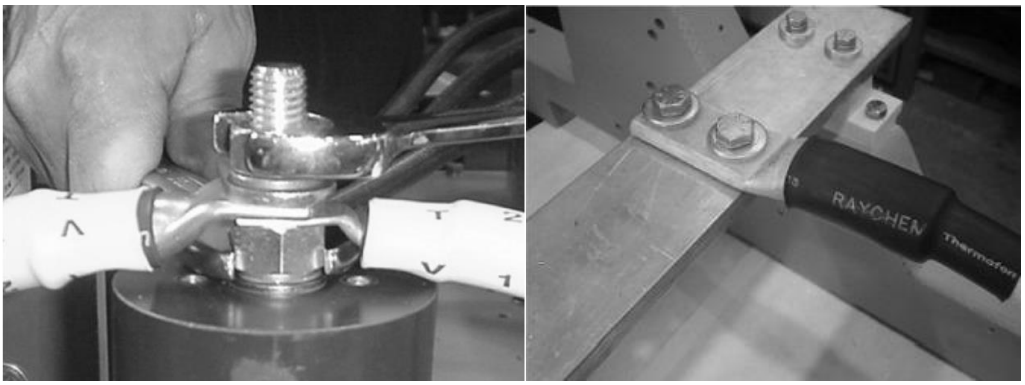

Figure 1: Showing the correct cable clamping methods.

The conductors must be mechanically supported as they enter the metal work of the terminal box, using an appropriate form of glanding. This glanding will help support the weight of the conductor and so will not subject the alternator terminal assembly to high levels of bending moment, which will be amplified by the vibratory movement of the whole alternator assembly in normal service. Problems can arise from additional mechanical loading associated with unsupported conductors, and poorly fitted Current Transformers which add to the already present electro-mechanical stress levels within the terminal structure.

The terminal assembly, and copper bars used as components of the terminal assembly, have been designed, verified and validated with all due consideration to current density and operating temperature. The tinned copper bars conform to **BS 1432**, copper grade C101, and they are supplied with 'hard conditioning' (H). The plating quality and performance comply with **BS EN 1456**.
Consideration of voltage drop related to the terminal assembly and copper bars current density is virtually irrelevant within the confines of an alternator's terminal box, because the copper bars are so short in length.

Operating Temperature

The copper bars in the terminal assembly are directly connected to the stator leads. The assembly will operate at levels of current density that will elevate the copper bar operating temperatures. The temperature will vary accordingly with the stator winding thermal conditions, which are related to the alternator's operational output rating (KVA).

Consideration of copper bar operating temperature must include due consideration of the conducted heat from the stator windings, and therefore, is not simply related to, or controlled by current density levels.

Consideration of the operating temperatures of the supporting terminal assembly does take into account conducted heat from the stator leads, with the terminal box ambient temperature being controlled by due design of terminal box ventilation scheme and air movement provided by the alternator's cooling fan.

Vibration

With the output terminal assembly (and terminal box) being part of the frame construction of each design of alternator, this whole terminal area will move in sympathy with the complete engine-alternator assembly. Movement will generally be in line with the imposed vibration characteristics created by the engine, which in turn is then conducted throughout the unique design of the Generating Set assembly.

With the alternator's terminal assembly being at a radial distance/offset from the Generating Set shaft centre line, the actual level of operational vibration in the terminal region will certainly be modified and amplified to any measured vibration levels identified by the **ISO8528-9** method. Consequently, the actual level and characteristic of terminal assembly and terminal box movement, resulting from imposed vibration, will need to be identified for each Generating Set manufacturer's unique design. AGN008 offers information on the vibration levels and shock load capabilities of the alternator.

S5L1D-G and S5L1D-H Stator Lead Spacers. For all alternator designs, vibration testing is conducted on the stator lead connections to the main terminal board arrangement, to ensure that any vibration stays within acceptable limits. Testing of the S5L1D-G and S5L1D-H alternators, with the new reconnectable terminal board arrangement that has been introduced, has resulted in the need to fit stator lead spacers. The normal design method of bunching the stator lead cables created excessive vibration.

The stator lead spacers have passed life cycle analysis for stiffness, vibration and material optimization. The stator leads with the spacers fitted have passed through rigorous ‘shaker rig’ testing, to ensure the spacers and the cable ties remains in place and effective. The testing was conducted over 10 million cycles at resonant frequency.
No such vibration issues have been observed on the other S5 core lengths, or on any other alternator.

On the S5L1D-G and S5L1D-H alternators, with the stator leads now spaced apart, the increased surface area for the cable to radiate heat has resulted in the additional benefit of better thermal distribution and so, a further small increase in power output.

Figure 2: Stator Lead Spacers fitted to the S5L1D-G and S5L1D-H alternators.

The stator lead spacers are fitted once the terminal board is connected, to allow for easier fitting on the rigid stator leads. The spacers are fitted between the four leads on each group. When the leads are clipped into the spacer, a cable tie is fitted around the diameter, between the wings of the spacer. The head of the cable tie is placed above a cable.

12 spacers are fitted to each alternator, two to each of the six groups of four stator leads that pass through the stator connection ring, to the terminal board. The stator lead spacers are fitted 125mm to 150mm from the terminal stud and the connection ring.

Terminal Box Torque (Parts and Fasteners)

Terminal box torque settings vary, depending on alternator type and size. The mounting and the fastening screws must withstand mechanical moments that occurs during Generating Set starting, operating and transient events. The required settings should be provided in specific alternator operating manual.

AC output connections

The cable must be suitable for the output voltage and the rated current of the Generating Set. In determining the alternator size for low, medium, and high voltage applications, allowances should be made for ambient temperature, method of installation, proximity of other cables, etc. The terminal box designs for low, medium and high voltage alternators are different, therefore the specific electrical wiring and connection diagrams of the load cables from alternator manufacturers must be used. For low-voltage alternators, power supply cables must be connected directly to the machine terminals (without adding washers etc.). For medium and high voltage alternators, power supply cables should be connected to separate terminals or to current transformer terminals.

CONNECTION CABLES

Resistance to Heat

We remind Generating Set manufacturers of the heat that will be generated within the alternator's windings. Temperatures approaching 150^{o}C are expected and this heat will conduct into the alternator's output terminals.

Movement Flexibility

The electro-mechanical assembly of a Generating Set is not a stationary assembly. Movement takes place in all three planes. It vibrates when running and goes through quite considerable oscillatory movements during starting and stopping. AGN008 offers information on the vibration levels and shock load capabilities of the alternator.

Cable types

The three-phase outputs from an alternator can be connected to the load via single-core cables or a multi-core cable as shown in Figure 3.

Figure 3: Showing the SWA armoured power single core cable (left) and multi-core cable (right) used for alternator output connections.

With single-core cables, each of the three-phase outputs are brought out from the terminal box via separate openings. With multi-core cables, the cables of all three phases (and neutral where applicable) are contained in the same trunking and exit the terminal box via the same opening. Multi-core cables are recommended due to its magnetic flux self-cancelling effect. For alternators with greater output power, single-core cables are common as the cross-section of each phase cable is large and cannot be easily contained in a common conduit or trunking.

Cable Routing

Cables may be laid discretely in the ground, run in ducts or clamped to cable trays. The load cables must be supported appropriately e.g. using vibration dampers on the Generating Set foundation as shown in Figure 4, to avoid a tight radius at the point of entry into the terminal box, clamped at the terminal box gland, and allows at least +/- 25mm movement by the Generating Set on its anti-vibration mountings, without causing excessive stress to the cables and alternator load terminals.

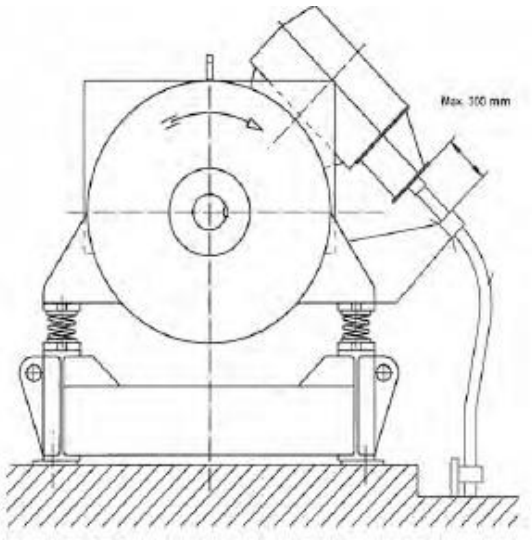

Figure 4: Showing a vibration damper for cable on the Generating Set foundation during installation.

Gland Plates

Gland plates are used to ensure a safe cable entry as shown in Figure 5 below. It grips the wire armouring and seals the entry of the cable. The glanding helps to support the weight of the conductor as it enter the metal work of the terminal box and so will not subject the alternator terminal assembly to high levels of bending moment. When the gland plate is made of ferrous material, it is recommended that a multi-core cable is used, as the net magnetic flux created around the cable will be close to zero. When single-core cables are used, non-ferrous gland plate such as Aluminium plate should be selected due to the low relative permeability of non-ferrous materials. However, when single core cables are used with a ferrous material, slots should be created between the cables and gland plate to break the magnetic flux created around the cable. The following illustration provides an example of an AvK DIG alternator fitted with Aluminium Gland Plates:

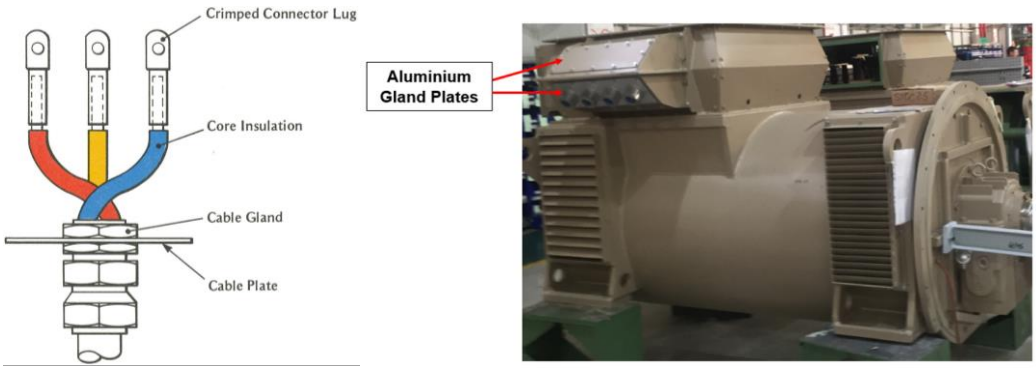

Figure 5: Showing an aluminium cable gland plates.

The three-phase outputs from an alternator can be connected to the load via single-core cables or a multi-core cable. Single-core cables mean that each of the three-phase outputs is brought out from the terminal box via separate openings. Multi-core cables, where the cables of all three phases (and neutral where applicable) are contained in the same trunk and exit the terminal box via the same opening, are recommended due to its flux self-cancelling effect. For alternators with larger output power, single-core cables are common as the cross-section of each phase cable is large and cannot be easily contained in a common conduit or trunk.

A current-carrying conductor creates magnetic field and a change of this magnetic field will induce Electromotive-force (EMF) on another magnetic material linked to the field. The alternator generates alternating current (AC) with alternating magnetic field. When these alternating magnetic fields pass through a ferrous gland plate, EMF will be induced on the plate, creating circulating current which leads to increased temperature of the gland plate.

Most marine societies specify rules for the installation of cables, which are not within the scope of STAMFORD | AvK. Several methods of installation are explained in these standards, for example trefoil cable formation, multi-core cables, and the use of non-magnetic materials between single core cables. Examples of these standards are:

- DNV-GL Ship Rules: Part 4, Chapter 8, Section 10
- BV Rules for the Classification of Steel Ships: Part C, Chapter 2, Section 12
- Lloyd's Register Rules for the Classification of Ships: Part 6, Chapter 2, Section 11

STAMFORD alternators are not supplied with an Aluminium gland plate option for most of the alternator designs from S0 up to P7 products. It is the responsibility of the electrical installation personnel to ensure that the correct installation standards are adhered to. The alternator's terminal box is constructed from removable panels, which can be modified to suit site-specific cable entry and glanding. To prevent swarf from entering the terminal box, the panels must be removed before being drilled or cut. The wiring diagram provided with each alternator must be referred to when making the electrical connections from the alternator's terminals.

Table 1 below summarises the availability of an Aluminium gland plate for each product in the STAMFORD and AvK ranges.

Products	**Aluminium Gland Plate**
S0/ S1/ P0/ P1	Not Available
UC22/ UC27	Not Available
S4	Option available for machine fitted with Dry Dust Air Filter
S5	Not Available
S6	Installed on IP44 alternators to avoid IP44 sealing being disturbed
S7	Installed on IP44 alternators to avoid IP44 sealing being disturbed. Aluminium side terminal panel option may be available for specific builds – refer to Applications Engineering
S9	Installed as standard on cable entry side
DSG/ DIG	Installed as standard on cable entry side

Table 1: Showing a summarised availability of an Aluminium gland plate for each product in the STAMFORD and AvK ranges.

The following illustration shows a S4L1D alternator fitted with Dry Dust Air Filter and Aluminium Gland Plate:

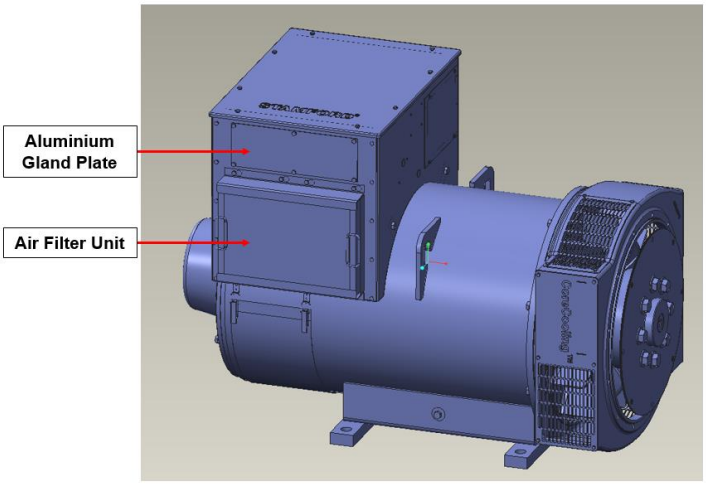

Figure 6: S4L1D alternator fitted with Dry Dust Air Filter and Aluminium Gland Plate.

Installation of electrical load cables and conductors

The installation of electrical load cables from the alternator's output terminals is not within the scope of STAMFORD | AvK. The Generating Set manufacturer installing the cables must ensure that correct installation methods in compliance with the relevant standards, such as **BS7671, National Electrical Code (NEC), UL2200 and CSA22-2**, as appropriate.

Good engineering practice for Generating Sets requires consideration of the electrical requirements for the chosen conductors destined to be connected to the alternator's output terminals and then over what distance will these 'un-protected' conductors travel. Particularly, Generating Set manufacturers and installers must carefully consider the engineering and environmental requirements for:

- The type of output cabling/conductor. Experience has shown that poorly chosen output cables from a Generating Set will fail. Therefore using standard PVC type cables, of single core or multicore, which are manufactured with few, large diameter, conductor strands and therefore are not flexible or designed for temperatures above even 100^{o}C, will NOT be suitable.

- The need to apply the correct torque settings for connecting the output cabling/conductors. Torque settings vary, depending on alternator type and size and the required settings should be provided with the alternator. For example: for UCI224 and UCI274 alternators, the torque settings is 20 – 30 Nm, for S4, S5, S6 and S7 alternators, the torque settings is 40 – 50 Nm.

- The associated glanding/bushings required for the cables/conductors required at the alternator's terminal box side.

- The need to provide physical support for the cables/conductors as they leave the vibrating mass of the engine and alternator, before they become clamped to a rigid and fixed structure.

- The need to terminate at a junction box fixed to a non-moving, rigid and fixed part of the Generating Set base assembly or to the floor space adjacent to the Generating Set.

- The junction box is often used to house the Generating Set Circuit Breaker. From this junction box the Generating Set's output needs to be conducted through appropriate cables, which again must be chosen for compliance with the conditions and environment.

- If the Generating Set Circuit Breaker is mounted within a junction box structure attached to the Generating Set's frame/body, then it can be expected that both the cables and terminals will have virtually zero relative movement, therefore offering the opportunity to use either solid bus-bars or a lamnicon type conductor.

- Here there is the need to consider Electro Magnetic Radiation from the cables. This will dictate the suitability of single core, or multicore cables, and the chosen method to achieve a Trefoil twist to neutralise radiated flux.

- If the Generating Set is to be connected to a nearby floor standing electrical cubicle, incorporating the Generating Set Circuit Breaker, then there is the obvious need to connect the moving/vibrating alternator terminals to a very flexible conductor, which will then exit the alternator's terminal box via suitably engineered glanding arrangement. This conductor will then travel to a floor mounted junction cubicle located adjacent to the Generating Set base frame. From this junction cubicle, the required type of marine specification cable can then be used to travel to the local electrical control panel incorporating the master Circuit Breaker and appropriate Generating Set output monitoring package.

- If the Generating Set is to be connected to a long run of cable, which is to be supported by cable tray, therefore, solidly fixed to walls /ceiling/ floor adjacent to the Generating Set and so, not moving in sympathy with the engine-alternator assembly, then great care must be taken with the choice of:

    - The cables specification, particularly attention to ensuring flexibility.

    - The cable's support and routing, between the floor/wall/ceiling mounted fixed cable tray and Generating Set moving/vibrating terminal box.

    - The cables entry to the terminal box and here, cable glanding and side of terminal box's inherent strength/weakness need to be considered.

    - Required modification to the terminal box cable entry region to carry the unsupported mass of a vibration-absorbing 'swan-neck' that has been engineered into the cable between the clamped and fixed section of cable and the moving glanded part of the cable at the terminal box side.

Reverse Terminal Arrangement

It is possible for the customer to request a reverse terminal arrangement on many STAMFORD and AvK alternators. This effectively offers the Generating Set manufacturer an alternator terminal assembly that is the mirror image of his standard arrangement and provides for cable entry from the opposite side of the alternator.

For changing the cable entry on an S5, S6 and S7 STAMFORD alternator after manufacturer, when ideally the Generating Set manufacturer would like his cable entry to be the mirror image of his standard arrangement – N W V U looking from the NDE – there is a design flaw. This is not possible, as the 'U' and 'W' stator cables cannot be switched over. The Generating Set manufacturer must therefore bring his cables into the terminal box in the configuration – N U V W. This decision must be made before he makes his cables entry. The Generating Set manufacturer should use the following procedure:

- Disconnect all main stator terminals and rotate the main terminal rail assembly. The Neutral terminal is now at the opposite end of the terminal box (non-drive end), so all phase terminals are shifted towards the drive end.

- NOTE: This means that the stator cables must also be shifted towards the drive end, so far, we have managed to do this on all STAMFORD frames sizes from S5 to S7 (6 ends out windings on S6 and S7 are more difficult).

- Remove the 'U' and 'W' phase markers on the terminal rail, and switch them over, ('U' phase becomes 'W' phase, and vice versa). All Neutral cables (the 2's) now become the phases, and all phases (the 1's) become the Neutral.

    - NOTE: It's easier to modify markings on the customer wiring diagram than alter the cable markers).

- Carefully removed cable ties and re-position the cables, to reach the new terminal positions.

- Move the DROOP C/T from W2 across to W1 cable (S1 - S2 remains as before).

- Cable tie all stator leads tightly together, making sure that all adjacent leads are tied, and are also tied with any touching cables. (This is essential to avoid cable sleeving fretting with vibration).

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