

P7 AC GENERATORS
INSTALLATION, SERVICE AND
MAINTENANCE

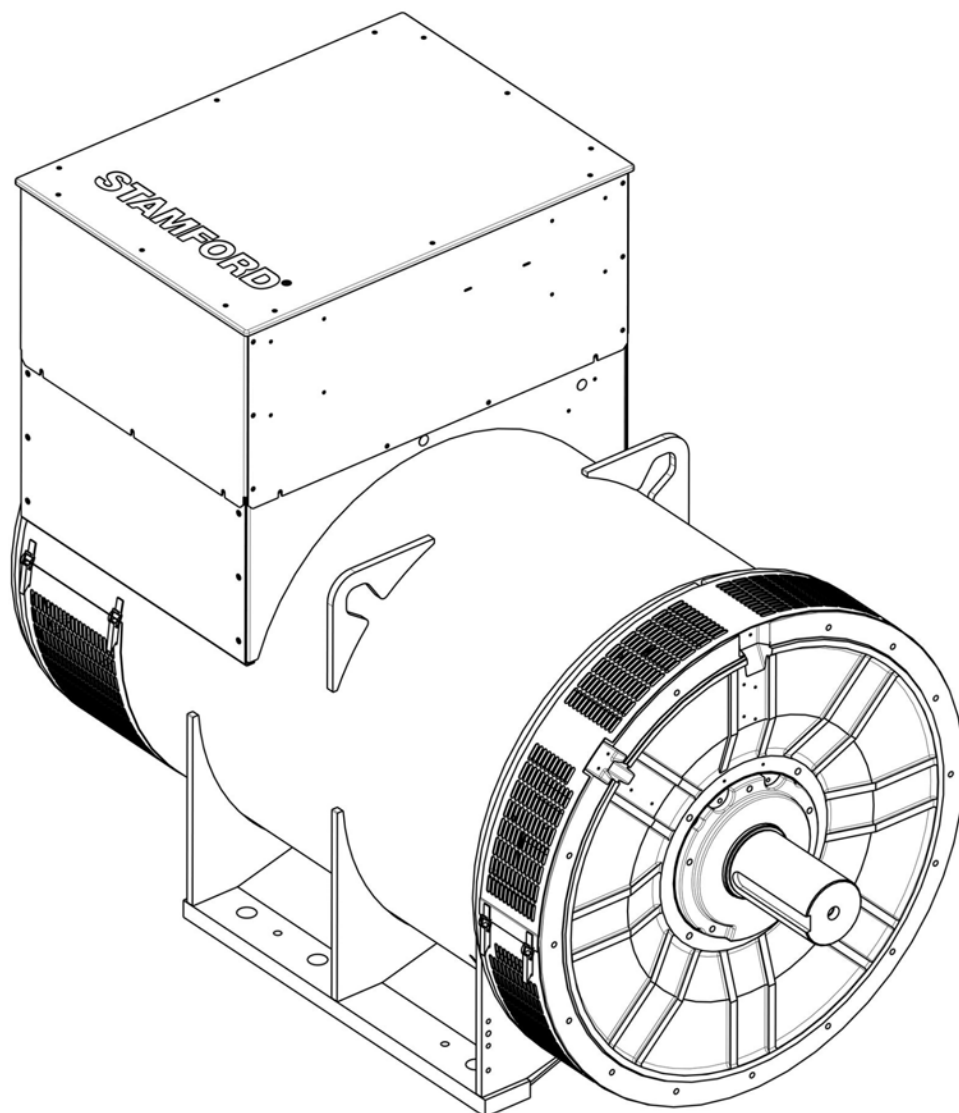


Table of Contents

1. FOREWORD	1
2. SAFETY PRECAUTIONS.....	3
3. SAFETY DIRECTIVES AND STANDARDS	7
4. INTRODUCTION	11
5. AUTOMATIC VOLTAGE REGULATORS (AVR).....	15
6. APPLICATION OF THE GENERATOR.....	19
7. INSTALLATION INTO THE GENERATING SET	25
8. SERVICE AND MAINTENANCE.....	35
9. FAULT FINDING	61
10. PARTS IDENTIFICATION.....	73
11. TECHNICAL DATA.....	77
12. SPARES AND AFTER SALES SERVICE	79
13. END OF LIFE DISPOSAL	81

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1 Foreword

1.1 The Manual

This manual contains guidance and instructions for the installation, servicing and maintenance of the generator.

Before operating the generator, read this manual and make sure that all personnel who work on the equipment have access to the manual and all additional documentation supplied with it. Misuse and failure to follow the instructions, and the use of non-approved parts, may invalidate the product warranty and lead to potential accidents.

This manual is an essential part of the generator. Make sure that the manual is available to all users throughout the life of the generator.

The manual is written for skilled electrical and mechanical technicians and engineers, who have prior knowledge and experience of generating equipment of this type. If in doubt, please seek expert advice or contact your local Cummins Generator Technologies subsidiary.

NOTICE

Information in this manual was correct when published. It may be superseded due to our policy of continuous improvement. Please visit www.cumminsgeneratortechnologies.com for latest documentation.

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2 Safety Precautions

2.1 Safety Information and Notices used in this manual

Danger, Warning and Caution panels are used in this manual to describe the sources of hazards, their consequences and how to avoid injury. Notice panels emphasise important or critical instructions.

 DANGER
Danger indicates a hazardous situation which, if not avoided, WILL result in death or serious injury.

 WARNING
Warning indicates a hazardous situation which, if not avoided, COULD result in death or serious injury.

 CAUTION
Caution indicates a hazardous situation which, if not avoided, COULD result in minor or moderate injury.

NOTICE
Notice refers to a method or practice which can result in product damage, or to draw attention to additional information or explanations.

2.2 Skill Requirements of Personnel

Service and maintenance procedures must only be carried out by experienced and qualified engineers, who are familiar with the procedures and the equipment.

2.3 Risk Assessment

A risk assessment has been performed on this product by Cummins, however a separate risk assessment must be performed by the user/operating company to establish all personnel-related risks. All affected users must be trained on the identified risks. Access to the Power Plant/Generating Set during operation must be restricted to persons who have been trained on these risks.

2.4 Personal Protective Equipment (PPE)

All persons operating, servicing, maintaining or working in or with a power plant or a generating set must wear appropriate Personal Protective Equipment (PPE)

Recommended PPE includes:

- Ear and Eye Protection
- Head and face protection
- Safety footwear
- Overalls that protect the lower arms and legs

Ensure that all persons are fully aware of the emergency procedures in case of accidents.

2.5 Noise

 **CAUTION**

Generators emit noise. Wear appropriate ear protection at all times. Maximum A-weighted noise emissions may reach 110 dB(A). Contact the supplier for application-specific details.

2.6 Electrical Equipment

 **DANGER**

Hazardous Voltage

Will shock, burn or cause death

All electrical equipment can be dangerous if not operated correctly. Always install, service and maintain the generator in accordance with this manual.

Work that requires access to electrical conductors must comply with all applicable local and national electrical safety procedures for the voltages involved and any site specific rules. Always use genuine branded replacement parts.

2.7 Lock Out/Tag Out

 **WARNING**

Risk of serious injury or death

Generators can retain mechanical and electrical energy

Isolate the generator from all sources of mechanical and electrical energy before starting service or maintenance work. Adopt a suitable lock-out/tag out process.

2.8 Lifting

 **WARNING**

Improper lifting can cause serious injuries to persons or can cause death.

Do not use the generator lifting points to lift the complete generating set (generator coupled to motive power source)

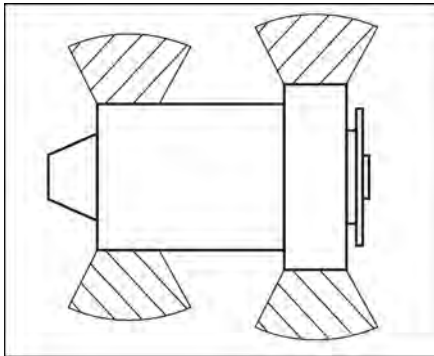
The lifting points provided are designed for lifting the generator only.

Do not remove the lifting label attached to one of the lifting points.

2.9 Generator Operating Areas

⚠ WARNING

In the event of catastrophic failure, machine parts may be ejected from the generator air inlet/outlet (shaded regions of diagram). Do not place controls near the air inlet/outlet and restrict personnel from these regions during machine running.



2.10 Hazard Warning Labels

Hazard warning labels are fixed to the generator. If the original labels are missing, damaged or painted over, replace them with the spare set supplied in a wallet attached to the generator. Label locations are shown on the back of the label set.



2.11 General Guidance

NOTICE

These safety precautions are for general guidance and supplement your own safety procedures and all applicable laws and standards.

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3 Safety Directives and Standards

STAMFORD AC generators meet applicable European safety directives, and national and international standards relevant to generators. The generator must be operated within the limits specified in the relevant standards and within the parameters on the generator rating plate.

Marine generators meet the requirements of all the major marine classification societies.

3.1 European Directives: EC Declaration of Conformity for Incorporation

EC Declaration of Conformity



This synchronous a.c. generator is designed for incorporation into an electricity generating-set and fulfils all the relevant provisions of the following EC Directive(s) when installed in accordance with the installation instructions contained in the product documentation:

2006/95/EC	Low Voltage Directive
2004/108/EC	The EMC Directive
2006/42/EC	The Machinery Directive

and that the standards and/or technical specifications referenced below have been applied:

EN 61000-6-1:2007	Electromagnetic compatibility (EMC). Generic standards – Part 6-1: Immunity for residential, commercial and light-industrial environments
EN 61000-6-2:2005	Electromagnetic compatibility (EMC). Generic standards – Part 6-2: Immunity for industrial environments
EN 61000-6-4:2007	Electromagnetic compatibility (EMC). Generic standards – Part 6-4: Emission standard for industrial environments
EN ISO 12100-1:2003	Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology
EN ISO 12100-1:2003	Safety of machinery - Basic concepts, general principles for design -Part 2: Technical principles
EN ISO 14121-1:2007	Safety of machinery - Risk assessment - Part 1: Principles
EN 60034-1:2004	Rotating electrical machines - Part 1: Rating and performance
BS ISO 8528-3:2005	Reciprocating internal combustion engine driven alternating current generating sets - Part 3: Alternating current generators for generating sets
BS 5000-3:2006	Rotating electrical machines of particular types or for particular applications - Part 3: Generators to be driven by reciprocating internal combustion engines - Requirements for resistance to vibration

The manufacturer's authorised representative in the Community and person empowered to draw up this declaration and to compile the relevant technical documentation, on behalf of the manufacturer is Mr Jeffrey Matthews - Director Engineering, Cummins Generator Technologies, Barnack Road, Stamford, Lincolnshire, PE9 2NB, England.

Signed: 

Description

Date: 21st December 2009

Serial Number

Registered in England under Registration No. 441273.
 Cummins Generator Technologies Ltd. Registered Office: Barnack Road, Stamford, Lincolnshire PE9 2NB, England.

DRAWING REF 450-1-0383-C

Each generator supplied in the European Economic Area (EEA) is supplied with an EC Declaration of Conformity for Incorporation into an electricity generating set. It is the responsibility of the generating set manufacturer to ensure that the complete generating set complies with EC Directives and standards.

Our authorized representative in the European Community is Mr Jeffrey Matthews, Engineering Director, Cummins Generator Technologies Ltd.

All generators meet the following Standards and Directives:

Directives:

- 2004/108/EC EMC Directive
- 2006/95/EC Low Voltage Directive
- 2006/42/EC Machinery Directive

Standards:

- EN 61000-6-1 Electromagnetic Compatibility, Generic Standards - Immunity for residential, commercial and light-industrial environments
- EN 61000-6-2 Electromagnetic Compatibility, Generic Standards - Immunity for industrial environments
- EN 61000-6-4 Electromagnetic Compatibility, Generic Standards - Emission standard for light-industrial environments
- EN ISO 12100-1 Safety of Machinery, Basic concepts, general principles for design - Basic terminology, methodology
- EN ISO 12100-2 Safety of Machinery, Basic concepts, general principles for design - Technical principles
- EN ISO 14121-1 Safety of Machinery, Risk assessment - Principles
- EN 60034-1 Rotating electrical machines - Rating and performance
- BS ISO 8528-3 Reciprocating internal combustion engine driven alternating current generating sets - alternating current generators for generating sets
- BS 5000-3 Rotating electrical machines - Generators to be driven by reciprocating internal combustion engines - Requirements for resistance to vibration

NOTICE

Once the generator is built into a generating set, it is the responsibility of the generating set manufacturer to ensure that the generating set complies with the relevant specifications and standards.

3.2 Additional Information for EMC Compliance

STAMFORD generators are designed to meet EMC emissions and immunity standards for industrial environments. Document reference N4/X/011 outlines additional equipment that may be required when the generator is installed in residential, commercial and light industrial environments.

The installation 'earth/ground' arrangements require the connection of the generator frame to the site protective earth conductor using a minimum lead length.

Installation, maintenance and servicing must be carried out by adequately trained personnel fully aware of the requirements of the relevant EC directives.

NOTICE

Cummins Generator Technologies is not liable for EMC compliance if unauthorised parts, not of STAMFORD brand, are used for maintenance and servicing.

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4 Introduction

4.1 General Description

P7 generators are of brushless rotating field design, available up to 690V, 50Hz (1000 RPM, 6 pole and 1500 RPM, 4 pole) or 60Hz (1200 RPM, 6 pole and 1800 RPM, 4 pole), and built to meet BS5000 Part 3 and international standards.

4.2 Serial Number Location

A unique serial number is stamped into the upper section of the drive end bracket and shown on two labels on the outside of the terminal box.

4.3 Rating Plate

The self-adhesive rating plate label, supplied with the generator, must be fixed after the generator set is fully assembled and painted.

 **WARNING**

The generator could overheat if operated outside the parameters specified on the rating plate. Overheating can cause catastrophic failure and serious injury from ejected debris. Always operate the generator within the rated parameters.

4.4 Product Authentication

The STAMFORD high security, anti-counterfeit hologram is located on the Tracking Label. Check that the dots are visible around the STAMFORD logo when viewing the hologram from different angles and the word "GENUINE" appears behind the logo. Use a flashlight to see these security features in low ambient light. Check that the generator is genuine by entering the unique 7 character hologram code at www.stamford-avk.com/verify.

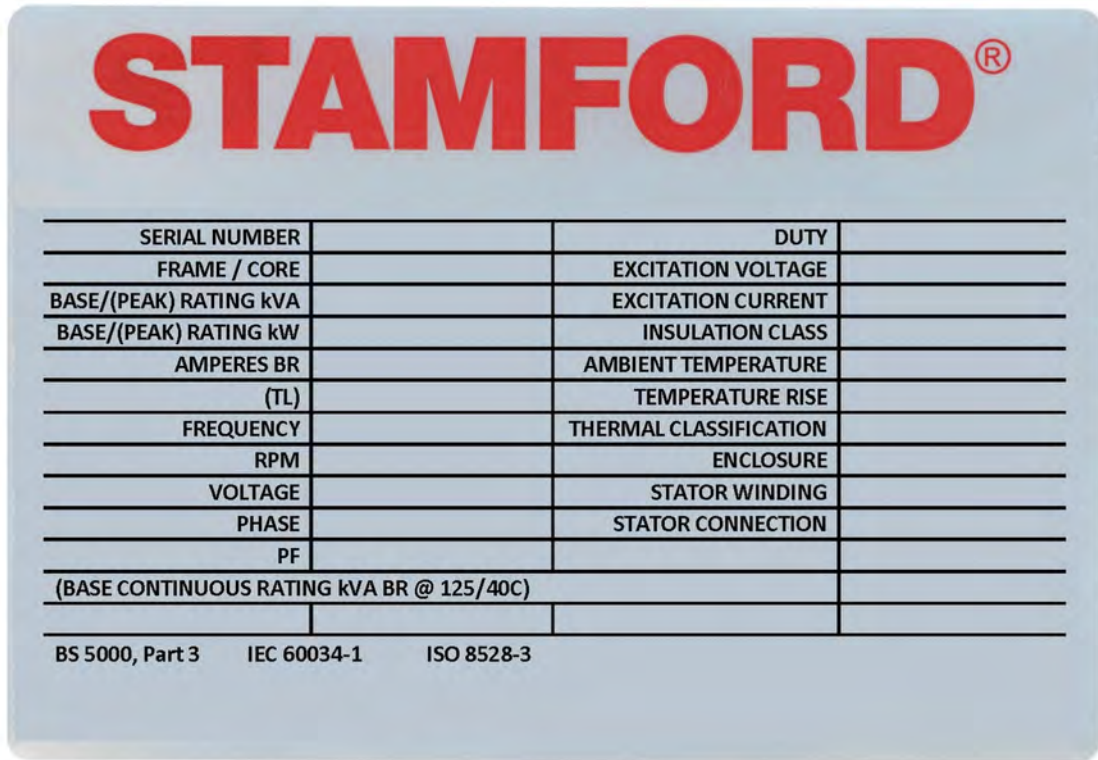


FIGURE 1. GLOBAL STAMFORD AC GENERATOR NAMEPLATE, COMPRISING RATING PLATE (ABOVE) AND TRACKING LABEL (BELOW)

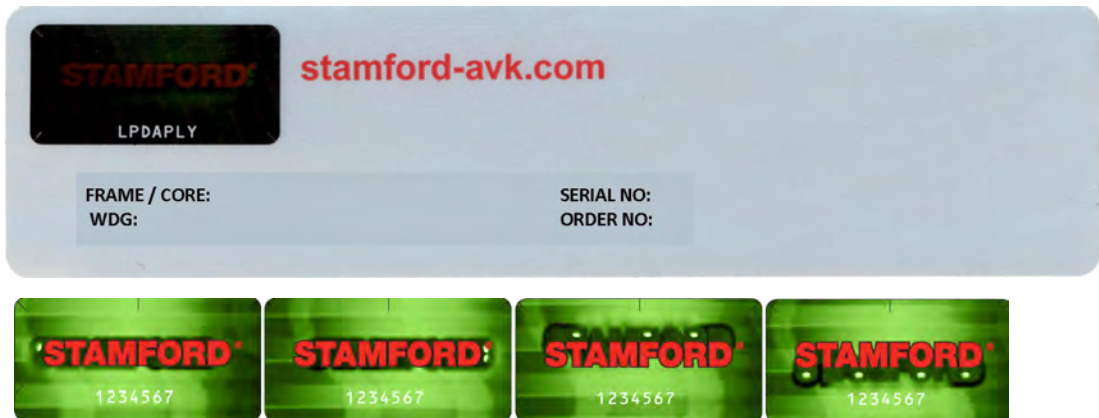


FIGURE 2. DOTS VISIBLE IN LEFT, RIGHT, UPPER AND LOWER VIEWS OF 3D HOLOGRAM

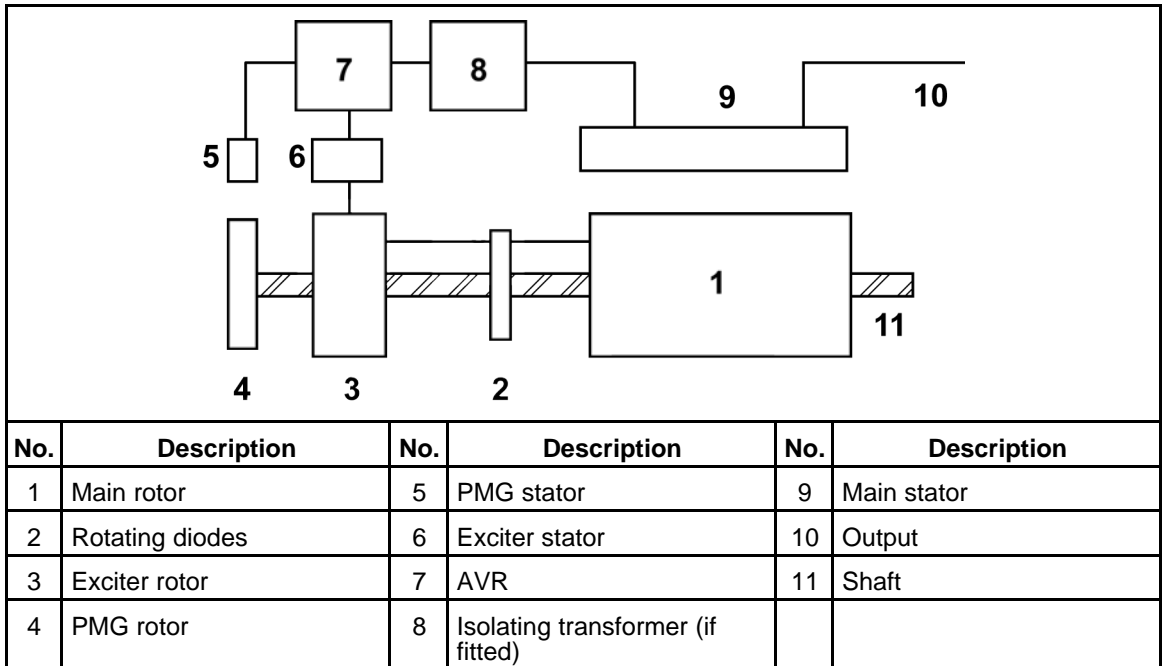
4.5 Separately-Excited AVR Controlled Generators

4.5.1 Permanent Magnet Generator (PMG) excited - AVR controlled generators

⚠ WARNING

Take appropriate precautions when handling the Permanent Magnet Generator (PMG). It has a strong magnetic field that could interfere with an implanted medical device or cause hand injury by trapping.

The AVR provides closed loop control by sensing the generator output voltage at the main stator windings and applying voltage to the exciter stator. Voltage induced in the exciter rotor, rectified by the rotating diodes, magnetises the main rotor which induces voltage in the main stator windings. The AVR is independently powered from voltage induced in the stator of an Permanent Magnet Generator (PMG) by a rotor of permanent magnets.



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5 Automatic Voltage Regulators (AVR)

Cummins Generator Technologies offer a selection of Automatic Voltage Regulators (AVRs) designed and built to achieve maximum performance from the range of STAMFORD brushless AC generators. Self-excited and separately-excited types are available, from low-cost analogue to sophisticated digital control. All STAMFORD AVRs are encapsulated to provide environmental protection, and are mounted on anti-vibration mounts for added mechanical protection.

All STAMFORD AVRs have the following features:

- connections to a remote hand trimmer accessory for fine control of the generator output voltage
- 'Under-Frequency Roll-Off' (UFRO) protection to reduce the generator output voltage if speed falls below a threshold, and
- connections to power factor and droop accessories for sharing reactive load in parallel with other generators or mains utility.

AVR specification, installation and adjustment information is available in the AVR manual supplied with the generator, or at www.cumminsgeneratortechnologies.com

NOTICE

AVR analogue inputs must be fully floating (galvanically isolated from ground), with an insulation strength of 500 V a.c.

5.1 Separately-excited

A separately-excited AVR receives power from a separate permanent magnet generator (PMG), mounted on the main generator shaft. The AVR controls the generator output voltage by automatic adjustment of the exciter stator field strength. The AVR excitation remains at full capability when sudden loads are applied to the generator, giving superior motor starting, short circuit and EMC performance.

5.1.1 MX341

The MX341 achieves voltage regulation of $\pm 1.0\%$ and protection against sustained over-excitation.

The AVR includes the following extra features:

- connections to an analogue signal from a power factor controller accessory, for example
- adjustable rate of voltage reduction with speed for (UFRO) protection
- soft-start control of generator output voltage rise when starting.

5.1.2 MX321

The MX321 achieves voltage regulation of $\pm 0.5\%$ and protection against sustained over-excitation.

The AVR includes the following extra features:

- connections to an analogue signal from a power factor controller accessory, for example

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- adjustable rate of voltage reduction with speed for (UFRO) protection
 - soft-start control of generator output voltage rise when starting
 - three-phase r.m.s. voltage sensing
 - over-voltage protection with internal shutdown of the AVR output device
 - adjustable delayed response (dwell) of excitation voltage to speed changes, and
 - adjustable short-circuit or starting current limit (with optional current sensing transformer accessory).

5.1.3 DM110

The DM110 digital excitation control system is a microprocessor-based controller. DM110 parameters are set and monitored with software on a connected personal computer (PC). When running without a PC, control status may be monitored by LED lamps on the controller .

The AVR includes the following extra features:

- integrated power factor control
- adjustable rate of voltage reduction with speed for (UFRO) protection
- soft-start control of generator output voltage rise when starting
- three-phase r.m.s. voltage sensing
- over-voltage protection with internal shutdown of the AVR output device
- adjustable excitation limiting, and
- full digital control.

5.2 AVR Accessories

Accessories to support AVR functions are factory-fitted or supplied separately with instructions for fitting and wiring by a competent technician.

5.2.1 Hand Trimmer (for remote voltage adjustment)

A hand trimmer can be fitted in a convenient position (typically in the generator set control panel) and connected to the AVR to provide fine adjustment of the generator voltage. The hand trimmer value and the adjustment range obtained is as defined in the Technical Specification. Refer to wiring diagram before removing the shorting link and connecting the hand trimmer.

5.2.2 Droop Transformer (for parallel operation – generator to generator)

A droop transformer can be fitted in a defined position in the generator main output wiring and connected to the AVR to enable parallel operation with other generators. The adjustment range is as defined in the Technical Specification. Refer to wiring diagram before removing the shorting link and connecting the droop transformer. The droop transformer **MUST** be connected in the correct main output terminal for proper operation (details are as shown in the machine wiring diagram).

5.2.3 Power Factor Controller (PFC) (for parallel operation – generator to mains utility)

An electronic control module is available for use with the AVR to provide power factor control of the generator output. The module uses generator voltage and output current as inputs and interfaces with the AVR to ensure the necessary flexibility of the generator excitation and hence control of the exported (or imported) kVAr. This allows full closed-loop control of the generator power factor at the point of connection into the mains utility. Other features allow the generator (or generators) to be automatically 'voltage-matched' prior to paralleling.

5.2.4 Current Limiting Transformers

Generator main output current can be electronically limited by connecting additional current transformers to the MX321 AVR. In any situation where the output current attempts to rise above a preset threshold (set on AVR) then the AVR will reduce the terminal voltage to restore the set current level. For unbalanced loads, operation is based on the highest of the three phase currents.

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6 Application of the Generator

It is the customer's responsibility to make sure that the selected generator is suitable for the final application.

⚠ CAUTION

Overloading a generator may lead to catastrophic failure.

6.1 Environment

STAMFORD generators are protected to IP23 as standard. IP23 is not adequate protection for use outdoors without additional measures.

Ambient Temperature	-15 °C to 40 °C
Relative Humidity	< 60%
Altitude	< 1000 m

The generator has been designed for the environment shown in the table. The generator can operate outside these conditions if it is rated accordingly: The nameplate gives details. If the operating environment is changed after purchase, refer to the factory for a revised generator rating.

6.2 Air Flow

TABLE 1. MINIMUM AIR FLOW AND MAXIMUM PRESSURE DROP

Generator type	50 Hz	60 Hz	Maximum intake to outlet pressure drop, mm (in) water gauge
	Minimum Air flow, m ³ /s (ft ³ /min)		
6 pole	1.79 (3793)	2.3 (4874)	6 (0.25)
4 pole	2.69 (5700)	3.45 (7310)	6 (0.25)

Make sure that the air inlets and outlets are not obstructed when the generator is running.

6.3 Airborne Contaminants

Contaminants such as salt, oil, exhaust fumes, chemicals, dust and sand will reduce the effectiveness of the insulation and the life of the windings. Consider using air filters and an enclosure to protect the generator.

6.4 Air Filters

Air filters trap airborne particulates above 5 microns. The filters must be cleaned or replaced regularly, depending on site conditions. Check the filters frequently to establish an appropriate service interval.

Generators with factory-fitted filters are rated to account for the reduced flowrate of cooling air. If filters are retrofitted, the generator rating must be reduced by 5%.

Air filters do not remove water. Keep the filters dry with additional protection. Wet filters further restrict airflow, causing the generator to overheat and leading to premature failure of the insulation.

6.5 Humid Conditions

The water carrying capacity of air depends on temperature. If the air temperature falls below its saturation point, dew may form on the windings reducing the electrical resistance of the insulation. In humid conditions additional protection may be required, even if the generator is fitted inside an enclosure. Anti-condensation heaters are supplied on request.

6.6 Anti-condensation heaters

 **WARNING**

Power to the anti-condensation heater is supplied from a separate source. Before doing any work on the heater, make sure the power is isolated and locked off.

Anti-condensation heaters raise the air temperature around the windings to deter condensation forming in humid conditions when the generator is not operating. Best practice is to energise the heaters automatically when the generator is off.

6.7 Enclosures

Fit an enclosure to protect the generator from adverse environmental conditions. Make sure that air entering the generator is of adequate flowrate, free from moisture and contaminants, and below the maximum ambient temperature on the rating plate.

Make sure there is sufficient access around the generator for safe maintenance.

6.8 Vibration

STAMFORD generators are designed to withstand the vibration levels encountered on generating sets built to meet the requirements of ISO 8528-9 and BS 5000-3. (Where ISO 8528 is taken to be broad band measurements and BS5000 refers to the predominant frequency of any vibrations on the generating set).

NOTICE

Exceeding either of the above specifications will have a detrimental effect on the life of the bearings and other components, and may invalidate the generator warranty.

6.8.1 Definition of BS5000–3

Generators shall be capable of continuously withstanding linear vibration levels with amplitudes of 0.25mm between 5Hz and 8Hz and velocities of 9.0mm/s r.m.s. between 8 Hz and 200 Hz, when measured at any point directly on the carcass or main frame of the machine. These limits refer only to the predominant frequency of vibration of any complex waveform.

6.8.2 Definition of ISO 8528-9

ISO 8528-9 refers to a broad band of frequencies; the broad band is taken to be between 10 Hertz and 1000 Hertz. The table below is an extract from ISO 8528-9 (Table C.1, value 1). This simplified table lists the vibration limits by kVA and speed for acceptable operation of standard generating set designs.

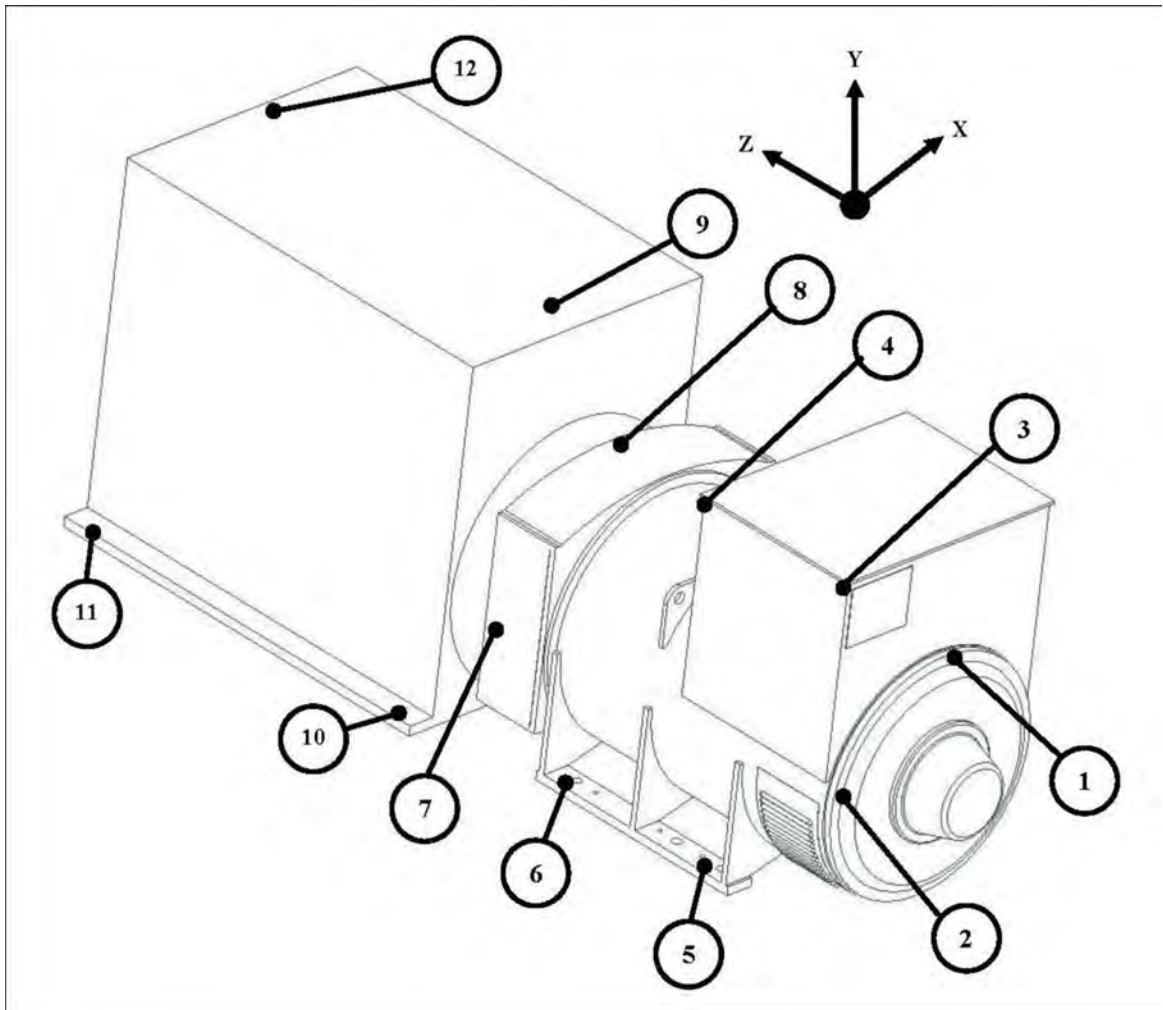
6.8.3 Linear Vibration Limits

Linear Vibration Levels As Measured On The Generator - P7				
Engine Speed RPM (min ⁻¹)	Power Output S (kVA)	Vibration Displacement r.m.s. (mm)	Vibration Velocity r.m.s. (mm/s)	Vibration Acceleration r.m.s. (mm/s ²)
1300 ≤ RPM ≤ 2000	250 < S	0.32	20	13
720 ≤ RPM < 1300	250 < S ≤ 1250	0.32	20	13
	1250 < S	0.29	18	11

The broad band is taken as 10 Hz - 1000 Hz

6.8.4 Linear Vibration Monitoring

We recommend using vibration analysing equipment to measure vibration at the positions shown below. Check that vibration of the generating set is below the limits stated in the standards. If vibration is above the limits, the generating set builder should investigate the root causes and eliminate them. Best practice is for the generating set builder to take initial readings as a reference and for the user to periodically monitor vibration, according to the recommended service schedule, to detect a deteriorating trend.



6.8.5 Excessive Vibration

⚠ WARNING

Excessive vibration can cause catastrophic failure of the generator, which could cause personal injury.

If the measured vibration of the generating set is not within the limits:

1. The generating set manufacturer should change the generating set design to reduce the vibration levels as much as possible.
2. Contact Cummins Generator Technologies to assess the impact on bearing and generator life expectancy.

6.9 Bearings

6.9.1 Bearing Life

Factors that reduce bearing life or lead to bearing failure include:

- Adverse operating conditions and environment
- Stress caused by misalignment of the generating set
- Vibration from the engine that exceeds the limits in BS 5000-3 and ISO 8528-9

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- Long periods (including transportation) where the generator is stationary and subjected to vibration can cause false brinelling wear (flats on the balls and grooves on the races)
 - Very humid or wet conditions that cause corrosion and deterioration of the grease by emulsification.

6.9.2 Health Monitoring of the Bearings

We recommend that the user checks the bearing condition, using vibration monitoring equipment. Best practice is to take initial readings as a reference and periodically monitor the bearings to detect a deteriorating trend. It will then be possible to plan a bearing change at an appropriate generating set or engine service interval.

6.9.3 Bearing Service Life Expectancy

Bearing manufacturers recognise that service life of bearings depends on factors that are outside their control: Rather than quote a service life, practicable replacement intervals are based on the L10 life of the bearing, the type of grease and the recommendations of the bearing and grease manufacturers.

For general-purpose applications; if the correct maintenance is carried out, vibration levels do not exceed the levels stated in ISO 8528-9 and BS5000-3, and the ambient temperature does not exceed 50°C, plan to replace the bearings within 30,000 hours of operation.

If in doubt about any aspect of bearing life on STAMFORD generators, contact your nearest supplier of STAMFORD generators or the Stamford factory.

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7 Installation into the Generating Set

7.1 Generator Dimensions

Dimensions are included in the data sheet specific to the generator model. Refer to the rating plate to identify the generator model .

NOTICE

Data sheets are available from www.cumminsgeneratortechnologies.com

7.2 Lifting the Generator

CAUTION

The generator lifting points are designed to lift the generator only. Do not lift the complete generating set (generator coupled to motive power source) by the generator lifting points. Keep the generator horizontal when lifting. Fit the transit bar to single bearing generators to keep the main rotor in the frame.

Lift the generator by shackle and pin attachment to the lifting points (lugs or eyes) provided. A label attached to a lifting point shows the correct lifting arrangement. Use chains of sufficient length, and a spreader bar if necessary, to make sure that the chains are vertical when lifting. Make sure that the capacity of the lifting equipment is sufficient for the generator mass shown on the label.

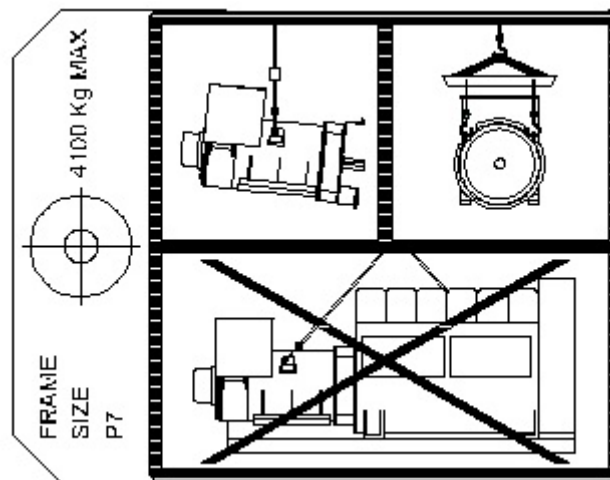


FIGURE 3. LIFTING LABEL

7.3 Storage

If the generator is not to be used immediately, it must be stored in a clean, dry, vibration free environment. We recommend the use of anti-condensation heaters.

Refer to Service and Maintenance section ([Chapter 8](#)) of this manual for further instructions for the bearings of stored generators.

7.3.1 After Storage

After a period of storage, carry out 'pre running checks' to determine the condition of the windings. If the windings are damp or the insulation is low, follow one of the 'drying out procedures', in the Service and Maintenance section ([Chapter 8](#)) of this manual.

For regreaseable bearings, if the generator has been in storage for 6 months or more, regrease the bearings before use. For sealed bearings, if the generator has been in storage for 12 months or more, replace the bearings before use.

7.4 Vibration Frequencies

The main vibration frequencies produced by the generator are as follows:

- 6-pole 1000 RPM 16⅔ Hz
- 6-pole 1200 RPM 20 Hz
- 4-pole 1500 RPM 25 Hz
- 4-pole 1800 RPM 30 Hz

Vibrations induced in the generator by the engine are complex. It is the responsibility of the generating set designer to ensure that the alignment and stiffness of the bedplate and mountings do not allow vibration to exceed BS5000 part 3 and ISO 8528 part 9 limits.

7.5 Generating Set Coupling

⚠ CAUTION

Do not use the fan to rotate the shaft as this can lead to damage and personal injury.



Efficient operation and long component life depend on minimising mechanical stresses on the generator. When coupled in a generating set, misalignment and vibration interactions with the prime mover engine can cause mechanical stress.

Generating sets need a substantial flat continuous bedplate to suit the installation site floor loading, with engine and generator mounting pads to make a firm base for accurate alignment. The height of all mounting pads must be within 0.25 mm for skid mounting, 3 mm for non-adjustable anti-vibration mounts (AVM) or 10 mm for adjustable height AVMs. Use shims to achieve level. The rotational axes of generator rotor and engine output shaft must be coaxial (radial alignment) and perpendicular to the same plane (angular alignment). The axial alignment of the generator and engine coupling must be within 0.5 mm, to allow for thermal expansion without unwanted axial force on the bearings at operating temperature.

Vibration can occur by flexing of the coupling. The generator is designed for a maximum bending moment not exceeding 275 kgm (2000 lbs ft). Check the maximum bending moment of the engine flange with the engine manufacturer.

Close-coupling of generator and engine can increase the rigidity of the generating set. Both single and two bearing generators can be close-coupled. The generating set builder must supply guarding for open-coupled applications.

To prevent rust during transit and storage, the generator frame spigot, rotor coupling plates and shaft extension have been treated with a rust preventative coating. Remove this before coupling the generating set.

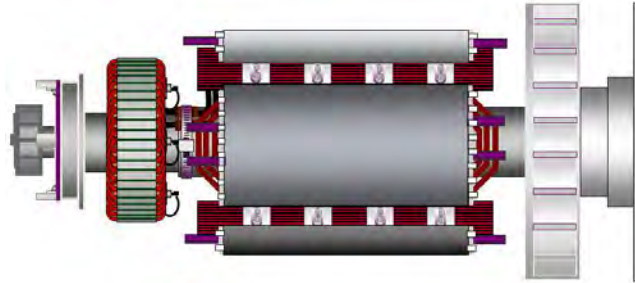


FIGURE 4. SINGLE BEARING GENERATOR ROTOR SHOWING COUPLING DISCS BOLTED TO DRIVE END COUPLING HUB (AT RIGHT)

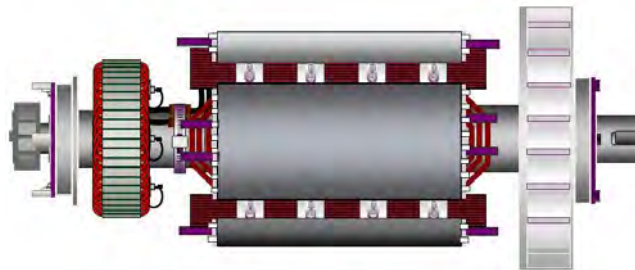


FIGURE 5. TWO BEARING GENERATOR ROTOR SHOWING SHAFT WITH KEYWAY FOR FLEXIBLE COUPLING (AT RIGHT)

7.6 Single Bearing

1. Remove the drive end transit bracket that keeps the rotor in place during transport before coupling to the engine.

⚠ CAUTION

Maintain the generator horizontal to keep the rotor in place

2. Remove the air outlet covers from the drive end of the generator to access the coupling and adaptor bolts.
3. Make sure the coupling discs are concentric with the adaptor.
4. Fit two alignment dowels into flywheel bolt holes 180 degrees apart to help align the disc and the flywheel.
5. Lift and offer the generator to the engine, barring the engine over by hand to align discs and flywheel.
6. Engage the alignment dowels into coupling disc bolt holes and push the generator towards the engine until the coupling discs are against the flywheel face.
7. Remove the rotor support bracket, if supplied.

⚠ CAUTION

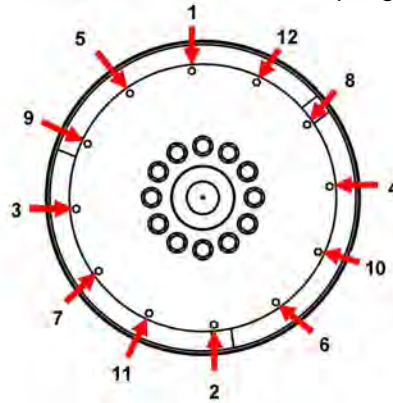
Do not pull the generator to the engine using bolts through the flexible discs.

8. Fit the adaptor bolts, using heavy gauge washers under the heads. Tighten the adapter bolts evenly around the adapter.
9. Check the torque of each bolt in a clockwise direction around the bolt circle to ensure all the bolts are tight. Refer to the engine manufacturer's manual for correct tightening torque.

⚠ CAUTION

Failure to secure bolts can lead to excessive vibration, which in turn can lead to catastrophic generator failure.

10. Remove the alignment dowels. Fit the coupling bolts, using heavy gauge washers



under the heads.

disc to the flywheel, in the sequence shown above.

Tighten the bolts to fix the coupling

11. Check the torque of each bolt in a clockwise direction around the bolt circle to ensure all the bolts are tight.

⚠ CAUTION

Failure to secure bolts can lead to excessive vibration, which in turn can lead to catastrophic generator failure.

12. Replace all covers.

7.7 Two Bearing

A flexible coupling, designed to suit the specific engine/generator combination, is recommended to minimise torsional vibration effects.

If a close coupling adaptor is used the alignment of machined faces must be checked by offering the generator up to the engine. Shim the generator feet if necessary.

7.8 Pre-Running Checks

Before starting the generating set, test the insulation resistance of windings, check all connections are tight and in the correct location. Ensure the generator air path is clear of obstructions. Replace all covers.

7.9 Insulation Resistance Test

NOTICE

Disconnect the AVR and voltage transformers (if fitted) before this test. Disconnect and earth all RTD and Thermistor temperature sensors (if fitted) before this test.

The resistance test must be carried out by a qualified person.

Generator Voltage (kV)	Test Voltage (V)	Minimum Insulation Resistance (MΩ)	
		In Service Generator	New Generator
Up to 1	500	5	10

You must dry out the generator windings if the measured insulation resistance is less than the minimum value. See the Service & Maintenance section ([Chapter 8](#)) of this manual.

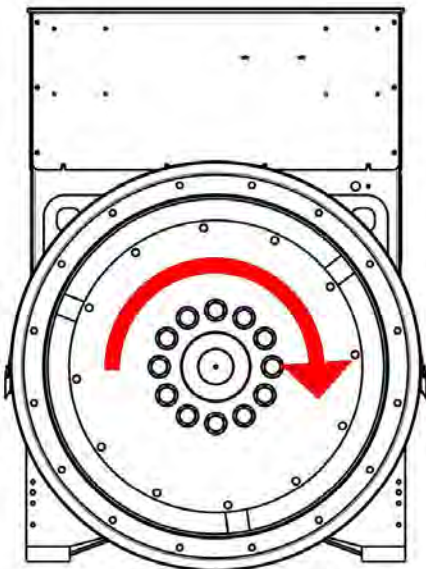
7.9.1 High Voltage Test

NOTICE

Windings have been tested at high voltage during manufacture. Repeated high voltage tests may degrade the insulation and reduce operating life. If a further test is required at installation for customer acceptance, it must be done at a reduced voltage, $V = 0.8 \times (2 \times \text{Rated Voltage} + 1000)$. Once in service, any further tests for maintenance purposes must be done after passing visual checks and insulation resistance tests, and at a reduced voltage, $V = (1.5 \times \text{Rated Voltage})$.

7.10 Direction of Rotation

The fan is designed for clockwise rotation, as viewed from the drive end of the generator (unless otherwise specified when ordered). If the generator must run counter-clockwise, please seek advice from Cummins Generator Technologies.



7.11 Phase Rotation

Main stator output is connected for a phase sequence of U V W when the generator runs clockwise, as viewed from the drive end. If the phase rotation must be reversed, the customer must re-connect the output cables in the terminal box. Ask Cummins Generator Technologies for a circuit diagram of 'reverse phase connections'.

7.12 Voltage and Frequency

Check that the voltage and frequency shown on the generator rating plate meet the requirements of the generating set application.

7.13 AVR Settings

The AVR is factory set for initial running tests. Check that the AVR settings are compatible with your required output. Refer to detailed instructions in the AVR manual for on- and off-load adjustments.

7.14 Electrical Connections

 **WARNING**

Incorrect electrical installation and system protection can cause personal injury. Installers must be qualified to perform electrical installation work and are responsible for meeting the requirements of any inspectorate, local electricity authority and site safety rules.

Fault current curves and generator reactance values are available on request from the factory so that the system designer can calculate the necessary fault protection and/or discrimination.

The installer must check that the generator frame is bonded to the generating set bedplate, and must bond to site earth. If anti-vibration mounts are fitted between the generator frame and its bedplate, a suitably-rated earth conductor must bridge across the anti-vibration mount.

Refer to wiring diagrams for electrical connection of the load cables. Electrical connections are made in the terminal box, constructed with removable panels to suit site-specific cable entry and glanding. Route single core cables through the insulated or non-magnetic gland plates supplied. Panels must be removed to be drilled or cut to prevent swarf entering the terminal box or generator. After wiring, inspect the terminal box, remove all debris using a vacuum cleaner if necessary and check that no internal components are damaged or disturbed.

As standard, the generator neutral is not bonded to the generator frame. If required, neutral may be connected to the earth terminal in the terminal box, by a conductor of at least one half of the sectional area of a phase lead.

Load cables must be supported appropriately to avoid a tight radius at the point of entry into the terminal box, clamped at the terminal box gland, and allow at least ± 25 mm movement by the generator set on its anti-vibration mountings, without causing excessive stress to the cables and generator load terminals.

The palm (flattened part) of load cable lugs must be clamped in direct contact with the main stator output terminals so that the whole palm area conducts the output current. The tightening torque of M12 fasteners is 70 Nm or 90 Nm for M16 fasteners (main nut) and 45 Nm (lock nut).

7.15 Grid Connection: Voltage Surges and Micro-Interruptions

Take precautions to prevent transient voltages generated by the connected load and/or the distribution system from causing damage to the generator components.

To identify any possible risk, all aspects of the generator's proposed application should be considered, especially the following:

- Loads with characteristics that result in large load step changes.
- Load control by switchgear, and power control by any method likely to generate transient voltage spikes.
- Distribution systems susceptible to external influences, such as lightning strikes.
- Applications involving parallel operation to a mains supply, where the risk of a mains disturbance in the form of a micro-interruption could occur.

If the generator is at risk from voltage surges or micro-interruptions, include adequate protection into the generation system, usually with surge arrestors and suppressors, to meet regulations and installation requirements.

Surge protection must reduce the peak voltage at the generator of a transient pulse of 5 μ s rise time to less than $1.25 \times \sqrt{2} \times (2 \times \text{rated output voltage} + 1000 \text{ V})$. Best practise is to fit protective devices close to the output terminals. Refer to guidance from professional bodies and specialist equipment suppliers for further advice.

7.16 Embedded Applications

These notes cover applications with the generator running in parallel with the mains utility such as CHP (sometimes called co-generation).

A typical Thermal Class for this duty is identified by ISO 8528 as a "basic continuous rating" (BR), Class 'F' rating - continuous duty. This offers the best operating efficiency, with low thermal stress for the winding insulation system.

Establish the operating voltage range of the local mains supply and the specified kVA, kVAR, and kW. Consider the full range of the required operating duty against the generator operating chart (capability diagram). A co-generation application is a continuous fixed duty, always within the 'BR' category, and no overload capability is expected.

The recommended level of protection for an embedded application is given below.

Protection	Minimum	Optional
Overcurrent	X	
Short Circuit	X	
Under Volts	X	
Over Volts	X	
Under Hz	X	
Over Hz	X	
Differential		X
Earth Fault		X
Stator Temperature Monitoring		X
Vibration Monitoring		X
Bearing Condition Monitor		X
Reverse Power	X	
Excitation Loss	X	
Power Factor Control	X	
Voltage Matching	X	
Mains Interruption (Vector Shift, Frequency Deviation)	X	

The generator overload and short circuit settings on the protection should be set so that they are below the thermal damage curve for the generator.

If the overload and short circuit protection is provided by a circuit breaker, take care with the protection settings. Circuit breakers are normally designed for operation with the utility supply, which sustains higher and longer durations of fault level than the generator can tolerate. The overcurrent and short circuit settings must be set according to the generator operating chart and not to the overcurrent/short circuit details supplied with the circuit breaker.

Generator data sheets are available to help calculate these settings.

7.17 Varying Load

Under certain conditions, load variations can reduce generator life.

Identify any possible risk, especially the following:

- Large capacitive loads (for example Power Factor Correction equipment) can affect generator stability and cause pole slip.
- Stepped grid voltage variation (for example Tap Changing).

If the generator is at risk from varying load, include adequate protection into the generation system by under-excitation protection.

7.18 Synchronisation

7.18.1 Parallel or Synchronising AC Generators

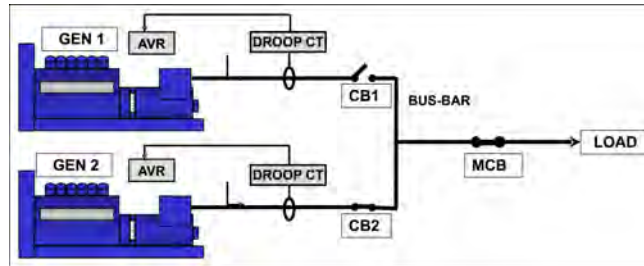


FIGURE 6. PARALLEL OR SYNCHRONISING AC GENERATORS

The quadrature droop current transformer (Droop CT) gives a signal proportional to reactive current; the AVR adjusts excitation to reduce circulating current and allow each generator to share reactive load. A factory-fitted droop CT is pre-set for 5% voltage drop at full-load zero power factor. Refer to the supplied AVR manual for droop adjustment.

- The synchronising switch/breaker (CB1, CB2) must be of a type that will not cause “contact bounce” when it operates.
- The synchronising switch/breaker must be adequately rated to withstand the continuous full load current of the generator.
- The switch/breaker must be able to withstanding the rigorous closing cycles during synchronising and the currents produced if the generator is paralleled out of synchronism.
- The closing time of the synchronising switch/breaker must be under the control of the synchroniser settings.
- The switch/breaker must be capable of operation under fault conditions such as short circuits. Generator data sheets are available.

NOTICE

The fault level may include a contribution from other generators as well as from the grid/mains utility.

The method of synchronising should be either automatic, or by check synchronising. The use of manual synchronising is not recommended. The settings on the synchronising equipment should be such that the generator will close smoothly.

⚠ CAUTION

Synchronising outside the following parameters may result in catastrophic failure of the generator.

The Phase sequence must match	
Voltage difference	+/- 0.5%
Frequency difference	0.1 Hz/sec
Phase angle	+/- 10°
C/B closing time	50 ms

The settings for the synchronising equipment to achieve this must be within these parameters.

The voltage difference when paralleling with the grid/mains utility is +/- 3% .

7.19 Regreasable bearings

After long storage periods grease in the exit port may become hard. To ensure correct function of machine remove any hard grease and refill with correct fresh grease. Refer to the Re-grease Bearings section ([Section 8.2.3](#)) of the Service and Maintenance chapter in this manual.

8 Service and Maintenance

8.1 Recommended Service Schedule

Refer to Safety Precautions section ([Chapter 2](#)) of this manual before starting any service and maintenance activity.

Refer to Parts Identification section ([Chapter 10](#)) for an exploded view of components and fastener information.

The recommended service schedule shows the recommended service activities in table rows, grouped by generator subsystem. Columns of the table show the types of service activity, whether the generator must be running, and the service levels. Service frequency is given in running hours or time interval, whichever is sooner. A cross (X) in the cells where a row intersects the columns shows a service activity type and when it is required. An asterisk (*) shows a service activity done only when necessary.

All service levels in the recommended service schedule can be purchased directly from Cummins Generator Technologies Customer Service Department,

Telephone: +44 1780 484732,

Email: service-engineers@cumminsgeneratortechnologies.com

TABLE 2. RECOMMENDED SERVICE SCHEDULE

System	SERVICE ACTIVITY X = required * = if necessary	Generator running	TYPE				SERVICE LEVEL						
			Inspect	Test	Clean	Replace	Commission	Post Commission 250 hrs / 0.5 year	Level 1 1000 hrs / 1 year	Level 2 10,000 hrs / 2 years	Level 3 30,000 hrs / 5 years		
Generator	Generator rating		X				X						
	Bedplate arrangement		X				X						
	Coupling arrangement		X				X			*		X	
	Environmental conditions and cleanliness		X				X	X	X	X		X	
	Ambient temperature (inside & outside)			X			X	X	X	X		X	
	Complete machine - damage, loose parts & earth bonds		X				X	X	X	X		X	
	Guards, screens, warning and safety labels		X				X	X	X	X		X	
	Maintenance access		X				X						
	Electrical nominal operating conditions & excitation	X		X			X	X	X	X		X	
	Vibration	X		X			X	X	X	X		X	
Windings	Condition of windings		X				X	X	X	X	X	X	
	Insulation resistance of all windings (PI test for MV/HV)			X			X	*	*	X		X	
	Insulation resistance of rotor, exciter and PMG			X				X	X				
	Temperature sensors	X		X			X	X	X	X		X	
	Customer settings for temperature sensors		X				X						
Bearings	Condition of bearings		X				X						X
	Grease exhaust & trap				X			X	X	X	X	X	
	Bearing grease	X				X			see label at bearing		X		X
	Bearing(s)					X					*		X
	Temperature sensors	X		X			X	X	X	X		X	
	Customer settings for temperature sensors		X				X						

System	SERVICE ACTIVITY X = required * = if necessary	Generator running	TYPE				SERVICE LEVEL							
			Inspect	Test	Clean	Replace	Commission	Post Commission	250 hrs / 0.5 year	Level 1	1000 hrs / 1 year	Level 2	10,000 hrs / 2 years	Level 3
Terminal Box	All generator/customer connections and cabling		X				X	X	X	X				X
Controls & Auxiliaries	Initial AVR & PFC set up	X		X			X							
	AVR & PFC settings	X		X				X	X	X	X	X	X	
	Customer connection of auxiliaries			X			X		X	X	X	X	X	
	Function of auxiliaries			X			X	X	X	X	X	X	X	
	Synchronisation settings		X				X							
	Synchronisation	X		X			X	X	X	X	X	X	X	
	Anti condensation heater					X						*	X	
Rectifier	Diodes and varistors		X				X	X	X	X	X			
	Diodes and varistors					X							X	
Cooling	Air inlet temperature	X		X			X	X	X	X	X	X	X	
	Air flow (rate & direction)	X	X				X							
	Condition of fan		X				X	X	X	X	X	X	X	
	Condition of air filter (where fitted)			X			X	X	X	X	X	X	X	
	Air filters (where fitted)					X	X			*	*	*	*	

1. Proper service and repair are vital to the reliable operation of your generator and the safety of anyone coming into contact with the generator.
2. These service activities are intended to maximise the life of the generator but shall not vary, extend or change the terms of the manufacturer's standard warranty or your obligations in that warranty.
3. Each service interval is a guide only, and developed on the basis that the generator was installed and is operated in accordance with the manufacturer's guidelines. If the generator is located and/or operated in adverse or unusual environmental conditions, the service intervals may need to be more frequent. The generator should be continually monitored between services to identify any potential failure modes, signs of misuse, or excessive wear and tear.

8.2 Bearings

8.2.1 Introduction

The generator rotor is supported by a bearing at the non-drive end (NDE) and by either a bearing or a coupling to the prime mover at the drive end (DE).

- If possible, turn the rotor of an out of service generator at least six revolutions every month to lubricate the bearing surfaces with grease and re-position the rotating elements to avoid false brinelling. If rotation is not possible and the storage period is over two years, replace the bearings before putting the generator into service.
- Lubricate each re-greaseable bearing with the correct quantity of recommended grease according to the recommended service schedule or the label fitted at the grease nipple (whichever is sooner).
- According to the recommended service schedule, replace each bearing by a new bearing containing the correct initial quantity of recommended grease, shown on a label next to the grease nipple.

8.2.2 Safety

⚠ DANGER

Safety guards must be removed to replace bearings. To prevent injury, isolate the generating set from all energy sources and remove stored energy. Use lock and tag safety procedures before starting work.

⚠ WARNING

External surfaces may be very hot. Exposed skin can suffer serious and permanent burns, depending on the temperature and contact time. Avoid contact or wear protective gloves.

⚠ CAUTION

Grease can cause contact dermatitis. Avoid contact with the hands by wearing suitable PPE.

NOTICE

Do not overfill a bearing with grease; the bearing may be damaged.
Do not mix lubricant types. Change gloves to handle different lubricant
Assemble bearings in static- and dust-free conditions while wearing lint free gloves.
Store removed parts and tools in static- and dust-free conditions, to prevent damage or contamination.
A bearing is damaged by the axial force needed to remove it from the rotor shaft. Do not reuse a bearing.
A bearing is damaged if the insertion force is applied through the bearing balls. Do not press fit the outer race by force on the inner race, or vice versa.
Do not try to turn the rotor by levering against the cooling fan vanes. The fan will be damaged.

8.2.3 Re-grease Bearings

8.2.3.1 Requirements

Personal Protective Equipment (PPE)	Wear mandatory site PPE
-------------------------------------	-------------------------

Consumables	Lint-free cleaning cloths
	Thin disposable gloves
Parts	Kluber Asonic GHY72 (ester oil/polyurea) grease
Tools	Grease gun (calibrated for volume or mass)

8.2.3.2 Re-grease Method

TABLE 3. REGREASING: GREASE TYPE AND QUANTITY

Bearing Position	Quantity of Kluber Asonic GHY72 grease	
	Volume (cm ³)	Mass (g)
Drive End (Core length F, G)	136	121
Drive End (Core length A to E)	100	89
Non-drive End (Core length A to G)	85	75

1. For each bearing, identify grease nipple, re-greasing label and bearing type.
2. Make sure the new grease is not contaminated.
3. Clean the grease gun nozzle and grease nipple.
4. Clean the grease exhaust.
5. Fit the grease gun to the grease nipple and add the correct quantity of grease.
6. Run the generator for at least ten minutes until no grease is expelled from the exhaust.
7. Clean the grease exhaust.
8. Inspect the colour and consistency of grease expelled from the exhaust and compare with new grease - whitish-beige of stiff consistency.
9. Replace the bearing if the expelled grease is severely discoloured or absent.

8.2.4 Replace Bearings

Follow the steps below, in order:

1. Follow the **Remove Non-Drive End** section to access NDE bearing
2. If the DE bearing is to be replaced, follow the **Remove Drive End** section to access DE bearing.
3. Assemble and fit the new NDE bearing (and DE bearing, as required) onto the rotor shaft, following the **Assemble Bearing** section .
4. If the DE bearing has been replaced, follow the **Assemble Drive End** section to refit DE components.
5. Follow the **Assemble Non-Drive End** section to refit NDE components.

8.2.4.1 Requirements

Re-greasable bearings

Personal Protective Equipment (PPE)	Wear mandatory site PPE. Wear heat-resistant gloves for handling heated parts.
Consumables	Lint-free cleaning cloths
	Thin disposable gloves
	Washing fluid
	Large plastic bags (to store parts)
	White anti-static assembly surface
Parts	NDE bearing
	DE bearing (if fitted)
	Kluber Asonic GHY72 (ester oil/polyurea) grease
	Kluber Altemp Q NB 50 anti-fretting lubricant
	O rings
Tools	Grease gun (calibrated for volume or mass)
	Washing bowl and brush
	Induction heater (with protective sleeve on bar)
	Torque wrench
	Bearing extraction three-legged puller
	Rotor support packing
	Rotor extension steel stub shaft
	Jack
	M10 x 120 guide studs x 2

8.2.4.2 Requirements

Sealed bearings

Personal Protective Equipment (PPE)	Wear mandatory site PPE. Wear heat-resistant gloves for handling heated parts.
Consumables	Thin disposable gloves
	Large plastic bags (to store parts)
Parts	NDE bearing
	DE bearing (if fitted)
	O rings
Tools	Induction heater (with protective sleeve on bar)
	Torque wrench
	Bearing extraction three-legged puller
	Rotor support packing

8.2.4.3 Remove Non-Drive End

1. Turn off the anti-condensation heater (if fitted) and isolate from supply.
2. Clean thoroughly with lint free cloths all tools to be used on greased parts.
3. Remove the PMG cover.
4. Remove the lower air inlet cover.
5. Remove the terminal box lid and upper side panel (left hand, viewed from NDE)

-
6. Remove the lower side panel (left hand, viewed from NDE) to improve access, cutting cable ties to release the exciter stator leads.
 7. Unplug the PMG control cable.
 8. Disconnect the grease pipe from the bearing cartridge and the NDE bracket.
 9. Disconnect the heater.
 10. Use a 10 mm open spanner to disconnect the RTD sensor for bearing temperature (if fitted) from the bearing.
 11. Remove the PMG stator and PMG rotor together as an assembly.
 12. Remove the NDE bearing cap assembly.
 13. Put the PMG assembly and NDE bearing cap parts into separate plastic bags. Seal the bags to protect the parts from debris.
 14. Turn the main rotor so that the NDE keyway is at the top of the rotor shaft. In this position, the lowest rotor pole is vertical and will support the rotor weight when the bearing is removed. If the rotor cannot be turned and no rotor pole is vertical, fit two rotor support packing pieces (see below) to support the lower two poles.
 15. Disconnect F1 (red) and F2 leads at the AVR, cut cable ties and withdraw the leads to the exciter stator.
 16. Fix the rotor extension stub shaft onto the rotor at the non-drive end, then lift it a small amount with a crane sling to support the rotor weight.
 17. Remove fasteners from NDE bearing cartridge.
 18. Fix two threaded guide studs at least 120 mm long into NDE bearing cartridge.
 19. Remove fasteners from NDE bracket.
 20. Insert two M10 jacking bolts part way into threaded holes on the NDE bracket horizontal centreline to open a gap for a shackle between the NDE bracket and the frame – approximately 10mm movement.
 21. Fix a shackle to the NDE bracket and support with a second crane sling.
 22. Insert the jacking bolts fully to release the NDE bracket from the frame.
 23. For generators with a DE bearing, insert a rotor support packing piece into the air gap between the lowest rotor pole and the stator, along the full length of the rotor pole. When the NDE bearing is removed, the packing will keep the rotor near-horizontal to reduce non-radial loading on the other bearing.
 24. Gently lower the crane sling to put the rotor weight onto the support packing and remove the sling.
 25. Remove the rotor extension stub shaft.
 26. Carefully slide the NDE bracket away from the generator along the guide studs to avoid damaging the exciter stator windings on the exciter rotor and set aside.
 27. Remove the guide studs.

8.2.4.4 Remove Drive End

1. Remove NDE components first, following **Remove Non-Drive End**.
2. Remove the DE air outlet screen and DE louvres.
3. Disconnect the generator from the prime mover.
4. Disconnect the grease tube.
5. Disconnect the RTD sensor for bearing temperature (if fitted).

6. Remove the DE bearing cap.
7. Remove fasteners from the DE bearing cartridge.
8. Fix two threaded guide studs at least 120 mm long into the DE bearing cartridge.
9. Use a crane sling and lifting eye to support the DE bracket.
10. Remove fasteners from the DE bracket.
11. Release the DE bracket by tapping with a mallet away from the frame.
12. Carefully slide the DE bracket away from the generator along the guide studs.
13. Remove the guide studs.

8.2.4.5 Assemble a Re-greasable Bearing

TABLE 4. INITIAL GREASING: GREASE TYPE AND QUANTITY

Bearing Position	Quantity of Kluber Asonic GHY72 grease							
	Cartridge		Bearing		Bearing Cap		TOTAL	
	Volume (cm ³)	Mass (g)	Volume (cm ³)	Mass (g)	Volume (cm ³)	Mass (g)	Volume (cm ³)	Mass (g)
Drive End (Core length F, G)	136	121	272	242	136	121	544	484
Drive End (Core length A to E)	104	92	208	185	104	92	416	369
Non-drive End (Core length A to G)	87	77	174	154	87	77	348	308

1. Remove the wavy washer (NDE only), grease flinger, circlip (NDE only), and the bearing and cartridge assembly from the main rotor shaft.
2. Heat the bearing cartridge and use the bearing extraction puller to remove the old bearing from the cartridge.
3. Prepare for assembly, by cleaning:
 - a. Wipe clean the anti-static assembly surface, using solvent on lint free cloth.
 - b. Wash the bearing cartridge, wavy washer (NDE only) and the bearing cap and inspect for contamination.
 - c. Wipe off excess washing fluid with a lint free cloth and place all components on the clean anti-static assembly surface.
 - d. Thoroughly clean the external surface of the grease gun nozzle using a lint free cloth.
4. Prepare the bearing:
 - a. Remove the bearing from its packaging.
 - b. Wipe off the preservative oil with a lint free cloth from the surface of the inner and outer rings.
 - c. Place the bearing on the clean anti-static assembly surface, with the bearing type identification markings face down.
5. Grease and assemble the bearing components:
 - a. Fit a new O ring in the groove in the bearing housing (NDE only).
 - b. Apply the specified quantity of grease to the back face of the bearing cartridge.
 - c. Apply a small amount of grease to the grooved sealing surface in the cartridge.

-
- d. Without rubbing in, use a lint free cloth to smear anti-fretting lubricant (Kluber Altemp Q NB 50) in a thin coherent layer to the bearing housing circumference.
 - e. Apply half the specified quantity of grease to the upper face of the bearing (without the bearing designation markings).
 - f. Press the grease into the bearing, ensuring good penetration into the raceways and between the balls.
 - g. Assemble the bearing into the bearing cartridge, greased side first, by pressing **ONLY** on the bearing outer race. Ensure the bearing outer race contacts the location shoulder.
 - h. Apply the remaining half of the specified quantity of grease to the exposed side of the bearing.
 - i. Press the grease into the bearing, ensuring good penetration into the raceways and between the balls.
 - j. Apply the specified quantity of grease to the inside face of the bearing cap.
 - k. Fill the grease exhaust slot, with grease.
 - l. Apply a small amount of grease to the grooved sealing surface in the bearing cap.
 - m. Fill the grease pipe and grease nipple with grease.
6. Fit the bearing components:
 - a. Heat the bearing and cartridge assembly to 90 to 100 °C in the induction heater.
 - b. Slide the bearing and cartridge assembly over the rotor shaft, pushing it firmly against the seating shoulder.
 - c. Oscillate the assembly (including inner race) 45 degrees in both directions, to ensure bearing is seated. Hold the bearing in place while it cools and contracts onto the rotor shaft.
 - d. Refit the circlip (NDE only) into the main rotor shaft groove.
 - e. Heat the grease flinger to 60 °C in the induction heater.
 - f. Slide the grease flinger over the rotor shaft and push it firmly against the bearing assembly. Hold the flinger in place while it cools and contracts onto the rotor shaft.
 - g. Fit the wavy washer (NDE only).
 - h. Wait for the bearing and cartridge assembly and flinger to cool to ambient temperature.
 - i. Fit the bearing cap over the grease flinger and fix to the bearing cartridge.
 7. Record bearing change on the Service Report.

8.2.4.6 Assemble a Sealed Bearing

1. Remove the wavy washer (NDE only), circlip (NDE only) and the bearing and cartridge assembly from the main rotor shaft.
2. Heat the bearing cartridge and use the bearing extraction puller to remove the old bearing from the cartridge.
3. Prepare for assembly, by cleaning:
 - a. Wipe clean the anti-static assembly surface, using solvent on lint free cloth.
 - b. Wash the bearing cartridge, wavy washer (NDE only) and the bearing cap and inspect for contamination.

-
- c. Wipe off excess washing fluid with a lint free cloth and place all components on the clean anti-static assembly surface.
 - d. Thoroughly clean the external surface of the grease gun nozzle using a lint free cloth.
4. Prepare the bearing:
 - a. Remove the bearing from its packaging.
 - b. Wipe off the preservative oil with a lint free cloth from the surface of the inner and outer rings.
 - c. Place the bearing on the clean anti-static assembly surface, with the bearing type identification markings face down.
 5. Assemble the bearing components:
 - a. Fit a new O ring in the groove in the bearing housing (NDE only).
 - b. Without rubbing in, use a lint free cloth to smear anti-fretting lubricant (Kluber Altemp Q NB 50) in a thin coherent layer to the bearing housing circumference.
 - c. Press the grease into the bearing, ensuring good penetration into the raceways and between the balls.
 - d. Assemble the bearing into the bearing cartridge, by pressing **ONLY** on the bearing outer race. Ensure the bearing outer race contacts the location shoulder.
 - e. Apply a small amount of grease to the grooved sealing surface in the bearing cap.
 6. Fit the bearing components:
 - a. Heat the bearing and cartridge assembly to 90 to 100 °C in the induction heater.
 - b. Slide the bearing and cartridge assembly over the rotor shaft, pushing it firmly against the seating shoulder.
 - c. Oscillate the assembly (including inner race) 45 degrees in both directions, to ensure bearing is seated. Hold the bearing in place while it cools and contracts onto the rotor shaft.
 - d. Refit the circlip (NDE only) into the main rotor shaft groove.
 - e. Fit the wavy washer (NDE only).
 - f. Wait for the bearing and cartridge assembly and flinger to cool to ambient temperature.
 - g. Fix the bearing cap to the bearing cartridge.
 7. Record bearing change on the Service Report.

8.2.4.7 Assemble Drive End

1. Slide the DE bracket onto the rotor shaft and locate over the DE bearing assembly.
2. Use a crane sling to lift the rotor and DE bracket at the drive end a small amount, to support the weight.
3. Refit the DE bracket onto the frame.
4. Refix the DE bearing cartridge to the DE bracket.
5. Refit the DE bearing cap.
6. Reconnect the grease pipe.
7. Reconnect the RTD sensor (if fitted).
8. Recouple the generator to the prime mover.

-
9. Refit the DE air outlet screen and DE louvres.

8.2.4.8 Assemble Non-Drive End

1. Fix the threaded guide studs into the NDE bearing cartridge.
2. Slide the NDE bracket onto the rotor shaft, guide onto the studs and locate over the NDE bearing assembly.
3. Fix the rotor extension shaft onto the rotor at the non-drive end, then lift it a small amount with a crane sling to support the rotor weight.
4. Remove the rotor support packing piece(s).
5. Fix the NDE bracket to the frame.
6. Remove the guide studs.
7. Fix the NDE bearing cartridge to the NDE bracket.
8. Gently lower the crane sling to put the rotor weight onto the bearing and remove the sling.
9. Remove the shaft extension tool.
10. Turn the rotor by hand to check bearing alignment and free rotation.
11. Refit the NDE bearing cap assembly.
12. Refit the PMG rotor and the PMG stator.
13. Reconnect the control cable plug.
14. Reconnect the grease pipe.
15. Reconnect the RTD sensor (if fitted).
16. Secure the heater and exciter stator leads inside the generator with heat stabilised cable ties.
17. Secure the leads with cable ties to the main stator leads and reconnect to the AVR.
18. Refit the PMG cover and lower air inlet cover.
19. Refit lower side panel, terminal box side panel and lid.
20. Reconnect the supply to the anti-condensation heater (if fitted).

8.3 Controls

8.3.1 Introduction

An operating generator is a harsh environment for control components. Heat and vibration can cause electrical connections to loosen and cables to fail. Routine inspection and test can identify an issue before it becomes a failure that incurs unplanned downtime.

8.3.2 Safety

 **DANGER**

This method involves removing safety covers to expose potentially live electrical conductors. Risk of serious injury or death by electrocution. To prevent injury, isolate the generating set electrically and prevent accidental mechanical movement. Disconnect the prime mover engine battery. Use lock and tag safety procedures and prove that the generating set is isolated from all energy sources before starting work.

8.3.3 Requirements

Personal Protective Equipment (PPE)	Wear mandatory site PPE
Consumables	
Parts	
Tools	Multimeter
	Torque wrench

8.3.4 Inspect and Test

1. Remove the terminal box lid
2. Check the tightness of M12 fasteners securing the load cables.
3. Check that cables are firmly clamped at the terminal box gland, and allow ± 25 mm movement by a generator on anti-vibration mounts.
4. Check that all cables are anchored and unstressed within the terminal box.
5. Check all cables for signs of damage caused by vibration, including insulation wear and wire strand breaks.
6. Check that all AVR accessories and current transformers are correctly fitted, and cables pass centrally through current transformers.
7. Isolate the anti-condensation heater supply and measure electrical resistance of the heater element(s). Replace heater element if open circuit.
8. Test the supply voltage to the anti-condensation heaters (if fitted). 100 V to 138 V a.c. should be present across each heater element when the generator is stopped. Refer to the wiring diagram for heater connections.
9. Check that AVR and AVR accessories within the terminal box are clean, securely fitted on anti-vibration mounts, and the cable connectors are firmly attached to the terminals. AVR and AVR accessories do not need further routine servicing.
10. For parallel operation, check that generator frequency signal cables to the synchronisation equipment are securely connected.
11. Refit the terminal box lid.

8.4 Cooling System

8.4.1 Introduction

Stamford generators are designed to meet standards supporting EU Safety Directives, and are rated for the effect of operating temperature on winding insulation.

BS EN 60085 (≡ IEC 60085) Electrical insulation – Thermal Evaluation and Designation classifies insulation by the maximum operating temperature for a reasonable service life. Although chemical contamination and electrical and mechanical stresses also contribute, temperature is the dominant aging factor. Fan cooling maintains a stable operating temperature below the insulation class limit.

If the operating environment differs from the values shown on the rating plate, rated output must be reduced by

- 3% for class H insulation for every 5°C that the temperature of the ambient air entering the cooling fan exceeds 40 °C, up to a maximum of 60 °C

- 3% for every 500m increase in altitude above 1000m, up to 4000 m, due to the reduced thermal capacity of lower density air, and
- 5% if air filters are fitted, due to restricted air flow.

Efficient cooling depends on maintaining the condition of the cooling fan, air filters and gaskets.

8.4.2 Safety

DANGER

Safety screens must be removed to inspect the cooling fan. To prevent injury, isolate the generating set from all energy sources and remove stored energy. Use lock and tag safety procedures before starting work.

WARNING

External surfaces may be very hot. Exposed skin can suffer serious and permanent burns, depending on the temperature and contact time. Avoid contact or wear protective gloves.

CAUTION

Where fitted, air filters remove particles above 5 microns from the generator cooling air inlet. High concentrations of these particles can be released when handling the filters, causing breathing difficulties and eye irritation. Wear effective respiratory and eye protection.

NOTICE

Do not attempt to rotate the generator rotor by levering against the vanes of the cooling fan. The fan is not designed to withstand such forces and will be damaged.

NOTICE

Filters are designed to remove dust, not moisture. Wet filter elements can cause reduced air flow and overheating. Do not allow filter elements to get wet.

8.4.3 Requirements

Personal Protective Equipment (PPE)	Wear mandatory site PPE
	Wear eye protection
	Wear respiratory protection
Consumables	Lint-free cleaning cloths
	Thin disposable gloves
Parts	Air filters (if fitted)
	Air filter sealing gaskets (if fitted)
Tools	

8.4.4 Inspect and Clean

NOTICE

Do not apply oil to the filter.

1. Inspect the fan for damaged vanes and cracks.
2. If air filters are fitted:
 - a. Remove air filters at the terminal box from their frames.
 - b. Wash and dry the air filters and gaskets to remove contaminant particles.
 - c. Inspect the filters and gaskets for damage and replace, as necessary.
 - d. Install the filters and gaskets.
3. Reinstall the generating set for running.
4. Make sure the air inlets and outlets are not blocked.

8.5 Coupling

8.5.1 Introduction

Efficient operation and long component life rely on minimising mechanical stresses on the generator. When coupled in a generating set, misalignment and vibration interactions with the prime mover engine can cause mechanical stress.

The rotational axes of generator rotor and engine output shaft must be coaxial (radial and angular alignment).

Torsional vibration can cause damage to internal combustion engine shaft-driven systems, if not controlled. The generating set manufacturer is responsible for assessing the effect of torsional vibration on the generator: Rotor dimensions and inertia, and coupling details are available on request.

8.5.2 Safety

NOTICE

Do not attempt to rotate the generator rotor by levering against the vanes of the cooling fan. The fan is not designed to withstand such forces and will be damaged.



8.5.3 Requirements

Personal Protective Equipment (PPE)	Wear mandatory site PPE
Consumables	
Parts	
Tools	Dial gauge
	Torque wrench

8.5.4 Inspect Mounting Points

1. Check the generating set bedplate and mounting pads are in good condition, not cracked
2. Check that rubber in anti-vibration mounts has not perished
3. Check vibration monitoring historical records for a trend of increasing vibration

8.5.4.1 Single Bearing Coupling

1. Remove the DE adapter screen and cover to access the coupling
2. Check that the coupling discs are not damaged, cracked or distorted, and the coupling disc holes are not elongated. If any are damaged, replace the complete set of discs.
3. Check tightness of bolts fixing the coupling discs to the engine flywheel. Tighten in the sequence shown for generator coupling in the Installation chapter, to the torque recommended by the engine manufacturer.
4. Replace the DE adapter screen and drip proof cover.

8.6 Rectifier System

8.6.1 Introduction

The rectifier converts alternating current (a.c.) induced in the exciter rotor windings into direct current (d.c.) to magnetise the main rotor poles. The rectifier comprises two semicircular annular positive and negative plates, each with three diodes. In addition to connecting to the main rotor, the dc output of the rectifier also connects to a matched pair of varistors (one at each end of the plates). These additional components protect the rectifier from voltage spikes and surge voltages that may be present on the rotor under various loading conditions of the generator.

Diodes provide a low resistance to current in one direction only: Positive current will flow from anode to cathode, or another way of viewing it is that negative current will flow from cathode to anode.

The exciter rotor windings are connected to 3 diode anodes to form the positive plate and to 3 diode cathodes to form the negative plate to give full wave rectification from a.c. to d.c. The rectifier is mounted on, and rotates with, the exciter rotor at the non-drive end (NDE).

8.6.2 Safety

⚠ DANGER
<p>This method involves removing safety covers to expose live electrical conductors. Risk of serious injury or death by electrocution from contact with conductors.</p> <p>This method involves removing safety screens to expose rotating parts. Risk of serious injury from entrapment. To prevent injury, isolate the generating set electrically and prevent mechanical movement.</p> <p>Disconnect the prime mover engine battery.</p> <p>Use lock and tag safety procedures and prove that the generating set is isolated from all energy sources before starting work.</p>

NOTICE
<p>Do not tighten a diode above the stated torque. The diode will be damaged.</p>

8.6.3 Requirements

Personal Protective Equipment (PPE)	Wear appropriate PPE.
Consumables	Loctite 241 thread locking adhesive
	Midland silicone heat sink compound type MS2623 or similar
Parts	Full set of three anode lead diodes and three cathode lead diodes (all from the same manufacturer)
	Two metal-oxide varistors (same type, same manufacturer, same voltage grading: A, B, C, D, E, F)
Tools	Multimeter
	Insulation Tester
	Torque wrench

8.6.4 Test and Replace Diodes

1. Disconnect the lead of one diode where it joins the windings at the insulated terminal post. Store fastener and washers.
2. Measure the voltage drop across the diode in the forward direction, using the diode test function of a multimeter.
3. Measure the resistance across the diode in the reverse direction, using the 1000 V d.c. test voltage of an insulation tester.
4. Diode is faulty if the voltage drop in the forward direction is outside the range 0.3 to 0.9 V, or the resistance is below 20 M Ω in the reverse direction.
5. Repeat steps 4 to 7 for the five remaining diodes.
6. If any diode is faulty, replace the full set of six diodes (same type, same manufacturer):
 - a. Remove diode(s).
 - b. Apply a small amount of heat sink compound **only** to the base of the replacement diode(s), not the threads.
 - c. Check polarity of diode(s).
 - d. Screw each replacement diode into a threaded hole in the rectifier plate.

-
- e. Apply 4.06 to 4.74 N m (36 to 42 lb in) torque to give good mechanical, electrical and thermal contact.
 - f. Replace both varistors with a matched pair (same type, same manufacturer and same voltage grading: A, B, C, D, E, F)
7. Reconnect and check that all leads are secure, washers fitted and fasteners tight.

8.6.5 Test and Replace Varistors

1. Inspect both varistors.
2. Record varistor as faulty if there are signs of overheating (discolouration, blisters, melting) or disintegration.
3. Disconnect one varistor lead. Store fastener and washers.
4. Measure the resistance across each varistor. Good varistors have a resistance greater than 100 MΩ.
5. Record varistor as faulty if the resistance is short circuit or open circuit in either direction.
6. If either varistor is faulty, replace both varistors with a matched pair (same type, same manufacturer and same voltage grading: A, B, C, D, E, F) and replace all diodes.
7. Reconnect and check that all leads are secure, washers fitted and fasteners tight.

8.7 Temperature Sensors

8.7.1 Introduction

Stamford generators are designed to meet standards supporting EU Safety Directives, and recommended operating temperatures. Temperature sensors (where fitted) detect abnormal overheating of the main stator windings and bearing(s). Sensors are of two types - Resistance Temperature Detector (RTD) sensors, with three wires, and Positive Temperature Coefficient (PTC) thermistors, with two wires – which are connected to a terminal block in the auxiliary or main terminal box. The resistance of Platinum (PT100) RTD sensors increases linearly with temperature.

TABLE 5. RESISTANCE (Ω) OF PT100 SENSOR BETWEEN 40 TO 180 °C

Temperature (°C)		+1 °C	+ 2 °C	+3 °C	+ 4 °C	+ 5 °C	+ 6 °C	+ 7 °C	+ 8 °C	+ 9 °C
40.00	115.54	115.93	116.31	116.70	117.08	117.47	117.86	118.24	118.63	119.01
50.00	119.40	119.78	120.17	120.55	120.94	121.32	121.71	122.09	122.47	122.86
60.00	123.24	123.63	124.01	124.39	124.78	125.16	125.54	125.93	126.31	126.69
70.00	127.08	127.46	127.84	128.22	128.61	128.99	129.37	129.75	130.13	130.52
80.00	130.90	131.28	131.66	132.04	132.42	132.80	133.18	133.57	133.95	134.33
90.00	134.71	135.09	135.47	135.85	136.23	136.61	136.99	137.37	137.75	138.13
100.00	138.51	138.88	139.26	139.64	140.02	140.40	140.78	141.16	141.54	141.91
110.00	142.29	142.67	143.05	143.43	143.80	144.18	144.56	144.94	145.31	145.69
120.00	146.07	146.44	146.82	147.20	147.57	147.95	148.33	148.70	149.08	149.46
130.00	149.83	150.21	150.58	150.96	151.33	151.71	152.08	152.46	152.83	153.21
140.00	153.58	153.96	154.33	154.71	155.08	155.46	155.83	156.20	156.58	156.95
150.00	157.33	157.70	158.07	158.45	158.82	159.19	159.56	159.94	160.31	160.68
160.00	161.05	161.43	161.80	162.17	162.54	162.91	163.29	163.66	164.03	164.40
170.00	164.77	165.14	165.51	165.89	166.26	166.63	167.00	167.37	167.74	168.11
180.00	168.48									

PTC thermistors are characterised by a sudden increase in resistance at a reference “switching” temperature. Customer-supplied external equipment may be connected to monitor the sensors and generate signals to raise an alarm and to shutdown the generating set.

BS EN 60085 (≅ IEC 60085) Electrical insulation – Thermal Evaluation and Designation classifies insulation of windings by the maximum operating temperature for a reasonable service life. To avoid damage to windings, signals should be set, appropriate to the insulation class shown on the generator rating plate.

TABLE 6. ALARM AND SHUTDOWN TEMPERATURE SETTINGS FOR WINDINGS

Windings insulation	Max. Continuous temperature (°C)	Alarm temperature (°C)	Shutdown temperature (°C)
Class B	130	120	140
Class F	155	145	165
Class H	180	170	190

Kluber Asonic GHY72 grease (an ester oil, with polyurea thickener) is recommended to lubricate the non-drive end (NDE) bearing and drive end (DE) bearing (where fitted). To detect overheating of bearings, control signals should be set according to the following table.

TABLE 7. ALARM AND SHUTDOWN TEMPERATURE SETTINGS FOR BEARINGS

Bearings	Alarm temperature (°C)	Shutdown temperature (°C)
Drive end bearing	45 + maximum ambient	50 + maximum ambient
Non-drive end bearing	40 + maximum ambient	45 + maximum ambient

8.7.2 Safety

⚠ DANGER

The main terminal box cover must be removed to test temperature sensors. Risk of serious injury or death by electrocution from contact with live electrical conductors. To avoid injury; isolate the generating set from all energy sources and remove stored energy. Use lock and tag safety procedures before starting work.

⚠ WARNING

External surfaces may be very hot. Exposed skin can suffer serious and permanent burns, depending on the temperature and contact time. Avoid contact or wear protective gloves.

8.7.3 Test RTD Temperature Sensors

1. Remove the terminal box lid.
2. Identify the sensor leads at the terminal block and where each sensor is fitted
3. Measure the resistance between the white and each red wire of one sensor
4. Calculate the sensor temperature from the measured resistance
5. Compare calculated temperature with temperature indicated by external monitoring equipment (if available)
6. Compare alarm and shutdown signal settings (if available) with recommended settings
7. Repeat steps 3 to 7 for each sensor
8. Refit the terminal box lid.
9. Contact Cummins Customer Service Help Desk to replace faulty sensors.

8.7.4 Test PTC Temperature Sensors

1. Remove the auxiliary terminal box lid.
2. Identify the sensor leads at the terminal block and where each sensor is fitted.
3. Measure the resistance between the two wires.
4. Sensor is faulty if resistance shows open circuit (infinity Ω) or short circuit (zero Ω).
5. Repeat steps 3 to 5 for each sensor.
6. Stop the generator and inspect the change in resistance as the stator winding cools.
7. Sensor is faulty if resistance does not change or change is not smooth.
8. Repeat step 8 for each sensor.
9. Refit the auxiliary terminal box lid.
10. Contact Cummins Customer Service Help Desk to replace faulty sensors.

8.8 Windings

8.8.1 Introduction

Generator performance depends on good electrical insulation of the windings. Electrical, mechanical and thermal stresses, and chemical and environmental contamination, cause the insulation to degrade. Various diagnostic tests indicate the condition of insulation by charging or discharging a test voltage on isolated windings, measuring current flow, and calculating the electrical resistance by Ohm's law.

When a DC test voltage is first applied, three currents can flow:

- Capacitive – to charge the winding to the test voltage (decays to zero in seconds),
- Polarising – to align the insulation molecules to the applied electric field (decays to near-zero in ten minutes), and
- Leakage – discharge to earth where the insulation resistance is lowered by moisture and contamination (increases to a constant in seconds).

For an insulation resistance test, a single measurement is made one minute after a DC test voltage is applied, when capacitive current has ended. For the polarization index test, a second measurement is made after ten minutes. An acceptable result is where the second insulation resistance measurement is at least double the first, because the polarization current has decayed. In poor insulation, where leakage current dominates, the two values are similar. A dedicated Insulation Tester takes accurate, reliable measurements and may automate some tests.

8.8.2 Safety

DANGER

Safety guards must be removed to test windings. To prevent injury, isolate the generating set from all energy sources and remove stored energy. Use lock and tag safety procedures before starting work.

WARNING

The winding keeps an electrical charge after the insulation resistance test. Risk of electric shock if the winding leads are touched. After each test, ground the winding to earth with an earth rod for five minutes to remove the charge.

NOTICE

The Automatic Voltage Regulator (AVR) contains electronic components which would be damaged by high voltage applied during insulation resistance tests. The AVR must be disconnected before doing any insulation resistance test. Temperature sensors must be grounded to earth before doing any insulation resistance test. Damp or dirty windings have a lower electrical resistance and could be damaged by insulation resistance tests at high voltage. If in doubt, test the resistance at low voltage (500 V) first

8.8.3 Requirements

Personal Protective Equipment (PPE)	Wear mandatory site PPE
Consumables	

Parts	
Tools	Insulation Test Meter
	Multimeter
	Millichm Meter or Micro Ohmmeter
	Clamp Ammeter
	Infrared thermometer

8.8.4 Test Windings Method

TABLE 8. TEST VOLTAGE AND MINIMUM ACCEPTABLE INSULATION RESISTANCE FOR NEW AND IN-SERVICE GENERATORS

	Test Voltage (V)	Minimum Insulation Resistance at 1 minute (MΩ)	
		New	In-service
Main stator	500	10	5
PMG stator	500	5	3
Exciter stator	500	10	5
Exciter rotor, rectifier & main rotor combined	500	10	5

1. Inspect the windings for mechanical damage or discolouration from overheating. Clean the insulation if there is hygroscopic dust and dirt contamination.
2. For main stators:
 - a. Disconnect the neutral to earth conductor (if fitted).
 - b. Connect together the three leads of all phase windings (if possible).
 - c. Apply the test voltage from the table between any phase lead and earth.
 - d. Measure the insulation resistance after 1 minute (IR_{1min}).
 - e. Discharge the test voltage with an earth rod for five minutes.
 - f. If the measured insulation resistance is less than the minimum acceptable value, dry the insulation, then repeat the method.
 - g. Reconnect neutral to earth conductor (if fitted).
3. For PMG and exciter stators, and combined exciter and main rotors:
 - a. Connect together both ends of the winding (if possible).
 - b. Apply the test voltage from the table between the winding and earth.
 - c. Measure the insulation resistance after 1 minute (IR_{1min}).
 - d. Discharge the test voltage with an earth rod for five minutes.
 - e. If the measured insulation resistance is less than the minimum acceptable value, dry the insulation, then repeat the method.
 - f. Repeat the method for each winding.
 - g. Remove the connections made for testing.

8.8.5 Dry the Insulation

Use the methods below to dry the insulation of the main stator windings. To prevent damage as water vapour is expelled from the insulation, make sure the winding temperature does not increase faster than 5 °C per hour or exceed 90 °C.

Plot the insulation resistance graph to show when drying is complete.

8.8.5.1 Dry with Ambient Air

In many cases, the generator can be dried sufficiently using its own cooling system. Disconnect the cables from the X+ (F1) and XX- (F2) terminals of the AVR so there is no excitation voltage supply to the exciter stator. Run the generating set in this de-excited state. Air must flow freely through the generator to remove the moisture. Operate the anti-condensation heater (if fitted) to assist the drying effect of the air flow.

After drying is complete, re-connect the cables between the exciter stator and AVR. If the generating set is not put into service immediately, turn on the anti-condensation heater (if fitted) and retest the insulation resistance before use.

8.8.5.2 Dry with Hot Air

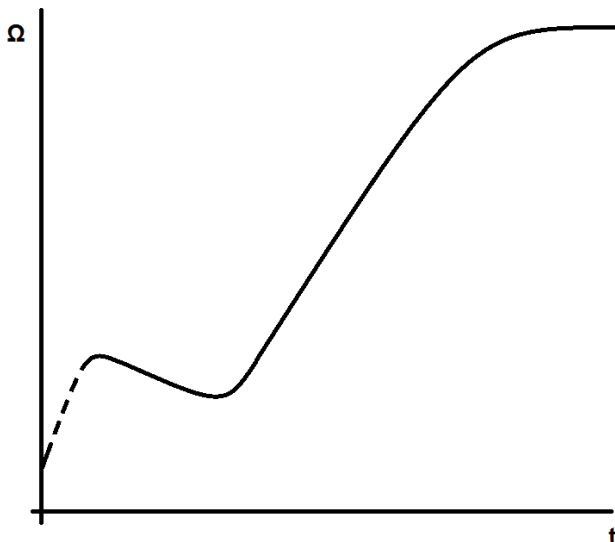
Direct the hot air from one or two 1 to 3 kW electrical fan heaters into the generator air inlet. Make sure each heat source at least 300mm away from the windings to avoid scorching or over-heating damage to the insulation. Air must flow freely through the generator to remove the moisture.

After drying, remove the fan heaters and re-commission as appropriate.

If the generating set is not put into service immediately, turn on the anti-condensation heaters (where fitted) and retest the insulation resistance before use.

8.8.5.3 Plot IR Graph

Whichever method is used to dry out the generator, measure the insulation resistance and temperature (if sensors fitted) of the main stator windings every 15 to 30 minutes. Plot a graph of insulation resistance, IR (y axis) against time, t (x axis).



A typical curve shows an initial increase in resistance, a fall and then a gradual rise to a steady state; if the windings are only slightly damp the dotted portion of the curve may not appear. Continue drying for another hour after steady state is reached.

NOTICE

The generator must not be put into service until the minimum insulation resistance is achieved.

8.8.6 Clean the Insulation

Remove the main rotor to gain access to the main stator windings to remove dirt contamination. Use clean warm water without detergents. Methods to remove and assemble the drive end (DE) and non-drive end (NDE) support are given in the Replace Bearing section of Service and Maintenance chapter.

8.8.6.1 Remove Main Rotor

NOTICE

The rotor is heavy, with a small clearance to the stator. Windings will be damaged if the rotor drops or swings in the crane sling and hits the stator or frame. To avoid damage, fit support packing and carefully guide the rotor ends throughout. Do not allow the sling to touch the fan.

NOTICE

To remove the main rotor safely and easily, use the following special tools: a rotor extension stub shaft, a rotor extension tube (of similar length to the rotor shaft) and a height-adjustable V roller extension tube support. Refer to the factory for the availability and specification of these tools.

1. Remove non-drive end bracket, see **Remove Non-Drive End** section.
2. For a two bearing generator, remove drive end bracket, see **Remove Drive End** section.
3. For a one bearing generator, remove drive end adapter as follows:
 - a. Disconnect the generator from the prime mover.
 - b. Remove the DE adapter.
4. Fix the rotor shaft extension stub shaft to the main rotor at the non-drive end.
5. Fix the extension tube to the stub shaft.
6. Position the V roller support underneath the shaft extension tube, close to the generator frame.
7. Raise the V roller support to lift the extension tube a small amount, to support the weight of the main rotor at the non-drive end.
8. Use a crane sling to lift the rotor at the drive end a small amount, to support its weight.
9. Carefully move the crane sling away so that the rotor withdraws from the generator frame, as the extension tube rolls on the V rollers, until the rotor windings are fully visible.
10. Support the rotor on wooden blocks to prevent it rolling and damaging the windings.
11. Tightly bind the crane sling near the middle of the main rotor windings, near the rotor centre of gravity.
12. Use a crane sling to lift the rotor a small amount, to test the rotor weight is balanced. Adjust the crane sling as necessary.

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13. Carefully move the crane sling away so that the rotor withdraws completely from the generator frame.
 14. Lower the rotor onto wooden block supports and prevent it rolling and damaging the windings.
 15. Remove the extension tube and stub shaft, as necessary.
 16. Mark the position of the sling (to assist re-assembly) and remove the crane sling, as necessary.

8.8.6.2 Install Main Rotor

NOTICE

The rotor is heavy, with a small clearance to the stator. Windings will be damaged if the rotor drops or swings in the crane sling and hits the stator or frame. To avoid damage, fit support packing between the rotor and stator and carefully guide the rotor ends throughout. Do not allow the sling to touch the fan.

NOTICE

To install the main rotor safely and easily, use the following special tools: a rotor extension stub shaft, a rotor extension tube (of similar length to the rotor shaft) and a height-adjustable V roller extension tube support. Refer to the factory for the availability and specification of these tools.

1. Fix the rotor shaft extension stub shaft to the main rotor at the non-drive end (or to the NDE bearing cartridge on some generator models).
2. Fix the extension tube to the stub shaft.
3. Tightly bind the crane sling near the middle of the main rotor windings near the rotor centre of gravity.
4. Use a crane sling to lift the rotor a small amount, to test the rotor weight is balanced. Adjust the crane sling as necessary.
5. Position the V roller support at the non-drive end, close to the generator frame.
6. Carefully use the crane sling to insert the rotor into the generator frame, extension tube first.
7. Guide the extension tube onto the V roller support. Adjust the height of the V roller support as necessary.
8. Insert the rotor into the generator frame, until the crane sling meets the frame.
9. Lower the rotor onto wooden blocks to prevent it rolling and damaging the windings.
10. Reposition the crane sling at the drive end of the rotor shaft.
11. Use the crane sling to lift the rotor at the drive end a small amount, to support its weight.
12. Carefully move the crane sling towards the generator frame, as the extension tube rolls on the V rollers, until the rotor windings are fully inserted.
13. Gently lower the crane sling to put the rotor weight onto the support packing and remove the sling.
14. For a two bearing generator, refit drive end bracket, see **Assemble Drive End** section.
15. For a one bearing generator, assemble the drive end as follows:
 - a. Refit the DE adapter

-
- b. Couple the generator to the prime mover.
 - c. Refit the upper and lower air outlet screen covers.
16. Refit the non-drive end bracket, see **Assemble Non-Drive End** section.
 17. Remove the rotor shaft extension tube.
 18. Remove the rotor shaft extension stub shaft.
 19. Remove the V roller support.

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9 Fault Finding

DANGER

Hazardous voltage.

Will shock, burn or cause death.

Fault finding methods include tests on live electrical conductors carrying high voltage. Risk of serious injury or death by electric shock. Fault finding must be done by competent, qualified persons trained in safe working practices.

Assess risk and work on or near live conductors only if absolutely necessary. Do not work on or near live conductors alone; another competent person must be present, trained to isolate energy sources and take action in an emergency.

Place warnings and prevent access to test area by unauthorised persons.

Make sure that tools, test instruments, leads and attachments are designed, inspected and maintained for use on the maximum voltages likely under normal and fault conditions.

Take suitable precautions to prevent contact with live conductors, including personal protective equipment (PPE), insulation, barriers and insulated tools.

Before starting any fault finding procedure, examine all wiring for broken or loose connections. If in doubt, refer to the wiring diagram supplied with the generator. Compare measurements with the test report supplied with the generator.

The following list is to aid in troubleshooting and is not exhaustive. If in doubt, consult the Cummins service department.

9.1 Without AVR

NOTICE

Do tests in order, unless stated otherwise. Do method steps in order. Achieve result before doing the next step, unless action (in bold) states otherwise.

TABLE 9. FAULTFINDING: WITHOUT AVR

TEST	METHOD		RESULT and ACTION
1 External Excitation	1	Disconnect the exciter stator positive X+ (F1) lead from the AVR.	-
	2	Disconnect the exciter stator negative XX- (F2) lead from the AVR.	-
	3	Test the resistance across the exciter stator winding between positive and negative leads, with a multimeter.	Resistance of exciter stator winding greater than minimum values (see Technical Data chapter)
	4	Connect an external 24 V variable d.c. source to the exciter stator leads, positive to positive, negative to negative. Test the voltage.	Measured excitation is 12 V d.c. (15 V d.c. for P80) $\pm 10\%$ error.
	5	Run the generator with no load connected. Test the speed.	Measured speed is within 4% of rated speed.
	6	Test the phase-to-phase and phase-to-neutral voltage at output terminals. Adjust variable d.c. source.	Measured output equal to rated voltage (with same error as excitation), balanced across phases within 1%. Main & exciter stators, main & exciter rotors, and rectifier diodes are functioning correctly. Go to test 7 If unbalanced by more than 1%, Go to test 2 If balanced within 1%, but output voltage is more than 10% below rated voltage, and test 3 not yet done, Go to test 3 If balanced within 1%, but output voltage is more than 10% below rated voltage, and test 3 already done, Go to test 4
2 Main Stator	A fault in the main stator will produce short circuit currents between turns in the windings. Test for symptoms to confirm diagnosis.		
	1	Disconnect main stator leads to exclude external components from the test.	-
	2	Test phase to neutral resistances of main stator windings with a micro ohmmeter.	Resistances of main stator windings dissimilar, and/or less than minimum values (see Technical Data chapter).
	3	Run up the generator within 4% of nominal speed, no load or excitation. Connect battery to exciter stator (see test 1).	When battery connected to excite generator, short circuit fault creates heat and burning smell. Engine sound changes with extra slight loading.
	4	-	Repair or replace faulty main stator winding
3 Rectifier	1	Test the rectifier varistors (see Service and Maintenance chapter)	Both varistors functioning correctly.
	2	Test the rectifier diodes (see Service and Maintenance chapter)	All diodes functioning correctly. Go to test 1

TEST	METHOD		RESULT and ACTION
4 Exciter Rotor	1	Inspect windings and insulation	Windings are not burnt or damaged.
	2	Disconnect the 6 exciter rotor leads from the a.c. connection studs on the rectifier.	-
	3	Taking 3 leads that were connected to the same rectifier plate, Test the phase-to-phase resistance, with a milliohm meter or micro ohmmeter.	Resistance of each phase pair greater than minimum values (see Technical Data chapter)
	4	Re-connect the exciter rotor leads.	Go to test 5
5 Main Rotor	1	Disconnect a main rotor lead from the connection stud on one of the rectifier plates.	-
	2	Test the resistance across the main rotor winding between positive and negative leads, with a multimeter or milliohm meter.	Resistance of main rotor greater than minimum value (see Technical Data chapter)
	3	Re-connect the main rotor lead.	Go to test 6
6 Exciter Stator Insulation	Poor insulation of the exciter stator winding can affect AVR performance.		
	1	Test the electrical insulation of the exciter stator winding (see Service and Maintenance chapter)	Resistance of exciter stator winding to earth is greater than minimum value. Go to test 7
7 AVR Sensing And Power Supply	Output voltage is sensed at the AVR for closed loop control of the excitation voltage. The generator wiring diagram shows how sensing leads 6, 7 & 8 (E1, E2, E3) at the output terminals are connected to the AVR, via transformers (as required). AVR power is also taken from the sensing leads or from a permanent magnet generator (PMG).		
	1	Disconnect the sensing and power supply(ies) from the AVR	-
	2	Follow the method of Test 1 to run the generator with excitation from a battery.	Generator runs within 4% of rated speed, 10% of rated output voltage, balanced within 1% across phases.
	3	Test the sensing voltage feedback at the AVR terminals. Check circuit between output terminals and AVR.	Measured voltage within range (see Generator Data), balanced across phases. No wiring or transformer faults.
	4	Disconnect battery, re-connect AVR and run generator.	See Faultfinding: self-excited AVR or Faultfinding: separately-excited AVR.

9.2 Separately-Excited AVR - OFF load

TABLE 10. FAULTFINDING: SEPARATELY-EXCITED AVR - OFF LOAD

SYMPTOM	CAUSE	ACTION
NO VOLTAGE (NO LOAD)	Faulty permanent magnet generator (PMG), stator or rotor .	Disconnect the PMG leads from AVR terminals P2, P3, P4. Run the generator at rated speed. Test the phase-to-phase voltage at P2, P3 & P4 leads of the PMG with an r.m.s. measuring instruction. Measured voltage 170 to 195 V a.c. (at 50 Hz), 204 to 234 V a.c. (at 60 Hz), balanced within 5% across phases. (Refer to factory for latest voltage ranges in design data specification DD-15590) Test the phase-to-phase resistance of the PMG stator windings with a multimeter. Resistance to be within 10% of expected value (see Technical Data chapter), balanced across phases. Replace or re-test according to PMG Fault Diagnosis table below.
	Insulation failure to earth (ground) on PMG stator.	Test the insulation resistance of PMG stator windings. (see Service and Maintenance chapter)
	Panel voltmeter faulty.	Test voltage at generator terminals with a multimeter.
	Connections loose, broken or corroded.	Inspect AVR push-on terminals. Repair or renew where necessary.
	AVR high excitation protection circuit activated, collapsing output voltage. AVR protection circuit is factory set to trip (refer to AVR data sheet for voltage set point) across AVR output X+ (F1), & XX- (F2), after pre-set time delay.	Check AVR LED. If lit, protection circuit is activated. Shut down engine, and re-start. If the voltage builds up normally but collapses again, the protection circuit has operated, & AVR LED will be lit. Run again & check the excitation voltage across AVR X+ (F1) and XX- (F2). If greater than voltage set point, the protection circuit is operating correctly. Follow Faultfinding without AVR to find cause of high excitation volts.
	Short circuit of varistor on rotating rectifier	Test varistors. (see Service and Maintenance chapter)
	Short circuit of diode(s) on rotating rectifier.	Test diodes. (see Service and Maintenance chapter)
	Open circuit in exciter stator windings	See: Faultfinding without AVR.
	AVR fault	Replace AVR and re-test.
	Winding fault. Open circuit or short circuit on any winding in the machine	See: Faultfinding without AVR.

SYMPTOM	CAUSE	ACTION
LOW VOLTAGE (NO LOAD)	Engine speed low	Test speed with tachometer. Adjust governor control to nominal speed.
	Under frequency protection (UFRO) circuit activated	Inspect UFRO LED at AVR. If lit, UFRO is activated, indicating low speed. Adjust engine speed to within -1% to +4% of nominal.
	AVR volts control or external hand trimmer incorrectly set	<ol style="list-style-type: none"> 1. Test engine speed is correct with tachometer, and UFRO is OFF. 2. Adjust voltage by AVR volts control, or remote trimmer.
	Panel voltmeter faulty or 'sticking'	Test voltage at generator terminals with a multimeter.
	AVR fault.	Replace AVR and re-test.
HIGH VOLTAGE (NO LOAD)	AVR volts control or external trimmer incorrectly set.	<ol style="list-style-type: none"> 1. Test engine speed is correct with tachometer, and UFRO is OFF. 2. Adjust voltage by AVR volts control, or remote trimmer.
	Voltage sensing input to AVR is open circuit or too low.	Test the AVR sensing supply feedback. (See: Faultfinding without AVR)
	Faulty AVR.	Replace AVR and retest.
UNSTABLE VOLTAGE (NO LOAD)	Engine speed hunting (unstable).	Test engine speed stability with a frequency meter or tachometer. Sometimes this problem will clear when load is applied.
	AVR stability control incorrectly adjusted.	Inspect AVR stability links or selection, adjust stability potentiometer. Check again on load.
	Connections loose or corroded.	Inspect all auxiliary board terminals. Inspect AVR push-on terminals. Repair or renew where necessary.
	Intermittent earth (ground) (low resistance of windings insulation).	Test the insulation resistance of all windings (See: Faultfinding without AVR).
UNBALANCED VOLTAGE (NO LOAD)	Fault in main stator winding.	Test the main stator windings. (See: Faultfinding without AVR)

TABLE 11. PMG FAULT DIAGNOSIS

PMG stator voltage		PMG stator phase-to-phase resistance	
		In range & balanced	Out of range or unbalanced
In range	Balanced	No fault	Re-test resistance
	Unbalanced	Check connector	Replace PMG stator
Out of range	Balanced	Replace PMG rotor	Replace PMG stator
	Unbalanced	Check connector	Replace PMG stator

9.3 Separately-Excited AVR - ON load

TABLE 12. FAULTFINDING: SEPARATELY-EXCITED AVR - ON LOAD

SYMPTOM	CAUSE	ACTION
LOW VOLTAGE (ON LOAD)	Engine speed low.	Test speed with tachometer. Adjust governor control to nominal speed.
	Under frequency protection (UFRO) circuit activated .	Inspect UFRO LED at AVR. If lit, UFRO is activated, indicating low speed. Adjust engine speed, to within -1% to +4% of nominal.
	Faulty permanent magnet generator (PMG) stator or rotor.	Disconnect the PMG leads from AVR terminals P2, P3, P4. Check voltage across leads with a Multimeter, with the set running at correct speed. For 50Hz, Voltage across P2, P3 and P4 should be approx. 160VAC – 180VAC. For 60Hz, Voltage is approx. 190VAC – 210VAC.
	AVR fault.	Replace AVR and re-test.
	Fault on winding or rotating diodes.	Any fault in this area will appear as high excitation voltage across X+ (F1) and XX- (F2). See Faultfinding without AVR.
	Voltage drop between generator and load, due to I ² R losses in the cable. This will be worse during current surges (e.g. motor starting).	Test the voltage at both ends of the cable at full load. In severe cases, a larger diameter cable is required.
HIGH VOLTAGE (ON LOAD)	Unbalanced load.	Test voltages on all phases. If unbalanced, re-distribute loading between phases.
	Leading Power Factor Load.	Test excitation volts across X+, (F1) and XX- (F2). A leading power factor will give an abnormally LOW d.c. excitation. Remove power factor correction capacitors from system at low load.
	Parallel droop transformer reversed.	Check for droop reversal. (See Faultfinding Parallel Operation).

SYMPTOM	CAUSE	ACTION
UNSTABLE VOLTAGE (ON LOAD)	Engine governing unstable (hunting)	Test engine speed stability with a frequency meter or tachometer for governor hunting, or cyclic irregularities in the engine.
	Leading power factor load created by power factor correction capacitors.	Isolate the power factor correction capacitors until sufficient motor load has been applied.
	Non linear loads, causing interaction between dynamic closed loop control systems.	Interaction of closed loop systems controlling the load, the generator and the engine. Instability is caused by oversensitive control settings. Try different settings of AVR stability, including changing the link to a smaller of larger kW range. Involve designers of the non-linear load to modify their control loop settings. Increase engine speed 'droop' to stabilise engine. Contact factory for further advice regarding non-linear loads.
	Fluctuations in load current, (motor starting, or reciprocating loads).	Test the load current on a stable supply, i.e. mains, or see Faultfinding without AVR using a variable d.c. supply.
	AVR stability control incorrectly adjusted.	Adjust AVR stability control, until voltage is stable.
UNBALANCED VOLTAGE (ON LOAD)	Single-phase loads (phase - neutral) unevenly distributed over the three phases.	Test current in each phase with clamp ammeter. The full load rated current must NOT be exceeded on any individual phase. Re-distribute load if necessary.
POOR VOLTAGE REGULATION (ON LOAD)	Large speed droop on engine. AVR UFRO protection activated.	Test the speed droop from no load to full load is no greater than 4%. Inspect AVR LED. If lit, increase engine speed.
	Unbalanced load.	Check voltage and load current on all phases. If unbalanced, redistribute the load more evenly across the phases.
	Parallel droop circuit incorrectly adjusted, or requires shorting switch for single running.	The droop circuit will give additional voltage droop of -3% at full load 0.8 power factor. For single running machines this can be improved by fitting a shorting switch across the droop CT input, (S1 – S2), on the AVR.
	Voltage drop between generator and load, caused by losses in supply cable, (I^2R losses).	Test the voltage at both ends of the cable run at full load. In severe cases, a larger diameter cable is required.
	AVR stability control incorrectly adjusted.	Adjust AVR control, until voltage is stable.
	Fault on rectifier or excitation winding.	Test the no load excitation volts across AVR X+ (F1) and XX- (F2). If higher than 12V dc, see Faultfinding without AVR.
	Under frequency protection (UFRO) activated.	Inspect UFRO LED at AVR. If lit, UFRO is activated, indicating low speed. Test speed with tachometer and adjust to correct nominal speed, (or frequency).

SYMPTOM	CAUSE	ACTION
POOR VOLTAGE RESPONSE TO LOAD SURGES OR MOTOR STARTING	Engine governor sticking or slow to respond.	Check performance of engine during application of load. Check if AVR LED is lit during motor starting. Check if AVR 'DIP' or 'DWELL' circuits are activated. Adjust as necessary. (See AVR instruction sheet).
	AVR 'UFRO' protection activated.	Test the speed droop from no load to full load is no greater than 4%. Inspect AVR LED. If lit, increase engine speed.
	Parallel droop circuit incorrectly set.	Too much droop will increase voltage dips when motor starting. Fit shorting switch for single running generators. See Faultfinding Parallel Operation.
	Load surges cause current to exceed 2.5 times the full load current.	Test current with a clamp ammeter. Voltage dip may be excessive if the current exceeds 2.5 times full load. Refer to factory for motor starting calculations.
	Voltage drop between generator and load, caused by I ² R losses in supply cable. This will be worse during current surges (e.g. motor starting).	Test the voltage at both ends of the cable at full load. In severe cases, a larger diameter cable is required.
	Motor contactors dropping out during starting, (large current surges, voltage dips greater than 30%).	All causes and actions in this section may apply to this problem. Refer to factory for typical voltage dips.
	AVR stability control incorrectly adjusted.	Set AVR stability control for optimum performance. Adjust anticlockwise until voltage is unstable, then slightly clockwise until stable.
	Fault on windings or rotating rectifier.	Any fault in this area will appear as high excitation voltage across X+ (F1) and XX- (F2). If higher than 12V d.c., see Faultfinding without AVR.
	Engine relief circuit activated during motor starting.	Check if AVR 'DIP' or 'DWELL' engine relief circuits are activated. Adjust as necessary. See AVR instructions for details.
AVR fault.		Replace and re-test on load.
VOLTAGE COLLAPSES (ON LOAD)	Protection circuit in AVR activated, due to high excitation condition across AVR output, (X+ (F1) and XX- (F2).	Excitation volts higher than 70V d.c. Test voltage across X+ (F1) and XX- (F2) on load. Ensure engine speed is correct at full load. Check output voltage, ensure it does not exceed the rated voltage. Check load current for overload.
	Protection circuit in AVR operated, due to fault in generator windings or diodes.	Check AVR LED. if lit, protection circuit is activated. Shut down engine, and re-start. If voltage returns as normal, but collapses again on load, protection circuit is activated, due to high excitation. Follow Faultfinding without AVR to find cause of high excitation volts.
	AVR fault.	Replace AVR and re-test on load.
	Severe overload or short circuit across phases.	Check load current with clamp ammeter.

9.4 Parallel Operation

TABLE 13. FAULTFINDING: PARALLEL OPERATION

SYMPTOM	CAUSE	ACTION
CIRCUIT BREAKER WILL NOT CLOSE WHEN ATTEMPTING PARALLEL OPERATION	Circuit breaker fitted with 'Check Synchronising' protection, which prevents out of phase synchronising.	Ensure that the synchroscope is indicating that machines are IN PHASE, or close to the eleven o'clock position, (when rotating in a clockwise direction). Ensure that the speed difference between the incoming set and the bus bar is small enough to prevent rapid rotation of the synchroscope, (or rapid fluctuations of the lights), before closing circuit breaker.
	Phase rotation of generators differs.	DO NOT ATTEMPT TO PARALLEL until the phase rotation of all generators are identical. Check the phase rotation of each generator. Exchange the connections of two of the phases to reverse the phase rotation of a generator.
	Voltage difference too high between the incoming generator and the bus bar.	The voltage on the incoming set can be up to 4% higher than the bus bar voltage. THIS IS NORMAL. Do not adjust original no-load Voltage settings. If difference is greater than 4%, check for excessive droop on the loaded generator(s).
UNSTABLE IN-PHASE CONDITION, BEFORE SYNCHRONISING	Governor drift on one or more of the engines.	Let engines warm up and stabilise before paralleling. If speed is still drifting check governors and engine condition.
	Load variation on the bus bar causing speed/ frequency changes on the loaded generator when synchronising.	Disconnect any rapidly varying load. Check that there is no likelihood of a motor or automatic load starting when attempting to synchronise. DO NOT attempt to parallel if the load current is unstable.
UNSTABLE FREQUENCY IN PARALLEL WHEN ON LOAD	Engine speed droop too 'tight' or cyclic irregularities (instability) between the engines. (Check kW meters for rapid shifting of kW power between sets).	Increase the engine governor speed droop to 4% (no load to full load). Check for "sticky" governors on a new engine. Check engines for cyclic problems, (firing, out of balance, etc),
STABLE VOLTAGE BEFORE AND AFTER BUT UNSTABLE WHILE SYNCHRONISING	Usually results from 'pick-up' through the synchronising panel and/or earth leakage protection circuits that can form a temporary 'closed loop' link between the generators during synchronisation.	The fluctuation will decay when the generators approach synchronism, (almost identical speeds), and will disappear completely when the circuit breaker is closed. The synchronising equipment, earth leakage protection, and/or wiring circuits in the switchboard can produce temporary pickup problems.

SYMPTOM	CAUSE	ACTION
CURRENT UNCONTROLLED, RISES FAST WHEN CIRCUIT BREAKER CLOSED	Parallel droop equipment reversed on one of the generators.	Check the droop CTs for reversal. Reverse lead S1-S2 on the droop CT. Test excitation volts - the generator with reversed droop will have highest excitation volts.
STABLE CIRCULATING CURRENT ON ALL GENERATORS, NOT REDUCED BY VOLTAGE ADJUSTMENT	Parallel droop reversed on ALL generators.	Check droops for reversal. Reverse leads S1-S2 to correct. This repeated wiring error will result in a stable circulating current which cannot be adjusted out by normal means.
STABLE CIRCULATING CURRENT ON BOTH GENERATORS AT NO LOAD	Voltage difference (excitation level) between the generators.	Check Voltages at no load, (identical frequencies), and ensure all generators have identical voltages. Do not adjust when load sharing.
	Parallel droop equipment reversed on BOTH generators. (Unlike ONE droop reversal, which is a highly UNSTABLE condition).	Check ALL droop CTs for reversal.
	Incorrect setting of parallel droop equipment.	Check settings of droop trimmers. Check droop CTs are in correct phase. Check CT output to AVR S1-S2 is correct.
UNBALANCED POWER ON KILOWATT METERS	Engines not sharing the power (kW) equally.	Adjust the governor droop of the engines to equalise the kilowatt sharing.
UNBALANCED CURRENT ON AMMETERS AFTER EQUILISING KILOWATTS	Voltage difference (excitation levels) between the machines.	Test the machines individually for exact voltage at no load.
	Parallel droop equipment incorrectly adjusted.	Adjust as stated in previous text.
UNBALANCED POWER AS LOAD INCREASED OR DECREASED	Engine governors are incompatible, or new governors 'sticking', causing unequal kW sharing over load range variations.	The engine governors must be adjusted to give similar no load to full load characteristics. Check for 'sticky' governors on new or repainted engines. Electronic governors should be set with a minimum 2% speed droop to ensure satisfactory kilowatt load sharing. If tighter speed regulation is required, an Isochronous Load Sharing system should be installed.
INCREASING UNBALANCED CURRENT AS LOAD INCREASED	Difference in parallel droop level settings. Difference in no load to full load voltage regulation of AVRs. These settings are the major contributing factors to the load/voltage characteristics of the machine, and therefore must be set to give equal characteristics to the machines with which it is paralleled.	Run each generator individually, and apply load at approximately 25%, 50% & 100% of full load. Test voltage at each load and compare values with the other generators. Adjust control systems to remove regulation differences. Repeat method with as much inductive load as possible i.e. motors, transformers etc. Adjust the parallel droop trimmers, to achieve equal inductive load sharing.

SYMPTOM	CAUSE	ACTION
POOR VOLTAGE REGULATION WHEN MACHINE RUNNING ALONE	Excess amount of parallel droop in circuit.	For normal voltage regulation as a single running machine, a shorting switch should be fitted across the parallel droop transformer. (S1-S2). This should be clearly marked 'Single' and 'Parallel' operation on the panel.
UNBALANCED POWER, ENGINES 'ROCK' ON MOUNTS	Electronic engine governor speed 'droop' characteristics are set too tight.	At least 2% engine droop is essential for kW (Active current) sharing. If 1% or less speed regulation is required, an electronic governing and Isochronous Load Sharing system should be installed.

9.5 AVR Fault Finding

This section has general advice to diagnose faults on AVRs. Further troubleshooting guidance is given in the Specification, Installation and Adjustments instructions or the Instruction Manual specific to the AVR model. The AVR has a protection circuit which operates under fault conditions after about 8 seconds (exact delay depends on AVR type). The circuit removes the generator excitation, causing output voltage to collapse, and latches until the generator is stopped and restarted. The system designer must make sure that this feature is compatible with the overall system protection.

Symptom	Action
VOLTAGE DOES NOT INCREASE WHEN STARTING	Check link K1:K2 on AVR or auxiliary terminals. Replace if necessary and restart.
VOLTAGE INCREASES WHEN STARTING TO WRONG VALUE	Check AVR volts control potentiometer setting. Correct if necessary. Check 'Hand Trimmer' if fitted. Adjust if necessary. Check generator speed. Correct if necessary and restart. Check AVR 'UFRO' indicator. If illuminated, see UFRO Setting Procedure.
VOLTAGE INCREASES VERY SLOWLY WHEN STARTING	Check generator accelerates as expected. Correct if necessary and restart. Check setting of adjustable ramp. Correct if necessary and restart.
VOLTAGE INCREASES TO HIGH VALUE WHEN STARTING	Check AVR wiring with wiring diagram.
VOLTAGE INCREASES TO HIGH VALUE THEN FALLS TO LOW VALUE WHEN STARTING	Check AVR wiring with wiring diagram.
VOLTAGE NORMAL THEN FALLS TO LOW VALUE WHEN RUNNING	Check generator loading Check rectifier system (see Service and Maintenance chapter)
VOLTAGE UNSTABLE EITHER WHEN RUNNING NO-LOAD OR ON-LOAD	Check that the generator speed is stable. Correct if necessary and restart. Check AVR wiring with wiring diagram. Adjust the AVR stability control slowly clockwise until steady.
VOLTAGE FALLS TO LOW VALUE WHEN LOAD APPLIED	Check generator speed is not dropping as load is applied. Correct if necessary and restart. Check AVR 'UFRO' indicator. If it illuminates as load is applied, see UFRO Setting Procedure.

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If all the tests and checks listed above fail to locate the generator fault then it must be assumed that the AVR is faulty. There are no serviceable items in the AVR.

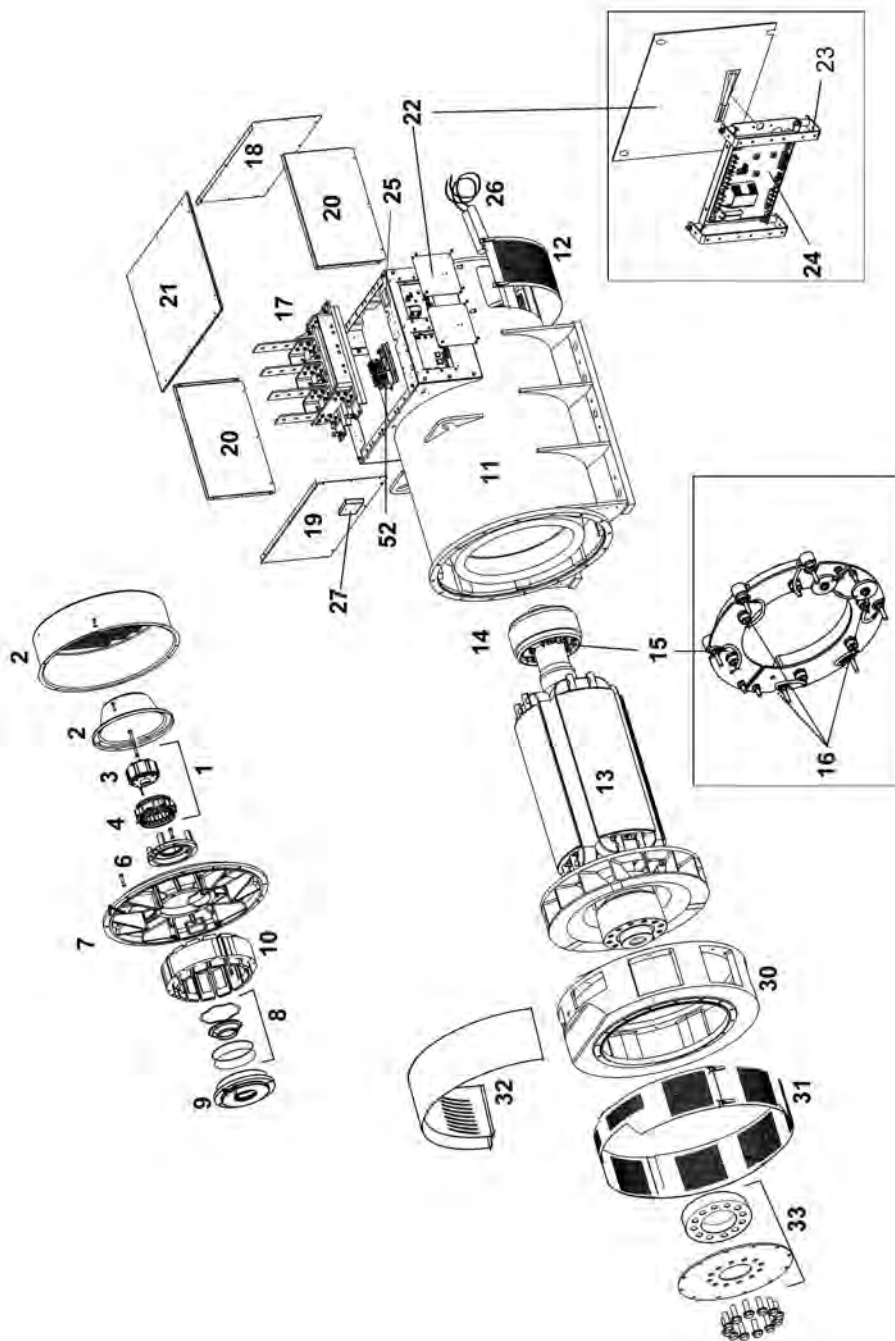
The AVR should be replaced only by a genuine STAMFORD part.

9.5.1 UFRO Setting Procedure

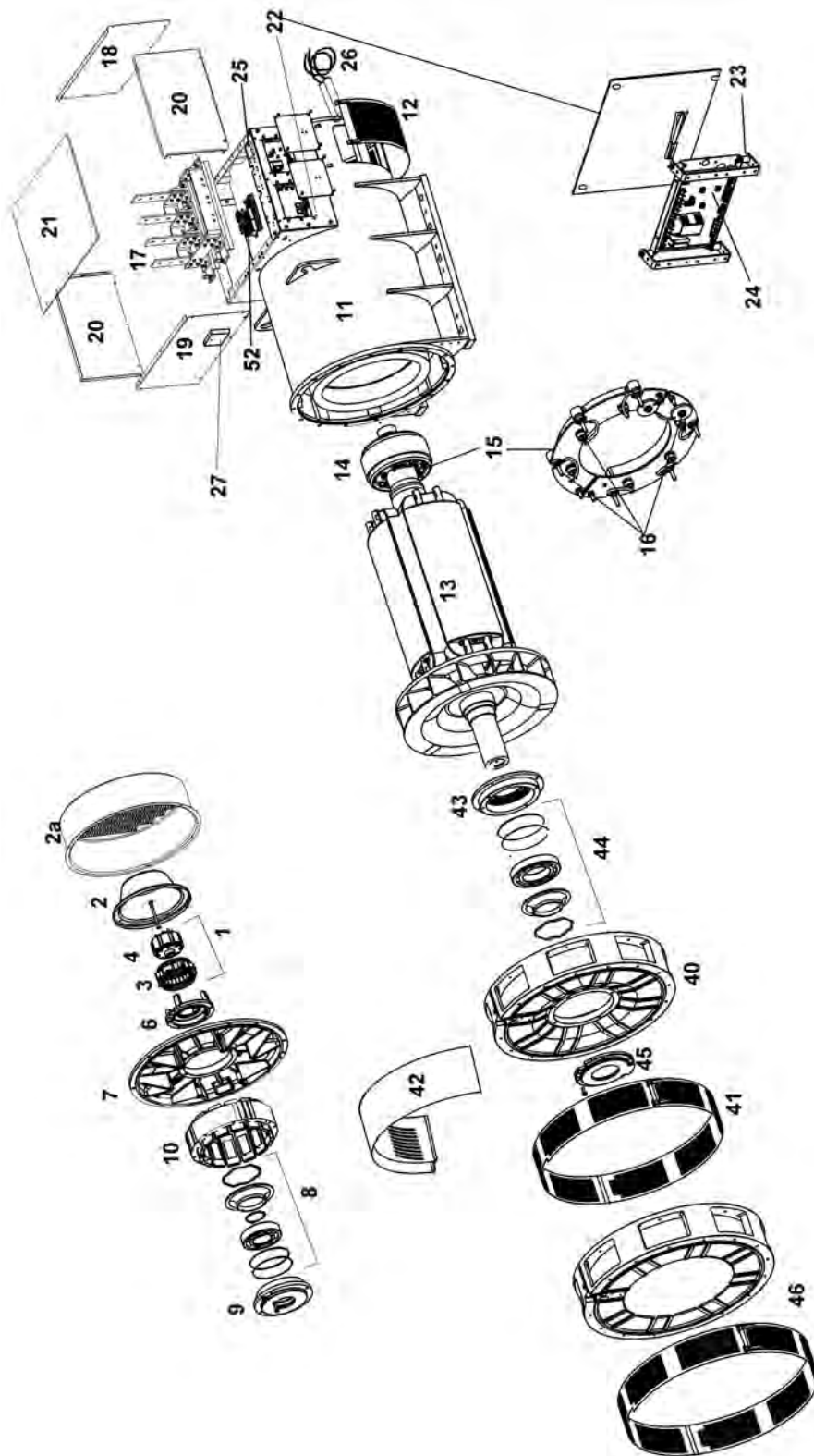
1. Stop the generator.
2. Check that the AVR UFRO selection link is set for the required operation frequency.
3. Start the generator set and run it with no load at rated speed.
4. If the voltage is now correct and the UFRO indicator is not illuminated, return to the fault finding procedure.
5. If the UFRO LED indicator is illuminated, continue as follows.
6. Adjust the UFRO control fully clockwise.
7. Set the generator speed to the desired UFRO threshold (typically 95% of rated speed).
8. Adjust the UFRO control slowly counter-clockwise until the UFRO indicator illuminates.
9. Return the control slightly clockwise until the indicator turns off.
10. The UFRO setting is now correct - return to the fault finding procedure.

10 Parts Identification

10.1 P7 Single Bearing Generator



10.2 P7 Two Bearing Generator



10.3 P7 Parts and Fasteners

TABLE 14. PARTS AND FASTENERS

Reference	Component	Fastener	Quantity	Torque (Nm)
1	Complete PMG parts	-	-	-
2/2a	PMG Cover/Air Inlet Cover	M8 x 16	4	26
3	PMG Rotor	M10 x 100	1	50
4	PMG Stator	M6 x 45	4	10
6	NDE Bearing Cap	M10 x 35	5	
7	NDE Bracket	M12 x 40	8	95
8	NDE Bearing	-	-	-
9	NDE Bearing Cartridge	M10 x 60	4	50
10	Exciter Stator	M8 x 90	6	26
11	Main Frame	-	-	-
12	Lower Air Inlet Cover	Split pin	2	-
13	Main Rotor	-	-	-
14	Exciter Rotor	-	-	-
15	Rectifier Assembly	M6 x 100	4	10
16	Diode/Varistor	-	-	4.75 / 3.0
17	Main Terminals	M12 x 40	12	45
18	Terminal Box End Panel NDE	M6 x 16	10	10
19	Terminal Box End Panel DE	M6 x 16	10	10
20	Terminal Box Side Panel	M6 x 16	10	10
21	Terminal Box Lid	M6 x 16	14	10
22	AVR Cover Plate	M6 x 16	4	10
23	AVR Mounting Bracket			
24	AVR			
25	Auxilliary Terminal Board	M6 x 25	8	10
26	Anti-condensation Heaters	-	-	-
27	Heater terminal Box			
30	DE Adapter (1 bearing)			
31	DE Air Outlet Screen (1 bearing)	M4 x 12	8	1.3
32	DE Louvres (1 bearing)			
33	DE Coupling Hub and Coupling Discs (1 bearing)		12	822
40	DE Bracket (2 bearing)	M12 x 50	12	95
41	DE Air Outlet Screen (2 bearing)	M4 x 12	8	1.3
42	DE Louvres (2 bearing)			
43	DE Bearing Cartridge (2 bearing)	M10 x 55	4	50
44	Complete DE Bearing parts	-	-	-
45	DE Bearing Cap	M10 x 35	5	50

Reference	Component	Fastener	Quantity	Torque (Nm)
46	DE Adapter (2 bearing)	M12 x 45	14	95
52	Isolation Transformer			

11 Technical Data

NOTICE

Compare measurements with the test certificate supplied with the generator.

11.1 P7 Winding Resistances

Generator Type	Resistance of windings at 20 °C (measured values should be within 10%)								
	Main Stator Phase to Neutral, L-N (ohms)					Exciter Stator (ohms)	Exciter Rotor, L-L (ohms)	Main Rotor (ohms)	PMG Stator, L-L (ohms)
	Winding 312	Winding 07	Winding 13	Winding 26	Winding 28				
PE / P734A	0.0016	0.0026	0.0013	0.0048	0.0031	17.5	0.126	1.67	2.6
PE / P734B	0.0016	0.0026	0.0013	0.0048	0.0031	17.5	0.126	1.67	2.6
PE / P734C	0.0012 6	0.002	0.0009	0.0034	0.0027	17.5	0.126	1.85	2.6
PE / P734D	0.0011 4	0.002	0.0009	0.0031	0.0019	17.5	0.126	1.98	2.6
PE / P734E	0.0009 3	0.0015	n/a	0.003	0.002	17.5	0.126	2.17	2.6
PE / P734F	0.0007 6	0.0011	0.0005	0.0022	0.0016	17.5	0.126	2.31	2.6
PE / P734G	0.0008	0.0011	n/a	0.0022	n/a	16	0.112	2.42	2.6
P736B	0.0027	0.0042	n/a	n/a	n/a	17	0.2	2.33	5.6
P736D	0.0018	0.0032	n/a	n/a	n/a	17	0.2	2.69	5.6
P736F	0.0014	0.002	n/a	n/a	n/a	20	0.28	3.25	5.6

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12 Spares and After Sales Service

We recommend the use of genuine STAMFORD service parts supplied from an authorised service outlet. For details of your nearest service outlet visit www.stamford-avk.com.

Aftermarket Help Desk

Phone: +44 (0) 1780 484744

Email: parts.enquires@cummins.com

12.1 Parts Orders

When ordering parts the machine serial number or machine identity number and type should be quoted, together with the part description. The machine serial number can be found on the name plate or frame.

12.2 Customer Service

Cummins Generator Technologies' service engineers are experienced professionals, trained extensively to deliver the best support possible. Our global service offers:

- 24/7 response to service emergencies, 365 days of the year.
- On-site ac generator commissioning
- On-site bearing maintenance & bearing condition monitoring
- On-site insulation integrity checks
- On-site AVR & accessories set-up
- Multi-lingual local engineers

Customer Service Help Desk:

Phone: +44 1780 484732 (24 hours)

Email: service-engineers@cumminsgeneratortechnologies.com

12.3 Recommended Service Parts

In critical applications a set of these service spares should be held with the generator.

Part	Number
Rectifier Set	RSK6001 (3 forward & 3 reverse diodes with varistors)
MX321 AVR	E000-23212/1P
MX341 AVR	E000-23412/1P
Sealed DE bearing (core length A to E)	45-0335
Sealed NDE bearing (core length A to E)	45-0336
Regreasable DE bearing (core length A to E)	45-0423
Regreasable DE bearing (core length F, G)	45-0425
Regreasable NDE bearing (core length A to E, two bearing)	45-0422
Regreasable NDE bearing (core length F, G, two bearing)	45-0424
Regreasable NDE bearing (core length A to G, one bearing)	45-0421
Klüber Grease	45-0281

12.4 Klüber Asonic GHY72 Grease

All bearings trials and calculated life expectancy are based on the use of Klüber Asonic GHY72.

13 End of Life Disposal

Companies specialising in reclaiming material from scrap products can reclaim most of the iron, steel and copper from the generator. For more details, please contact Customer Service.

13.1 Recyclable material

Mechanically separate the base materials, iron, copper and steel, removing paint, polyester resin, and insulation tape and/or plastics residues from all components. Dispose of this 'waste material'

The iron, steel and copper can now be recycled.

13.2 Items requiring specialist treatment

Remove electrical cable, electronic accessories and plastic materials from the generator. These components need special treatment to remove the waste from the reclaimable material.

Forward the reclaimed materials for recycling.

13.3 Waste material

Dispose of waste material from both of the above processes via a specialist disposal company.

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