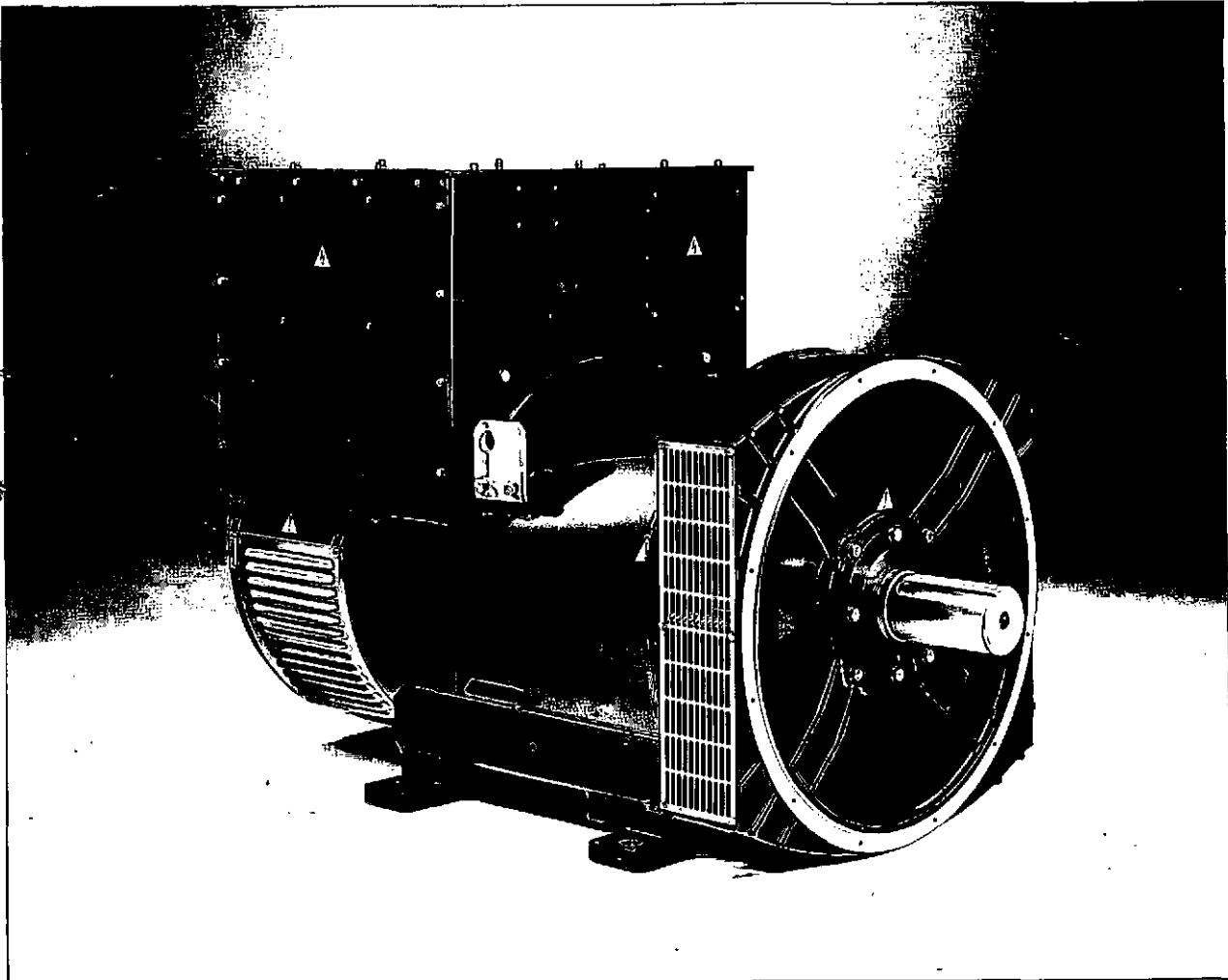
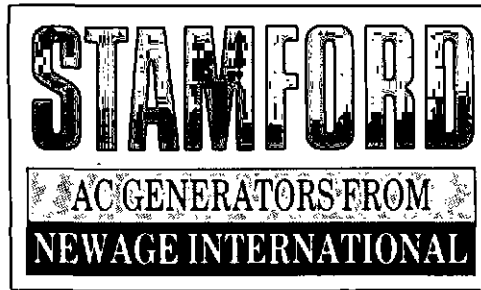




Installation, Service & Maintenance Manual

for AC generators with the following prefixes:

HCI; HCM; HCK 4,5,6,7.

SAFETY PRECAUTIONS

Before operating the generating set, read the generating set operation manual and this generator manual and become familiar with it and the equipment.

SAFE AND EFFICIENT OPERATION CAN ONLY BE ACHIEVED IF THE EQUIPMENT IS CORRECTLY OPERATED AND MAINTAINED.

Many accidents occur because of failure to follow fundamental rules and precautions.

ELECTRICAL SHOCK CAN CAUSE SEVERE PERSONAL INJURY OR DEATH.

Observe all **WARNING/CAUTION** notices.

- Ensure installation meets all applicable safety and local electrical codes. Have all installations performed by a qualified electrician.
- Do not operate the generator with protective covers, access covers or terminal box covers removed.
- Disable engine starting circuits before carrying out maintenance.
- Disable closing circuits and/or place warning notices on any circuit breakers normally used for connection to the mains or other generators, to avoid accidental closure.

Observe all **IMPORTANT, CAUTION, WARNING, and DANGER** notices, defined as:

Important ! Important refers to hazard or unsafe method or practice which can result in product damage or related equipment damage.

Caution ! Caution refers to hazard or unsafe method or practice which can result in product damage or personal injury.



Warning !

Warning refers to a hazard or unsafe method or practice which **CAN** result in severe personal injury or possible death.



Danger !

Danger refers to immediate hazards which **WILL** result in severe personal injury or death.

FOREWORD

The function of this book is to provide the user of the Stamford generator with an understanding of the principles of operation, the criteria for which the generator has been designed, and the installation and maintenance procedures. Specific areas where the lack of care or use of incorrect procedures could lead to equipment damage and/or personal injury are highlighted, with **WARNING** and/or **CAUTION** notes, and it is important that the contents of this book are read and understood before proceeding to fit or use the generator.

The Service, Sales and technical staff of Newage International are always ready to assist and reference to the company for advice is welcomed.



Warning !

Incorrect installation, operation, servicing or replacement of parts can result in severe personal injury or death, and/or equipment damage.

Service personnel must be qualified to perform electrical and mechanical service.

EC DECLARATION OF INCORPORATION

All Stamford generators are supplied with a declaration of incorporation for the relevant EC legislation, attached in the form of a label as below.

EC DECLARATION OF INCORPORATION

IN ACCORDANCE WITH THE SUPPLY OF MACHINERY (SAFETY) REGULATIONS 1992
AND THE SUPPLY OF MACHINERY (SAFETY) (AMENDMENT) REGULATIONS 1994
IMPLEMENTING THE EC MACHINERY DIRECTIVE 89/392/EEC AS AMENDED BY 91/368/EEC.

THIS STAMFORD A.C. GENERATOR WAS
MANUFACTURED BY NEWAGE INTERNATIONAL LTD, BARNACK ROAD,
STAMFORD, LINCOLNSHIRE, ENGLAND.

THIS COMPONENT MACHINERY MUST NOT BE PUT INTO SERVICE UNTIL THE
MACHINERY INTO WHICH IT IS TO BE INCORPORATED HAS BEEN DECLARED IN
CONFORMITY WITH THE PROVISIONS OF THE SUPPLY OF MACHINERY (SAFETY)
REGULATIONS 1992/MACHINERY DIRECTIVE.

FOR AND ON BEHALF OF THE MANUFACTURER

NAME
POSITION:

SIGNATURE

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SECTION 1

INTRODUCTION

1.1 INTRODUCTION

The HC range of generators is of brushless rotating field design, available up to 660V/50Hz or 60Hz and built to meet B.S. 5000 Part 3 and international standards.

1500 rpm (50Hz) or 1800 rpm (60Hz) 4 pole generators are available from 200kW to 2000kW in four frame sizes - HC4, HC5, HC6 and HC7.

1000 rpm (50Hz) or 1200 rpm (60Hz) 6 pole generators are available from 224kW to 1300kW in two frame sizes - HC6 and HC7.

Frame sizes HC4 and HC5 may be provided with a stator fed excitation system using SX440 or SX421 AVR, or with the permanent magnet generator (PMG) powered excitation system, using the MX341 or MX321 AVR.

Frames HC6 and HC7 are fitted with the PMG system using the MX321 AVR.

1.2 DESIGNATION

H	C	.	I	4	4	4	C	1
H	C	.	M	5	4	4	C	2
H	C	.	I	6	3	4	G	1
H	C	.	I	6	3	6	G	2
H	C	.	M	6	3	4	G	2

GENERATOR TYPE HC

SPECIFIC TYPE K = VOLUTED ADAPTOR
AND UNI-DIRECTIONAL FAN

INDUSTRIAL = (I) OR MARINE = (M)

FRAME SIZE AND CONTROL TYPE ON HC/MV
SHAFT HEIGHT IN CM ON BC/UC

NUMBER OF POLES 2, 4, OR 6

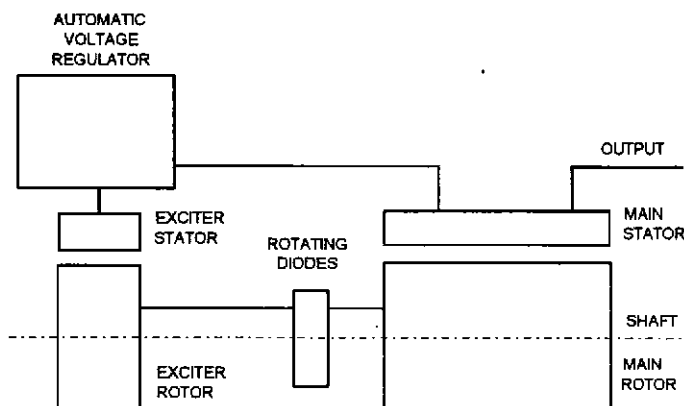
CORE LENGTH

NUMBER OF BEARINGS 1 OR 2

SECTION 2

PRINCIPLE OF OPERATION

2.1 SELF-EXCITED AVR CONTROLLED GENERATORS

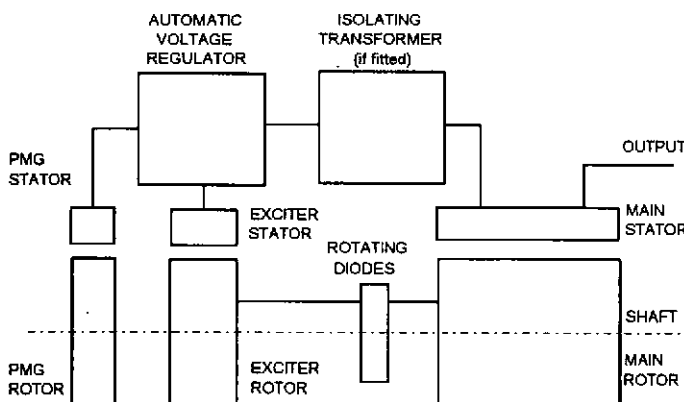


The main stator provides power for excitation of the exciter field via the SX440 (or SX421) AVR which is the controlling device governing the level of excitation provided to the exciter field. The AVR responds to a voltage sensing signal derived from the main stator winding. By controlling the low power of the exciter field, control of the high power requirement of the main field is achieved through the rectified output of the exciter armature.

The SX440 AVR senses average voltage on two phases ensuring close regulation. In addition it detects engine speed and provides voltage fall off with speed, below a pre-selected speed (Hz) setting, preventing over-excitation at low engine speeds and softening the effect of load switching to relieve the burden on the engine.

The SX421 AVR in addition to the SX440 features has three phase rms sensing and also provides for over voltage protection when used in conjunction with an external circuit breaker (switchboard mounted).

2.2 PERMANENT MAGNET GENERATOR (PMG) EXCITED - AVR CONTROLLED GENERATORS



The permanent magnet generator (PMG) provides power for excitation of the exciter field via the AVR MX341 (or MX321) which is the controlling device governing the level of excitation provided to the exciter field. The AVR responds to a voltage sensing signal derived, via an isolating transformer in the case of MX321 AVR, from the main stator winding. By controlling the low power of the exciter field, control of the high power requirement of the main field is achieved through the rectified output of the exciter armature.

The PMG system provides a constant source of excitation power

irrespective of main stator loading and provides high motor starting capability as well as immunity to waveform distortion on the main stator output created by non linear loads, e.g. thyristor controlled dc motor.

The MX341 AVR senses average voltage on two phases ensuring close regulation. In addition it detects engine speed and provides an adjustable voltage fall off with speed, below a pre-selected speed (Hz) setting, preventing over-excitation at low engine speeds and softening the effect of load switching to relieve the burden on the engine. It also provides over-excitation protection which acts following a time delay, to de-excite the generator in the event of excessive exciter field voltage.

The MX321 provides the protection and engine relief features of the MX341 and additionally incorporates 3 phase rms sensing and over-voltage protection.

The detailed function of all the AVR circuits is covered in the load testing section (subsection 4.7).

2.3 AVR ACCESSORIES

The SX440, MX341 and MX321 AVRs incorporate circuits which, when used in conjunction with accessories, can provide for parallel operation either with 'droop' or 'astatic' control, VAR/PF control and in the case of the MX321 AVR, short circuit current limiting.

Function and adjustment of the accessories which can be fitted inside the generator terminal box are covered in the accessories section of this book.

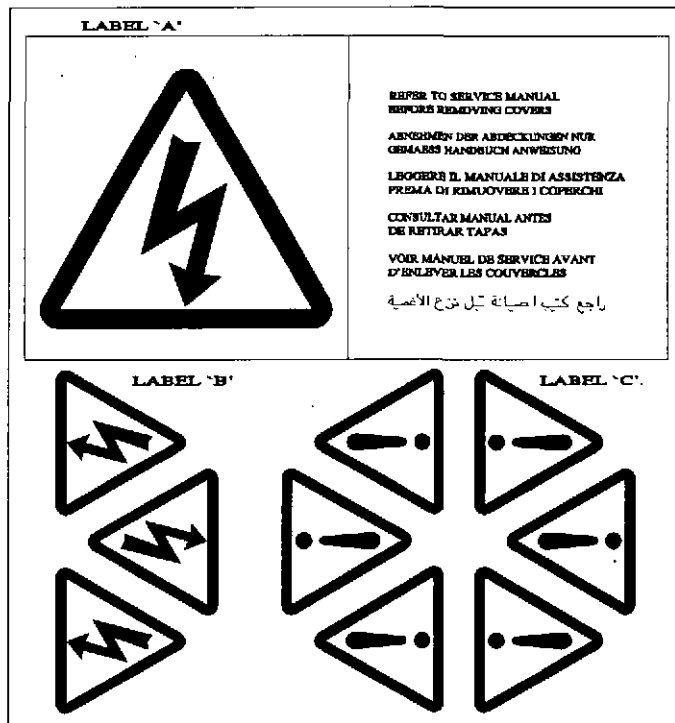
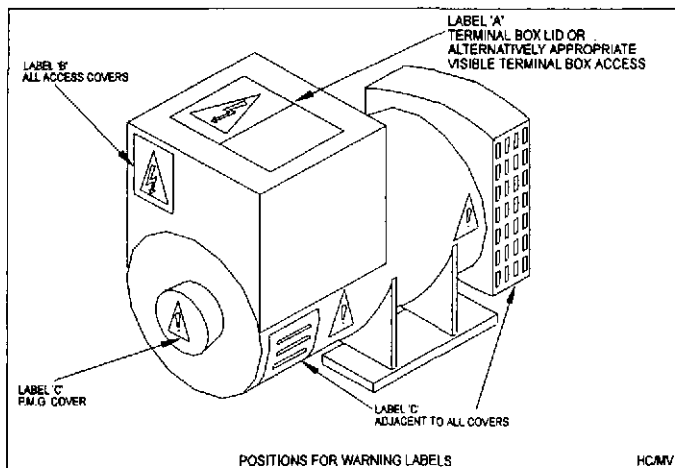
Separate instructions are provided with other accessories available for control panel mounting.

SECTION 3

APPLICATION OF THE GENERATOR

The generator is supplied as a component part for installation in a generating set. It is not, therefore, practicable to fit all the necessary warning/hazard labels during generator manufacture. The additional labels required are packaged with this Manual, together with a drawing identifying their locations. (see below).

It is the responsibility of the generating set manufacturer to ensure that the correct labels are fitted, and are clearly visible.



The generators have been designed for use in a maximum ambient temperature of 40°C. in accordance with B.S. 5000.

Ambients in excess of 40°C. can be tolerated with reduced ratings - refer to the generator nameplate for rating and ambient.

In the event that the generator is required to operate in an ambient in excess of the nameplate value or at altitudes in excess of 1000 metres above sea level, refer to the factory.

The generators are of air-ventilated screen protected drip-proof design and are not suitable for mounting outdoors unless adequately protected by the use of canopies. Anti-condensation heaters are recommended during storage and for standby duty to ensure winding insulation is maintained in good condition.

When installed in a closed canopy it must be ensured that the ambient temperature of the cooling air to the generator does not exceed that for which the generator has been rated.

The canopy should be designed such that the engine air intake to the canopy is separated from the generator intake, particularly where the radiator cooling fan is required to draw air into the canopy. In addition the generator air intake to the canopy should be designed such that the ingress of moisture is prohibited, preferably by use of a two stage filter.

The air intake/outlet must be suitable for the air flow given in the following table with additional pressure drops less than or equal to those given below:

Frame	Air Flow		Additional (intake/outlet) Pressure Drop
	50Hz	60Hz	
HC4	0.5m ³ /sec (1180cfm)	0.67m ³ /sec (1420cfm)	6mm water gauge (0.25")
	0.644m ³ /sec (1357cfm)	0.77m ³ /sec (1633cfm)	6mm water gauge (0.25")
HCK4	0.86m ³ /sec (1820cfm)	1.03m ³ /sec (2190cfm)	6mm water gauge (0.25")
	0.99m ³ /sec (2093cfm)	1.185m ³ /sec (2519cfm)	6mm water gauge (0.25")
HC5	0.81m ³ /sec (1720cfm)	0.97m ³ /sec (2060cfm)	6mm water gauge (0.25")
	1.32m ³ /sec (2800cfm)	1.58m ³ /sec (3360cfm)	6mm water gauge (0.25")
HCK5	1.52m ³ /sec (3220cfm)	1.82m ³ /sec (3864cfm)	6mm water gauge (0.25")
HC6			
HC7			
HCK7			

If specified at the time of ordering, the generator itself may be fitted with air filters. These are oil charged gauze filters and require charging during installation.

Important ! Reduction in cooling air flow or inadequate protection to the generator can result in damage and/or failure of windings.

Dynamic balancing of the generator rotor assembly has been carried out during manufacture in accordance with BS 6861 Part 1 Grade 2.5 to ensure vibration limits of the generator are in accordance with BS 4999 Part 142.

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

4 pole	1500 rpm	25Hz
"	1800 rpm	30Hz
6 pole	1000 rpm	16.7Hz
"	1200 rpm	20Hz

However, vibrations induced by the engine are complex and contain frequencies of 1.5, 3, 5 or more times the fundamental frequency of vibration. These induced vibrations can result in generator vibration levels higher than those derived from the generator itself. It is the responsibility of the generating set designer to ensure that the alignment and stiffness of the bedplate and mountings are such that the vibration limits of B.S. 5000 Part 3 are not exceeded.

In standby applications where the running time is limited and reduced life expectancy is accepted, higher levels than specified in B.S. 5000 can be tolerated, up to a maximum of 18mm/sec.

Two bearing generators require a substantial bedplate with engine/generator mounting pads to ensure a good base for accurate alignment. Close coupling of engine to generator can increase the overall rigidity of the set. A flexible coupling, designed to suit the specific engine/generator combination, is recommended to minimise torsional effects.

Alignment of single bearing generators is critical and vibration can occur due to the flexing of the flanges between the engine and generator. A substantial bedplate with engine/generator mounting pads is required.

For the purposes of establishing set design the bending moment at the engine flywheel housing to generator adaptor interface should not exceed that given in the table below:-

FRAME	BENDING MOMENT
4/5	140kgm. (1000ft.lbs.)
6/7	275kgm. (2000ft.lbs.)

The maximum bending moment of the engine flange must be checked with the engine manufacturer.

Torsional vibrations occur in all engine-driven shaft systems and may be of a magnitude to cause damage at certain critical speeds. It is therefore necessary to consider the torsional vibration effect on the generator shaft and couplings.

It is the responsibility of the generator set manufacturer to ensure compatibility, and for this purpose drawings showing the shaft dimensions and rotor inertias are available for customers to forward to the engine supplier. In the case of single bearing generators coupling details are included.

Important ! Torsional incompatibility and/or excessive vibration levels can cause damage or failure of generator and/or engine components.

The standard terminal box is arranged for cable entry on the right hand side looking from the non drive end of the generator. If specified at the time of order cable entry may be arranged on the opposite side.

The terminal box is constructed with removable panels for easy adaptation to suit specific glanding requirements. Within the terminal box there are insulated terminals for line and neutral connections and provision for earthing. Additional earthing points are provided on the generator feet.

Fault current curves (decrement curves), together with generator reactance data, are available on request to assist the system designer to select circuit breakers, calculate fault currents and ensure discrimination within the load network.



Warning !

Incorrect installation, service or replacement of parts can result in severe personal injury or death, and/or equipment damage. Service personnel must be qualified to perform electrical and mechanical service.



Warning !

No earth connections are made on the generator and reference to site regulations for earthing must be made. Incorrect earthing or protection arrangements can result in personal injury or death.

The neutral is NOT connected to the frame.

SECTION 4

INSTALLATION - PART 1

4.1 LIFTING



Warning !

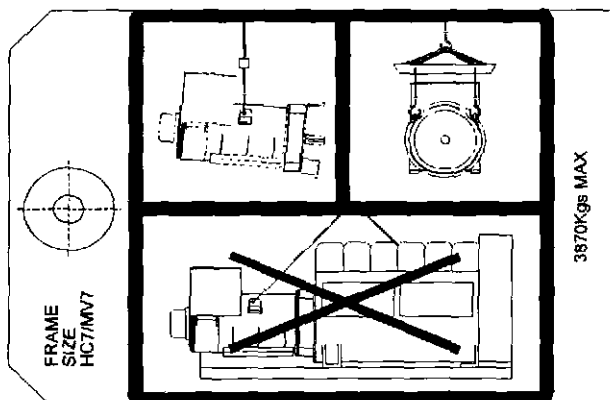
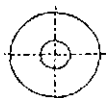
Incorrect lifting or inadequate lifting capacity can result in severe personal injury or equipment damage. MINIMUM LIFTING CAPACITY REQUIRED IS AS INDICATED ON THE LIFTING LABEL.

Generator lifting lugs should not be used for lifting the complete generating set.

Two lifting lugs are provided for use with a shackle and pin type lifting aid. Chains of suitable length and lifting capacity must be used. Lifting points are designed to position the craneage point as close to the centre of gravity of the generator as possible, but due to design restrictions it is not possible to guarantee that the generator frame will remain horizontal while lifting. Care is therefore needed to avoid personal injury or equipment damage. The correct lifting arrangement is shown on the label attached to the lifting lug. (See sample below).

IMPORTANT

REFER TO SERVICE MANUAL BEFORE REMOVING COVERS. IT IS THE GENERATOR SET MANUFACTURER'S RESPONSIBILITY TO FIT THE SELF ADHESIVE WARNING LABELS SUPPLIED WITH THE GENERATOR. THE LABEL SHEET CAN BE FOUND WITH THE INSTRUCTION BOOK.



Single bearing generators are supplied fitted with a rotor retaining bar at the drive end of the shaft. Single bearing generators are also fitted with wooden wedges supporting the fan for transit purposes.

Once the bar is removed, to couple the rotor to engine, the rotor is free to move in the frame, and care is needed during coupling and alignment to ensure the frame is kept in the horizontal plane.

4.2 ASSEMBLY TO ENGINE

4.2.1 TWO BEARING GENERATORS

A flexible coupling should be fitted and aligned in accordance with the coupling manufacturer's instruction.

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. Ensure adaptor guards are fitted after generator/engine assembly is complete. Open coupled sets require a suitable guard, to be provided by the set builder.

Axial loading of the generator bearings should be avoided. Should it be unavoidable contact the factory for advice.

Caution ! Incorrect guarding and/or generator alignment can result in personal injury and/or equipment damage.

4.2.2 SINGLE BEARING GENERATORS TYPES HC & HCK

Alignment of single bearing generators is critical. If necessary shim the generator feet to ensure alignment of the machined surfaces.

The sequence of assembly to the engine should generally be as follows:

1. On the engine check the distance from the coupling mating face on the flywheel to the flywheel housing mating face. This should be within 0.5mm of nominal dimension. This is necessary to ensure that a thrust is not applied to the a.c. generator bearing or engine bearing.
2. Check that the bolts securing the flexible plates to the coupling hub are tight and locked into position. Refer to Section 7, subsection 7.5.3.3 for tightening torques.
3. Remove covers from the drive end of the generator to gain access to coupling and adaptor bolts. Check coupling joint interfaces are clean and lubricant free.

4. TYPE HC GENERATORS

Check that coupling discs are concentric with adaptor spigot. This can be adjusted by the use of tapered wooden wedges between the fan and adaptor. HC7 generators are provided with the means of raising the rotor height by following a "jacking" process using two tapped holes in under side of D.E. end bracket and the two provided M10 set screws and sheet metal wear plates inserted between the end of jacking screw and under side of aluminium fan. Alternatively the rotor can be suspended by means of a rope sling through the adaptor opening.

Offer the generator to engine and engage both coupling discs and housing spigots at same time, pushing generator towards engine until coupling discs are against flywheel face, and housing spigots located.

TYPE HCK GENERATORS

Screw the two supplied location studs into diametrically opposite engine flywheel tapped holes, about the horizontal centre line. Offer the generator to engine, locating rotor coupling discs over the location studs, pushing generator towards engine until housing spigots locate and coupling discs are against flywheel face.

5. Fit housing and coupling bolts taking care to use heavy gauge washers between coupling bolt head and coupling disc. Tighten bolts evenly around assembly sufficiently to ensure correct alignment.

TYPE HCK GENERATORS

Remove location studs and replace with coupling-flywheel bolts.

6. Tighten housing bolts.
7. Tighten coupling disc to flywheel bolts. Refer to engine manufacturers manual for correct tightening torque.

8. TYPE HC GENERATORS

Remove rotor aligning aids, either wooden wedges, or the two M10 set screws and sheet metal wear plates.

Caution ! Incorrect guarding and/or generator alignment can result in personal injury and/or equipment damage.

4.3 EARTHING

The generator frame should be solidly bonded to the generating set bedplate. If antivibration mounts are fitted between the generator frame and its bedplate a suitably rated earth conductor (normally one half of the cross sectional area of the main line cables) should bridge across the antivibration mount.



Refer to local regulations to ensure that the correct earthing procedure has been followed.

Warning !

4.4 PRE-RUNNING CHECKS

4.4.1 INSULATION CHECK

Before starting the generating set, both after completing assembly and after installation of the set, test the insulation resistance of windings.

The AVR should be disconnected during this test.

A 500V Megger or similar instrument should be used. Disconnect any earthing conductor connected between neutral and earth and megger an output lead terminal U, V or W to earth. The insulation resistance reading should be in excess of $5M\Omega$ to earth. Should the insulation resistance be less than $5M\Omega$ the winding must be dried out as detailed in the Service and Maintenance section of this Manual.

Important ! The windings have been H.V. tested during manufacture and further H.V. testing may degrade the insulation with consequent reduction in operating life. Should it be necessary to demonstrate H.V. testing, for customer acceptance, the tests must be carried out at reduced voltage levels i.e. Test Voltage = $0.8 (2 \times \text{Rated Voltage} + 1000)$

4.4.2 DIRECTION OF ROTATION

TYPE HC GENERATORS

These machines are fitted with a radial bladed fan and are suitable for running in either direction of rotation.

TYPE HCK GENERATORS

These machines are fitted with inclined bladed fan and are only suitable for running in a clockwise direction looking at D.E. of generator.

Phase Rotation

The generator is supplied to give a phase sequence of U V W with the generator running clockwise looking at the drive end (unless otherwise specified at the time of ordering). If the generator phase rotation has to be reversed after the generator has been despatched apply to factory for appropriate wiring diagrams.

4.4.3 VOLTAGE AND FREQUENCY

Check that the voltage and frequency levels required for the generating set application are as indicated on the generator nameplate.

HC4/5 generators normally have a 12 ends out reconnectable winding. If it is necessary to reconnect the stator for the voltage required, refer to diagrams in the back of this manual.

4.4.4 AVR SETTINGS

To make AVR selections and adjustments remove the AVR cover and refer to 4.4.4.1, 4.4.4.2, 4.4.4.3 or 4.4.4.4 depending upon type of AVR fitted. Reference to the generator nameplate will indicate AVR type (SX440, SX421, MX341 or MX321).

Most of the AVR adjustments are factory set in positions which will give satisfactory performance during initial running tests. Subsequent adjustment may be required to achieve optimum performance of the set under operating conditions. Refer to 'Load Testing' section for details.

4.4.4.1 TYPE SX440 AVR

The following 'jumper' connections on the AVR should be checked to ensure they are correctly set for the generating set application.

Refer to Fig. 1 for location of selection links.

1. Frequency selection terminals

50Hz operation LINK C-50
60Hz operation LINK C-60

2. Stability selection terminals

Frame HC4/5 LINK B-C
Frame HC6/7 LINK A-B

3. Sensing selection terminals

LINK 2-3
LINK 4-5
LINK 6-7

4. Excitation Interruption Link

LINK K1-K2

4.4.4.2 TYPE SX421 AVR

The following 'jumper' connections on the AVR should be checked to ensure they are correctly set for the generating set application.

Refer to Fig. 2 for location of selection links.

1. Frequency selection terminals

50Hz operation LINK C-50
60Hz operation LINK C-60

2. Stability selection terminals

Frame HC4/5 LINK B-C
Frame HC6/7 LINK A-B

3. Excitation Interruption Link

Linked at auxiliary terminal block.

K1-K2

4.4.4.3 TYPE MX341 AVR

The following 'jumper' connections on the AVR should be checked to ensure they are correctly set for the generating set application.

Refer to Fig. 3 for location of selection links.

1. Frequency selection terminals

4 pole 50Hz operation LINK 2-3
4 pole 60Hz operation LINK 1-3
6 pole 50Hz operation NO LINK
6 pole 60Hz operation LINK 1-2

2. Stability selection terminals

Frame HC4/5 LINK B-C
Frame HC6/7 LINK A-B

3. Sensing selection terminals

LINK 2-3
LINK 4-5
LINK 6-7

4. Excitation Interruption Link

LINK K1-K2

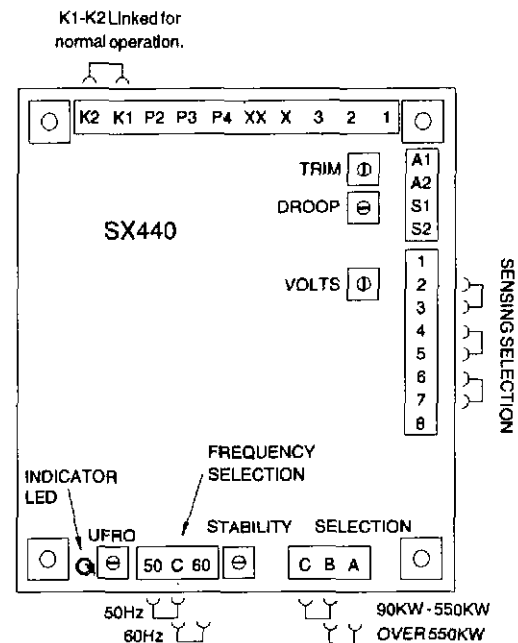


Fig. 1

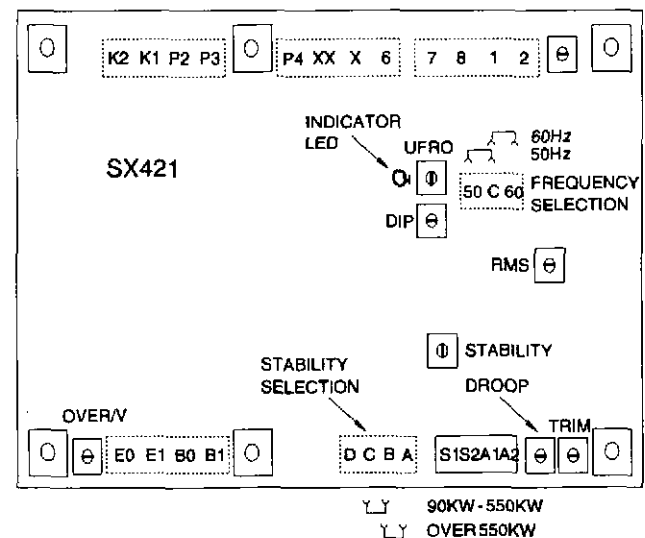


Fig. 2

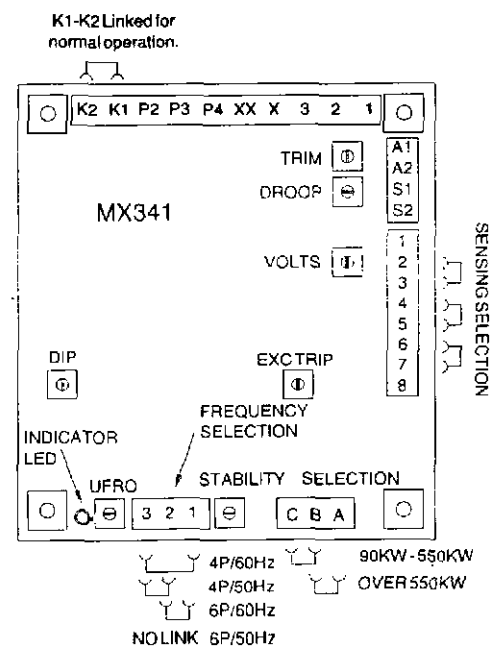


Fig. 3

4.4.4.4 TYPE MX321 AVR

The following 'jumper' connections on the AVR should be checked to ensure they are correctly set for the generating set application.

Refer to Fig. 4 for location of selection links.

1. Frequency selection terminals

4 pole	50Hz operation	LINK 2-3
4 pole	60Hz operation	LINK 1-3
6 pole	50Hz operation	NO LINK
6 pole	60Hz operation	LINK 1-2

2. Stability selection terminals

Frame HC4/5	LINK B-C
Frame HC6/7	LINK A-B

3. Excitation Interruption Link

Linked at auxiliary terminal block.

K1-K2

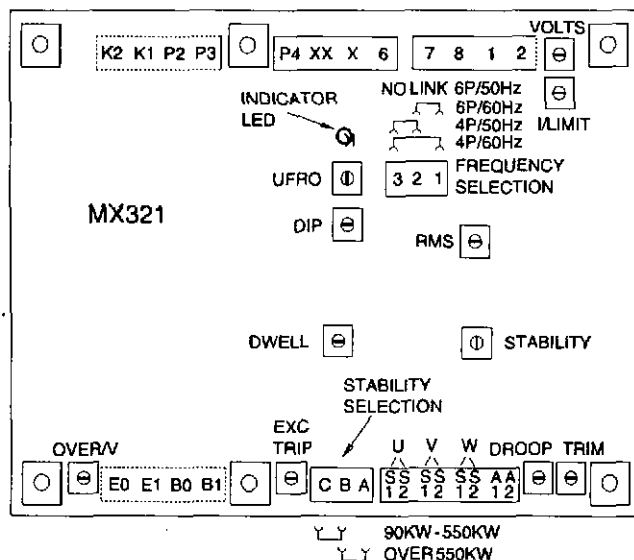


Fig. 4

4.5 GENERATOR SET TESTING



Warning !

During testing it may be necessary to remove covers to adjust controls exposing 'live' terminals or components. Only personnel qualified to perform electrical service should carry out testing and/or adjustments.

4.5.1 TEST METERING/CABLING

Connect any instrument wiring and cabling required for initial test purposes with permanent or spring-clip type connectors.

Minimum instrumentation for testing should be line - line or line to neutral voltmeter, Hz meter, load current metering and kW meter. If reactive load is used a power factor meter is desirable.

Important ! When fitting power cables for load testing purposes, ensure cable voltage rating is at least equal to the generator rated voltage. The load cable termination should be placed on top of the winding lead termination and clamped between the two nuts provided, on HC4/5 generators.

Caution ! Check that all wiring terminations for internal or external wiring are secure, and fit all terminal box covers and guards. Failure to secure wiring and/or covers may result in personal injury and/or equipment failure.

4.6 INITIAL START-UP



Warning !

During testing it may be necessary to remove covers to adjust controls exposing 'live' terminals or components. Only personnel qualified to perform electrical service should carry out testing and/or adjustments. Refit all access covers after adjustments are completed.

On completion of generating set assembly and before starting the generating set ensure that all engine manufacturer's pre-running procedures have been completed, and that adjustment of the engine governor is such that the generator will not be subjected to speeds in excess of 125% of the rated speed.

Important ! Overspeeding of the generator during initial setting of the speed governor can result in damage to the generator rotating components.

In addition remove the AVR access cover and turn VOLTS control fully anti-clockwise. Start the generating set and run on no-load at nominal frequency. Slowly turn VOLTS control potentiometer clockwise until rated voltage is reached. Refer to Fig. 5a, 5b, 5c or 5d for control potentiometer location.

Important ! Do not increase the voltage above the rated generator voltage shown on the generator nameplate.

The STABILITY control potentiometer will have been pre-set and should normally not require adjustment, but should this be required, usually identified by oscillation of the voltmeter, refer to Fig. 5a, 5b, 5c or 5d for control potentiometer location and proceed as follows:-

- 1) Run the generating set on no-load and check that speed is correct and stable
- 2) Turn the STABILITY control potentiometer clockwise, then turn slowly anti-clockwise until the generator voltage starts to become unstable.

The correct setting is slightly clockwise from this position (i.e. where the machine volts are stable but close to the unstable region).

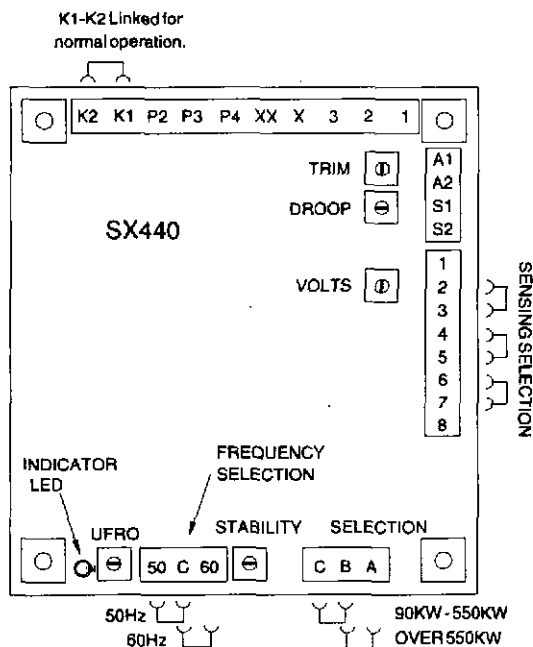


Fig. 5a

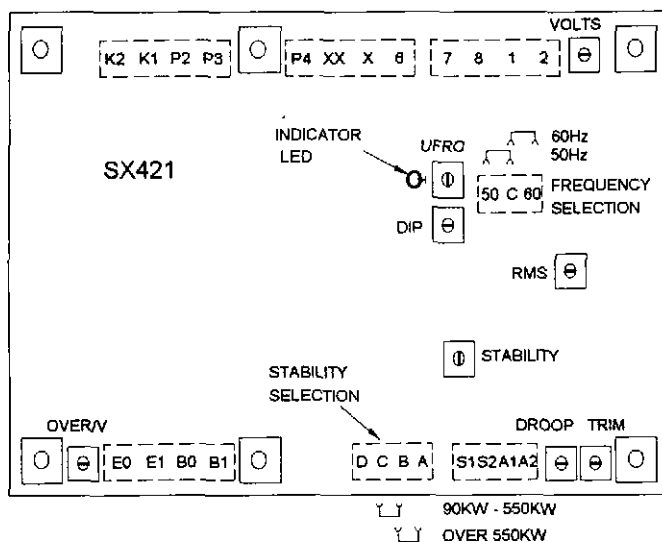


Fig. 5b

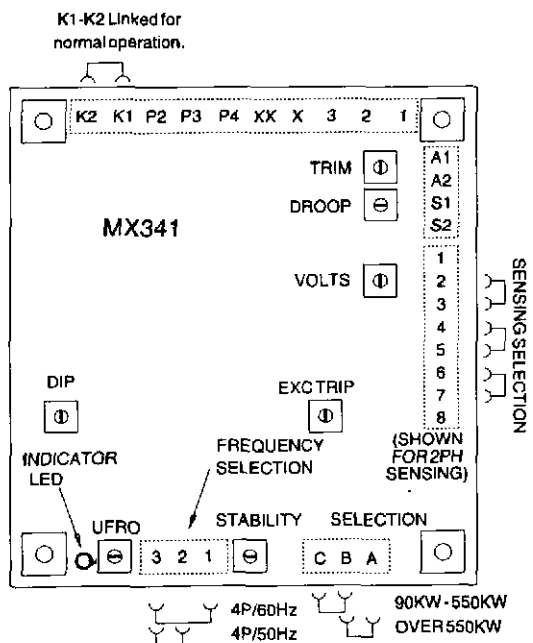


Fig. 5c

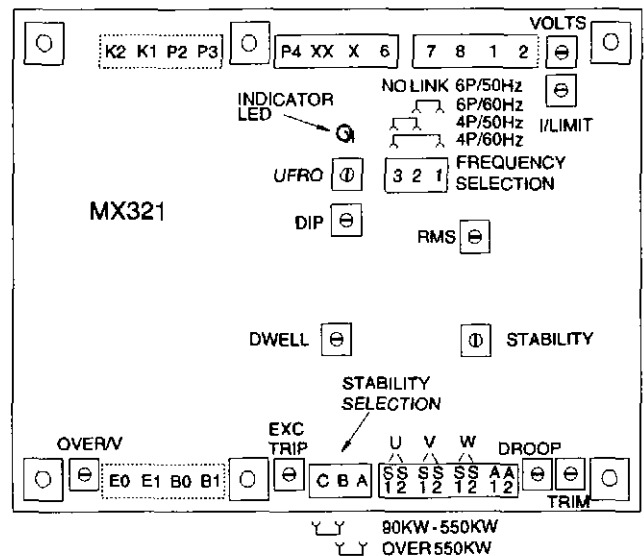


Fig. 5d

4.7 LOAD TESTING



Warning !

During testing it may be necessary to remove covers to adjust controls exposing 'live' terminals or components. Only personnel qualified to perform electrical service should carry out testing and/or adjustments. Refit all access covers after adjustments are completed.

4.7.1 AVR ADJUSTMENTS

Refer to Fig. 5a, 5b, 5c or 5d for control potentiometer locations.

Having adjusted VOLTS and STABILITY during the initial start-up procedure, other AVR control functions should not normally need adjustment. If instability on load is experienced recheck stability setting. Refer to subsection 4.6.

If however, poor voltage regulation on-load or voltage collapse is experienced, refer to the following paragraphs on each function to a) check that the symptoms observed do indicate adjustment is necessary, and b) to make the adjustment correctly.

4.7.1.1 UFRO (Under Frequency Roll Off) (AVR Types SX440, SX421, MX341 and MX321)

The AVR incorporates an underspeed protection circuit which gives a voltage/speed (Hz) characteristic as shown:

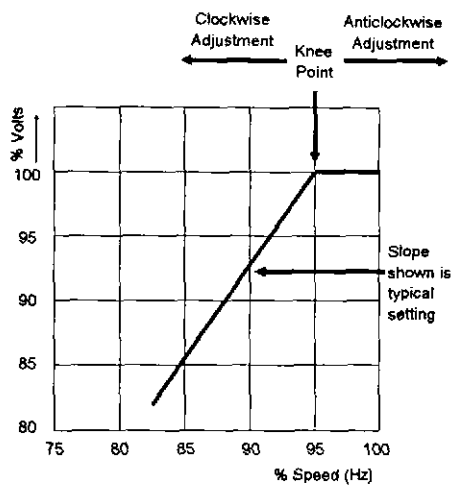


Fig. 6

The UFRO control potentiometer sets the "knee point".

Symptoms of incorrect setting are a) the light emitting diode (LED) indicator, just above the UFRO Control potentiometer, being permanently lit when the generator is on load, and b) poor voltage regulation on load, i.e. operation on the sloping part of the characteristic.

Clockwise adjustment lowers the frequency (speed) setting of the "knee point" and extinguishes the LED. For Optimum setting the LED should illuminate as the frequency falls just below nominal frequency, i.e. 47Hz on a 50Hz generator or 57Hz on a 60Hz generator.

Important ! With AVR Types MX341 and MX321. If the LED is illuminated and no output voltage is present, refer to EXC TRIP and/or OVER/V sections below.

4.7.1.2 EXC TRIP (Excitation Trip) AVR Types MX341 and MX321

An AVR supplied from a permanent magnet generator inherently delivers maximum excitation power on a line to line or line to neutral short circuit. In order to protect the generator windings the AVR incorporates an over excitation circuit which detects high excitation and removes it after a pre-determined time, i.e. 8-10 seconds.

Symptoms of incorrect setting are the generator output collapses on load or small overload, and the LED is permanently illuminated.

The correct setting is 70 volts +/- 5% between terminals X and XX.

4.7.1.3 OVER/V (Over Voltage) AVR Types SX421 and MX321

Over voltage protection circuitry is included in the AVR to remove generator excitation in the event of loss of AVR sensing input.

The MX321 has both internal electronic de-excitation and provision of a signal to operate an external circuit breaker. The SX421 only provides a signal to operate an external breaker, which MUST be fitted if over voltage protection is required.

Incorrect setting would cause the generator output voltage to collapse at no-load or on removal of load, and the LED to be illuminated.

The correct setting is 300 volts 5% across terminals E1, E0.

Clockwise adjustment of the OVER/V control potentiometer will increase the voltage at which the circuit operates.

4.7.1.4 TRANSIENT LOAD SWITCHING ADJUSTMENTS AVR Types SX421, MX341 and MX321

The additional function controls of DIP and DWELL are provided to enable the load acceptance capability of the generating set to be optimised. The overall generating set performance depends upon the engine capability and governor response, in conjunction with the generator characteristics.

It is not possible to adjust the level of voltage dip or recovery independently from the engine performance, and there will always be a 'trade off' between frequency dip and voltage dip.

DIP-AVR Types SX421, MX341 and MX321

The dip function control potentiometer adjusts the slope of the voltage/speed (Hz) characteristic below the knee point as shown below:

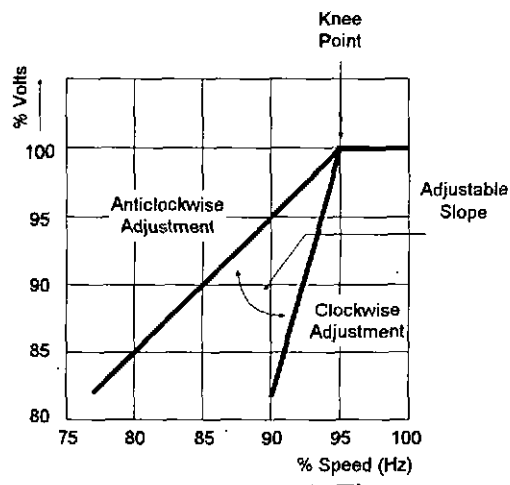


Fig. 7

DWELL-AVR Type MX321

The dwell function introduces a time delay between the recovery of voltage and recovery of speed.

The purpose of the time delay is to reduce the generator kW below the available engine kW during the recovery period, thus allowing an improved speed recovery.

Again this control is only functional below the "knee point", i.e. if the speed stays above the knee point during load switching there is no effect from the DWELL function setting.

Clockwise adjustment gives increased recovery time.

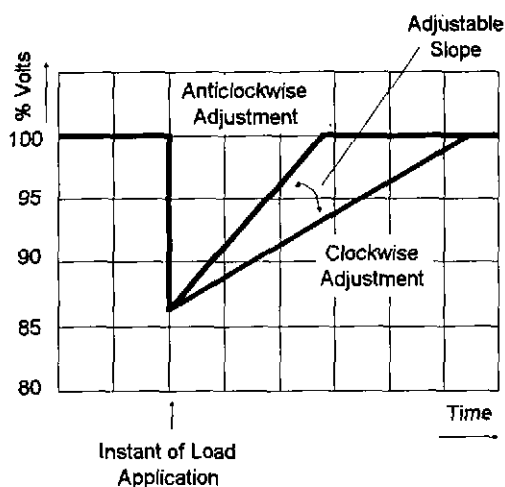


Fig. 8

The graphs shown above are representations only, since it is impossible to show the combined effects of voltage regulator and engine governor performance.



Warning !

Failure to refit covers can result in operator personal injury or death.

4.8 ACCESSORIES

Refer to the "ACCESSORIES" Section of this Manual for setting up procedures related to generator mounted accessories.

If there are accessories for control panel mounting supplied with the generator refer to the specific accessory fitting procedures inserted inside the back cover of this book.

Replace AVR access cover after all adjustments are completed.

SECTION 5

INSTALLATION - PART 2

5.1 GENERAL

The extent of site installation will depend upon the generating set build, e.g. if the generator is installed in a canopied set with integral switchboards and circuit breaker, on site installation will be limited to connecting up the site load to the generating set output terminals. In this case reference should be made to the generating set manufacturer's instruction book and any pertinent local regulations.

If the generator has been installed on a set without switchboard or circuit breaker the following points relating to connecting up the generator should be noted.

5.2 GLANDING

The terminal box is arranged for glanding on the right hand side (or if specifically ordered on the left hand side) viewed from the non drive end. Both panels are removable for drilling/punching to suit glands/or glanding boxes. If single core cables are taken through the terminal box side panel an insulated or non-magnetic gland plate should be fitted.

Incoming cables should be supported from either below or above the box level and at a sufficient distance from the centre line of the generating set so as to avoid a tight radius at the point of entry into the terminal box panel, and allow movement of the generator set on its anti-vibration mountings without excessive stress on the cable.

Before making final connections, test the insulation resistance of the windings. The AVR should be disconnected during this test and RTD leads grounded.

A 500V Megger or similar instrument should be used. Should the insulation resistance be less than $5M\Omega$ the windings must be dried out as detailed in the Service and Maintenance section of this manual.

When making connections to the terminals the incoming cable termination should be placed on top of the winding lead termination(s) and clamped with the nut provided.

Important ! To avoid the possibility of swarf entering any electrical components in the terminal box, panels must be removed for drilling.

5.3 EARTHING

The neutral of the generator is not bonded to the generator frame as supplied from the factory. An earth terminal is provided inside the terminal box adjacent to the main terminals. Should it be required to operate with the neutral earthed a substantial earth conductor (normally equivalent to one half of the section of the line conductors) must be connected between the neutral and the earth terminal inside the terminal box. Additional earth terminals are provided on the generator feet. These should be already bonded to the generating set bedplate by the generating set builder, but will normally be required to be connected to the site earth system.

Caution ! Reference to local electricity regulations or safety rules should be made to ensure correct earthing procedures have been followed.

5.4 PROTECTION

It is the responsibility of the end user and his contractors/sub-contractors to ensure that the overall system protection meets the needs of any inspectorate, local electricity authority or safety rules, pertaining to the site location.

To enable the system designer to achieve the necessary protection and/or discrimination, fault current curves are available on request from the factory, together with generator reactance values to enable fault current calculations to be made.



Warning !

Incorrect installation and/or protective systems can result in personal injury and/or equipment damage. Installers must be qualified to perform electrical installation work.

5.5 COMMISSIONING

Ensure that all external cabling is correct and that all the generating set manufacturer's pre-running checks have been carried out before starting the set.

Generators fitted with air filters should have the filters charged with oil prior to commissioning. Refer to Service Section for charging procedure (subsection 7.3.2).

The generator AVR controls will have been adjusted during the generating set manufacturer's tests and should normally not require further adjustment.

Should malfunction occur during commissioning refer to Service and Maintenance section 'Fault Finding' procedure (subsection 7.4).

SECTION 6

ACCESSORIES

Generator control accessories may be fitted, as an option, in the generator terminal box. If fitted at the time of supply, the wiring diagram(s) in the back of this book shows the connections. When the options are supplied separately, fitting instructions are provided with the accessory.

The following matrix indicates availability of accessories with the differing AVR's.

AVR Model	Parallel-ing Droop or Astatic	Manual Voltage Regulator	VAR/PF Control	Current Limit
SX440	✓	✗	✓	✗
SX421	✓	✗	✓	✗
MX341	✓	✓	✓	✗
MX321	✓	✓	✓	✓

6.1 REMOTE VOLTAGE ADJUST (ALL AVR TYPES)

A remote voltage adjust (hand trimmer) can be fitted.

SX440, SX421 Remove link 1-2 at the auxiliary terminals MX341 and MX321 and connect adjuster to terminals 1 and 2.

6.2 PARALLEL OPERATION

Understanding of the following notes on parallel operation is useful before attempting the fitting or setting of the droop kit accessory. When operating in parallel with other generators or the mains, it is essential that the phase sequence of the incoming generator matches that of the busbar and also that all of the following conditions are met before the circuit breaker of the incoming generator is closed on to the busbar (or operational generator).

- 1) Frequency must match within close limits.
- 2) Voltages must match within close limits.
- 3) Phase angle of voltages must match within close limits.

A variety of techniques, varying from simple synchronising lamps to fully automatic synchronisers, can be used to ensure these conditions are met.

Once connected in parallel a minimum instrumentation level per generator of voltmeter, ammeter, wattmeter (measuring total power per generator), and frequency meter is required in order to adjust the engine and generator controls to share kW in relation to engine ratings and kVAR in relation to generator ratings.

Important ! Failure to meet conditions 1, 2, and 3 when closing the circuit breaker, will generate excessive mechanical and electrical stresses, resulting in equipment damage.

It is important to recognise that

- 1) kW are derived from the engine, and speed governor characteristics determine the kW sharing between sets and
- 2) kVAR are derived from the generator, and excitation control characteristics determine the kVAR sharing.

Reference should be made to the generating set manufacturer's instructions for setting the governor controls.

6.2.1 DROOP

The most commonly used method of kVAR sharing is to create a generator voltage characteristic which falls with decreasing power factor (increasing kVAR). This is achieved with a current transformer (C.T.) which provides a signal dependent on current phase angle (i.e. power factor) to the AVR.

The current transformer has a burden resistor on the AVR board, and a percentage of the burden resistor voltage is summed into the AVR circuit. Increasing droop is obtained by turning the DROOP control potentiometer clockwise.

The diagrams below indicate the effect of droop in a simple two generator system:-

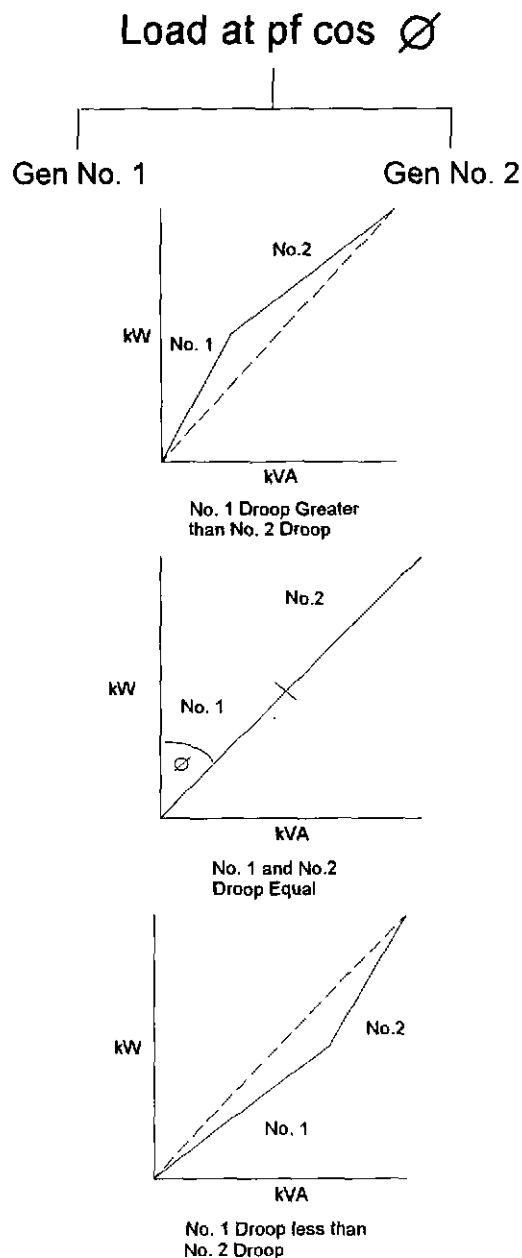


Fig. 9

Generally 5% droop at full load current zero p.f. is sufficient to ensure kVar sharing.

If the droop accessory has been supplied with the generator it will have been set to a nominal 5% droop at full load zero power factor current, and diagrams will be included inside the back cover of this book.

Although nominal droop setting may be factory set it is advisable to go through the setting procedure below.

6.2.1.1 SETTING PROCEDURE

Depending upon available load the following settings should be used - all are based on rated current level.

0.8 P.F. LOAD (at full load current) SET DROOP TO 3%
0 P.F. LOAD (at full load current) SET DROOP TO 5%

Setting the droop with low power factor load is the most accurate.

Run each generator as a single unit at rated frequency or rated frequency + 4% depending upon type of governor and nominal voltage. Apply available load to rated current of the generator. Adjust 'DROOP' control potentiometer to give droop in line with above table. Clockwise rotation increases amount of droop. Refer to Fig. 9a, 9b, 9c or 9d for potentiometer locations.

Note 1)

Reverse polarity of the C.T. will raise the generator voltage with load. The polarities S1-S2 shown on the wiring diagrams are correct for clockwise rotation of the generator looking at the drive end. Reversed rotation requires S1-S2 to be reversed.

Note 2)

The most important aspect is to set all generators equal. The precise level of droop is less critical.

Note 3)

A generator operated as a single unit with a droop circuit set at rated load 0.8 power factor is unable to maintain the usual 0.5% regulation. A shorting switch can be connected across S1-S2 to restore regulation for single running.

Important ! LOSS OF FUEL to an engine can cause its generator to motor with consequent damage to the generator windings. Reverse power relays should be fitted to trip main circuit breaker. LOSS OF EXCITATION to the generator can result in large current oscillations with consequent damage to generator windings. Excitation loss detection equipment should be fitted to trip main circuit breaker.

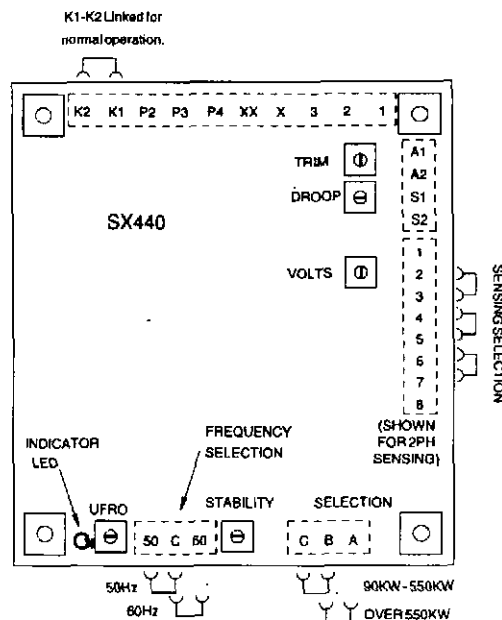


Fig. 9a

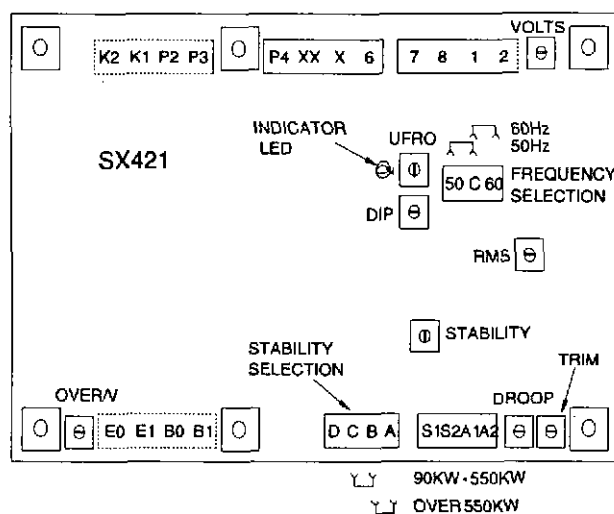


Fig. 9b

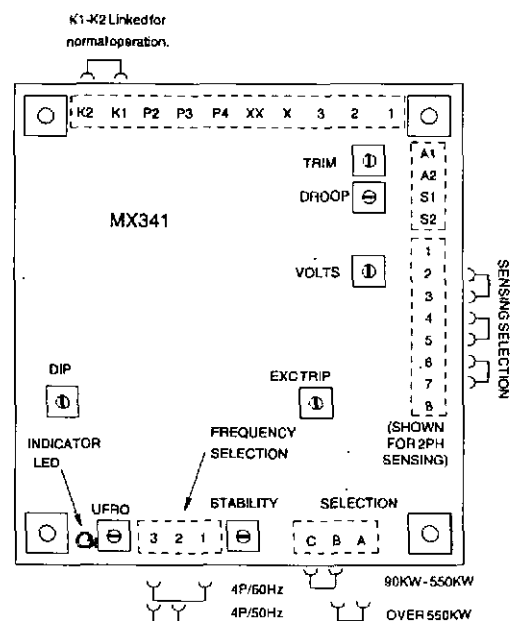


Fig. 9c

6.5.1 SETTING PROCEDURE

Run the generating set on no-load and check that engine governor is set to control nominal speed.

Stop the generating set. Remove the link between terminals K1-K2 at the auxiliary terminal block and connect a 5A switch across the terminals K1-K2.

Turn the "I/LIMIT" control potentiometer fully anticlockwise. Short circuit the stator winding with a bolted 3 phase short at the main terminals. An AC current clip-on ammeter is required to measure the winding lead current.

With the switch across K1-K2 open start the generating set.

Close the switch across K1-K2 and turn the "I/LIMIT" control potentiometer clockwise until required current level is observed on the clip-on ammeter. As soon as correct setting is achieved open the K1-K2 switch.

Should the current collapse during the setting procedure, the internal protective circuits of the AVR will have operated. In this event shut down the set and open the K1-K2 switch. Restart the set and run for 10 minutes with K1-K2 switch open, to cool the generator windings, before attempting to resume the setting procedure.

Important ! Failure to carry out the correct COOLING procedure may cause overheating and consequent damage to the generator windings.

6.6 POWER FACTOR CONTROLLER (PFC3)

This accessory is primarily designed for those generator applications where operation in parallel with the mains supply is required.

Protection against loss of mains voltage or generator excitation is not included in the unit and the system designer must incorporate suitable protection.

The electronic control unit requires both droop and kVAr current transformers. When supplied with the generator, wiring diagrams inside the back cover of this manual show the connections and the additional instruction leaflet provided gives details of setting procedures for the power factor controller (PFC3).

The unit monitors the power factor of the generator current and adjusts excitation to maintain the power factor constant.

This mode can also be used to control the power factor of the mains if the point of current monitoring is moved to the mains cables. Refer to the factory for appropriate details.

It is also possible to operate the unit to control kVAr of the generator if required. Refer to the factory for appropriate details.

SECTION 7

SERVICE AND MAINTENANCE



Warning !

Service and fault finding procedures present hazards which can result in severe personal injury or death. Only personnel qualified to perform electrical and mechanical service should carry out these procedures.

Ensure engine starting circuits are disabled before commencing service or maintenance procedures. Isolate any anti-condensation heater supply.

As part of routine maintenance procedures, periodic attention to winding condition (particularly when generators have been idle for a long period) and bearings is recommended. (Refer to subsections 7.1 and 7.2 respectively).

When generators are fitted with air filters regular inspection and filter maintenance is required. (Refer to subsection 7.3).

7.1 WINDING CONDITION

The condition of the windings can be assessed by measurement of insulation resistance to earth.

The AVR should be disconnected during this test and any resistance temperature detector (RTD) leads grounded. A 500V 'Megger' or similar instrument should be used.

The insulation resistance to earth of all windings should be in excess of 1.0 MΩ.

Should the insulation resistances be less than these values, drying out of the generator windings is essential.

Drying out may be carried out by directing warm air from a fan heater or similar apparatus into the generator air inlets and/or outlets.

Alternatively, the alternator main stator windings may be short circuited with a bolted 3 phase short at the main terminals and the generating set run with the AVR disconnected at terminals X and XX. A d.c. supply is connected to the leads X and XX (X must be connected to the positive of the d.c. supply and XX to the negative of the d.c. supply). The d.c. supply must be variable from 0 - 24 volts and capable of supplying 1.0 amp. An a.c. current clip-on ammeter or similar instrument is required to measure the winding lead current.

Set the d.c. supply voltage to zero. Start the generating set and slowly increase the d.c. voltage to pass current through the main stator winding. The current level should not exceed the rated current of the generator.

Normally 30 minutes is sufficient to dry out windings by this method.

Important ! The short circuit must not be applied with the AVR connected in circuit. Current in excess of the rated generator current will cause damage to the windings.

After drying out, the insulation resistances should be rechecked to verify minimum resistances quoted above are achieved.

On re-testing it is recommended that the main stator insulation resistance is checked as follows:-

Separate the neutral leads			
Ground	V and W	phase and megger	U phase to ground
"	U and W	" " "	V " " "
"	U and V	" " "	W " " "

If the minimum value of 1.0MΩ is not obtained, drying out must be continued and the test repeated.

7.2 BEARINGS

All bearings are sealed for life but are regreaseable if dis-mantled for inspection during a major overhaul. Refer to subsection 7.5.3.2 for regreasing instructions. Periodic checks for overheating or noise during the life of the bearings are recommended. If excessive vibration develops after a period of time this may be due to bearing wear - the bearing should then be examined for damage or loss of grease and replaced if necessary. Refer to subsection 7.5.3.2.

In any event the bearing should be replaced after 40000 hours in service.

Important ! Bearing life is subject to working conditions and environment.

Important ! Long stationary periods in an environment where there is vibration can cause false brinnelling which puts flats on the ball and grooves on the races. Very humid atmospheres or wet conditions can emulsify the grease causing corrosion.

Important ! High axial vibration from the engine or misalignment of the set will stress the bearing.

Important ! Grease nipples may be fitted at customers request. In these cases overgreasing must be avoided as this will lead to excessive bearing temperatures and reduction in bearing life.

Important ! Use only Lithium based grease Mobilux No EP2 or Shell Alvania R3.

7.3 AIR FILTERS

The frequency of filter maintenance will depend upon the severity of the site conditions. Regular inspection of the elements will be required to establish when cleaning is necessary.



Danger !

Removal of filter elements enables access to LIVE parts. Only remove elements with the generator out of service.

7.3.1 CLEANING PROCEDURE

Remove the filter elements from the filter frames. Immerse or flush the element with a suitable degreasing agent until the element is clean.

As an alternative procedure a high pressure water hose with a

flat nozzle can be used. Sweep the water spray back and forth across the element from the clean side (fine mesh side of element) holding the nozzle firmly against the element surface. Cold water may be adequate depending upon type of contamination although hot water is preferable.

The element can be inspected for cleanliness by looking through the filter towards the light.

When thoroughly clean, no cloudy areas will be seen. Dry elements thoroughly before attempting to carry out the recharging procedure.

7.3.2 RECHARGING (CHARGING)

Charging is best done by totally immersing the dry element into a dip tank containing "Filterkote Type K" or commercial lubricating oil SAE 20/50. Oils of higher or lower viscosity are not recommended.

Allow elements to completely drain before refitting the elements into the frames and putting into service.

Important ! Before commencing any fault finding procedures examine all wiring for broken or loose connections.

7.4 FAULT FINDING

Four types of excitation control system, involving four types of AVR, can be fitted to the range of generators covered by this manual. The systems can be identified by a combination of AVR type, where applicable, and the last digit of the generator frame size designation. Refer to the generator nameplate then proceed to the appropriate subsection as indicated below:-

DIGIT	EXCITATION CONTROL	SUBSECTION
4	SX440 AVR	7.4.1
4	SX421 AVR	7.4.2
3	MX341 AVR	7.4.3
3	MX321 AVR	7.4.4

7.4.1 SX440 AVR - FAULT FINDING

No voltage build-up when starting set	1. Check link K1-K2. 2. Check speed. 3. Check residual voltage. Refer to subsection 7.4.5. Follow separate excitation test procedure to check generator and AVR. Refer to subsection 7.5.
Unstable voltage either on no-load or with load	1. Check speed stability. 2. Check stability setting. Refer to subsection 4.6.
High voltage either on no-load or with load	1. Check speed. 2. Check that generator load is not capacitive (leading power factor).
Low voltage no-load	1. Check speed. 2. Check link 1-2 or external hand trimmer leads for continuity.
Low voltage on-load	1. Check speed. 2. Check UFRO setting. Refer to subsection 4.7.1.1. 3. Follow separate excitation procedure to check generator and AVR. Refer to subsection 7.5.

7.4.2 SX421 AVR - FAULT FINDING

No voltage build-up when starting set	1. Check circuit breaker ON. Refer to subsection 6.4.1. 2. Check speed. 3. Check residual voltage. Refer to subsection 7.4.5. 4. Follow separate excitation test procedure to check generator and AVR. Refer to subsection 7.5.
Unstable voltage either on no-load or with load	1. Check speed stability. 2. Check stability setting. Refer to subsection 4.6.
High voltage either on no-load or with load	1. Check speed. 2. Check link 1-2 or external hand trimmer leads for continuity. Check continuity of leads 7-8 and P3-P2 for continuity. 3. Check that generator load is not capacitive (leading power factor).
Low voltage no-load	1. Check speed. 2. Check link 1-2 or external hand trimmer leads for continuity.
Low voltage on-load	1. Check speed. 2. Check UFRO setting. Refer to subsection 4.7.1.1. 3. Follow separate excitation procedure to check generator and AVR. Refer to subsection 7.5.
Excessive voltage/speed dip on load switching	1. Check governor response. 2. Refer to generating set manual. Check 'DIP' setting. Refer to subsection 4.7.1.4

7.4.3 MX341 AVR - FAULT FINDING

No voltage build-up when starting set	1. Check link K1-K2 on auxiliary terminals. 2. Follow Separate Excitation Test Procedure to check machine and AVR. Refer to subsection 7.5.
Loss of voltage when set running	1. First stop and re-start set. If no voltage or voltage collapses after short time, follow Separate Excitation Test Procedure. Refer to subsection 7.5.
Generator voltage high followed by collapse	1. Check sensing leads to AVR. 2. Refer to Separate Excitation Test Procedure. Refer to subsection 7.5.
Voltage unstable, either on no-load or with load	1. Check speed stability. 2. Check "STAB" setting. Refer to Load Testing section for procedure. Refer to subsection 4.6.
Low voltage on-load	1. Check speed. 2. If correct check "UFRO" setting. Refer to subsection 4.7.1.1.
Excessive voltage/speed dip on load switching	1. Check governor response. Refer to generating set manual. Check "DIP" setting. Refer to subsection 4.7.1.4.
Sluggish recovery on load switching	1. Check governor response. Refer to generating set manual.

7.4.4 MX321 AVR - FAULT FINDING

No voltage build-up when starting set	1. Check link K1-K2 on auxiliary terminals. Follow Separate Excitation Test Procedure to check machine and AVR. Refer to subsection 7.5.
Loss of voltage when set running	1. First stop and re-start set. If no voltage or voltage collapses after short time, follow Separate Excitation Test Procedure. Refer to subsection 7.5.
Generator voltage high followed by collapse	1. Check sensing leads to AVR. 2. Refer to Separate Excitation Test Procedure. Refer to subsection 7.5.
Voltage unstable, either on no-load or with load	1. Check speed stability. 2. Check "STAB" setting. Refer to Load Testing section for procedure. Refer to subsection 4.6.
Low voltage on-load	1. Check speed. 2. If correct check "UFRO" setting. Refer to subsection 4.7.1.1.
Excessive voltage/speed dip on load switching	1. Check governor response. Refer to generating set manual. Check "DIP" setting. Refer to subsection 4.7.1.4.
Sluggish recovery on load switching	1. Check governor response. Refer to generating set manual. Check "DWELL" setting. Refer to Load Testing section 4.7.1.4.

7.4.5 RESIDUAL VOLTAGE CHECK

This procedure is applicable to generators with either SX440 or SX421 AVR.

With the generator set stationary remove AVR access cover and leads X and XX from the AVR.

Start the set and measure voltage across AVR terminals P2-P3 on SX440 or SX421 AVR. A minimum level of 5 volts is required at these terminals. If the voltage is less than 5 volts, stop the set. Replace leads X and XX on the AVR terminals. Using a 12 volt d.c. battery as a supply clip leads from battery negative to AVR terminal XX, and from battery positive through a diode to AVR terminal X. See Fig. 10.

Important ! A diode must be used as shown below to ensure the AVR is not damaged.

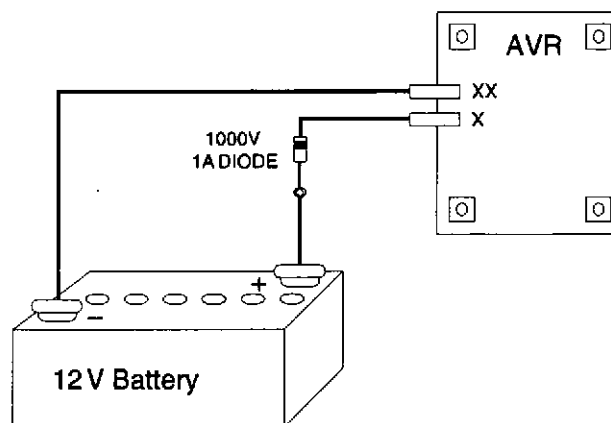


Fig. 10

Important ! If the generating set battery is used for field flashing, the generator main stator neutral must be disconnected from earth.

Restart the set and note output voltage from main stator, which should be approximately nominal voltage, or voltage at AVR terminals P2-P3 on SX440 or SX421 which should be between 170 and 250 volts.

Stop the set and unclip battery supply from terminals X and XX. Restart the set. The generator should now operate normally. If no voltage build-up is obtained it can be assumed a fault exists in either the generator or the AVR circuits. Follow the SEPARATE EXCITATION TEST PROCEDURE to check generator windings, rotating diodes and AVR. Refer to subsection 7.5.

7.5 SEPARATE EXCITATION TEST PROCEDURE

The generator windings, diode assembly and AVR can be checked using this procedure.

- 1) With the generating set stationary remove AVR access cover and leads X and XX from the AVR or transformer control rectifier bridge
- 2) Connect a 60W 240 volt household lamp to AVR terminals X and XX. (Only required for section 7.5.2.1.
- 3) Connect a 0-12 volt, 1.0 Amp d.c. supply to leads X and XX. The positive of the d.c. supply is connected to the lead marked X and the negative to the lead marked XX.

The procedure is simplified by dividing into two sections:

7.5.1 GENERATOR WINDINGS, ROTATING DIODES and PERMANENT MAGNET GENERATOR (PMG)

7.5.2 EXCITATION CONTROL TEST.

7.5.1 GENERATOR WINDINGS, ROTATING DIODES and PERMANENT MAGNET GENERATOR (PMG)

Important ! The resistances quoted apply to standard windings. For generators having windings other than those specified refer to factory for details.
Ensure all disconnected leads are isolated and free from earth.

This procedure is carried out with leads X and XX disconnected at the AVR or transformer control rectifier bridge and using a 12 volt d.c. supply to leads X and XX.

Start the set and run at rated speed.

Measure the voltages at the AVR terminals P2, P3 and P4. These should be balanced and within the following ranges:-

50Hz generators - 170-180 volts
60Hz generators - 200-216 volts

Important ! Incorrect speed setting will give proportional error in voltage output.

Measure the voltages at the main output terminals U, V and W. If voltages are balanced and within 10% of the generator nominal voltage, refer to 7.5.1.1.

If voltages are unbalanced, refer to 7.5.1.2.

Check voltages at AVR terminals 6, 7 and 8. These should be balanced and between 175-240 volts.

If voltages at main terminals are balanced but voltages at 6, 7, and 8 are unbalanced, check continuity of leads 6, 7 and 8. Where an isolation transformer is fitted (MX321 AVR) check transformer windings. If faulty the transformer unit must be replaced.

Should the voltages be unbalanced stop the set, remove the PMG sheet metal cover from the non drive end bracket and disconnect the multipin plug in the PMG output leads. Check leads P2, P3, P4 for continuity. Check the PMG stator resistances between output leads. These should be balanced and within 10% of the value given in the table below:-

FRAME SIZE	PMG STATOR RESISTANCE
4 - 4 Pole	4.64
5/6/7 - 4 Pole	2.56
6/7 - 6 Pole	5.70

If resistances are unbalanced and/or incorrect the PMG stator must be replaced. If the voltages are balanced but low and the PMG rotor winding resistances are correct - the PMG rotor must be replaced.

7.5.1.1 BALANCED MAIN TERMINAL VOLTAGES

If all voltages are balanced within 1% at the main terminals, it can be assumed that all exciter windings, main windings and main rotating diodes are in good order, and the fault is in the AVR control. Refer to subsection 7.5.2 for test procedure.

If voltages are balanced but low, there is a fault in the main excitation windings or rotating diode assembly. Proceed as follows to identify:-

Rectifier Diodes

The diodes on the main rectifier assembly can be checked with a multimeter. The flexible leads connected to each diode should be disconnected at the terminal end, and the forward and reverse resistance checked. A healthy diode will indicate a very high resistance (infinity) in the reverse direction, and a low resistance in the forward direction. A faulty diode will give a full deflection reading in both directions with the test meter on the 10,000 ohms scale, or an infinity reading in both directions. On an electronic digital meter a healthy diode will give a low reading in one direction, and a high reading in the other.

Replacement of Faulty Diodes

The rectifier assembly is split into two plates, the positive and negative, and the main rotor is connected across these plates. Each plate carries 3 diodes, the negative plate carrying negative biased diodes and the positive plate carrying positive biased diodes. Care must be taken to ensure that the correct polarity diodes are fitted to each respective plate. When fitting the diodes to the plates they must be tight enough to ensure a good mechanical and electrical contact, but should not be overtightened. The recommended torque tightening is 4.06 - 4.74Nm (36-42lb in).

Surge Suppressor

The surge suppressor is a metal-oxide varistor connected across the two rectifier plates to prevent high transient reverse voltages in the field winding from damaging the diodes. This device is not polarised and will show a virtually infinite reading in both directions with an ordinary resistance meter. If defective this will be visible by inspection, since it will normally fail to short circuit and show signs of disintegration. Replace if faulty.

Important ! HC6/7 generators are fitted with two suppressors which are a matched pair. If either component is defective both must be replaced.

Main Excitation Windings

If after establishing and correcting any fault on the rectifier assembly the output is still low when separately excited, then the main rotor, exciter stator and exciter rotor winding resistances should be checked (see Resistance Charts), as the fault must be in one of these windings. The exciter stator resistance is measured across leads X and XX. The exciter rotor is connected to six studs which also carry the diode lead terminals. The main rotor winding is connected across the two rectifier plates. The respective leads must be disconnected before taking the readings.

Resistance values should be within 10% of the values given in the tables below:-

4 POLE GENERATORS			
FRAME SIZE	MAIN ROTOR	EXCITER STATOR	EXCITER ROTOR
4-4C	0.91	18	0.136
4-4D	1.04	18	0.136
4-4E	1.17	18	0.136
4-4F	1.35	18	0.136
5-4C	1.55	17	0.174
5-4D	1.77	17	0.174
5-4E	1.96	17	0.174
5-4F	2.16	17	0.174
6-4G	1.44	17	0.158
6-4H	1.54	17	0.158
6-4J	1.73	17	0.158
6-4K	1.95	17	0.158
7-4E	1.25	17	0.096
7-4F	1.40	17	0.096
7-4G	1.64	17	0.096
7-4H	1.75	17	0.096

6 POLE GENERATORS			
FRAME SIZE	MAIN ROTOR	EXCITER STATOR	EXCITER ROTOR
6-6G	1.12	17	0.2
6-6H	1.33	17	0.2
6-6J	1.50	17	0.2
6-6K	1.75	17	0.2
7-6E	2.33	17	0.2
7-6F	2.83	17	0.2
7-6G	3.25	20	0.28

7.5.1.2 UNBALANCED MAIN TERMINAL VOLTAGES

If voltages are unbalanced, this indicates a fault on the main stator winding or main cables to the circuit breaker. NOTE: Faults on the stator winding or cables may also cause noticeable load increase on the engine when excitation is applied. Disconnect the main cables and separate the winding leads U1-U2, (U5-U6), V1-V2, (V5-V6), W1-W2, (W5-W6) to isolate each winding section.

Note:- leads suffixed 5 and 6 apply to 12 wire windings only.

Measure each section resistance - values should be balanced and within 10% of the value given below:-

MAIN STATOR SECTION RESISTANCES				
4 POLE GENERATORS				
SECTION RESISTANCES				
FRAME SIZE	WINDING 11	WINDING 12	WINDING 17	WINDING 07
4-4C	0.0085	N/A	0.0115	N/A
4-4D	0.007	N/A	0.010	N/A
4-4E	0.0055	N/A	0.0075	N/A
4-4F	0.005	N/A	0.0052	N/A
5-4C	0.0068	N/A	0.0105	N/A
5-4D	0.0057	N/A	0.0079	N/A
5-4E	0.0043	N/A	0.0068	N/A
5-4F	0.0037	N/A	0.0049	N/A
6-4G	0.0037	0.0148	N/A	0.011
6-4H	0.0027	0.0108	N/A	0.0072
6-4J	0.0024	0.0096	N/A	0.006
6-4K	0.0019	0.0076	N/A	0.0052
7-4E	N/A	0.0076	N/A	0.0104
7-4F	N/A	0.0056	N/A	0.008
7-4G	N/A	0.0044	N/A	0.0060
7-4H	N/A	0.0036	N/A	0.0044

6 POLE GENERATORS				
SECTION RESISTANCES				
FRAME SIZE	WINDING 11	WINDING 12	WINDING 17	WINDING 07
6-6G	0.0135	0.054	N/A	0.045
6-6H	0.0095	0.0378	N/A	0.0306
6-6J	N/A	0.0294	N/A	0.0207
6-6K	0.0059	0.0234	N/A	0.0165
7-6E	N/A	0.0162	N/A	0.0126
7-6F	N/A	0.0108	N/A	0.0096
7-6G	N/A	0.0084	N/A	0.006

Measure insulation resistance between sections and each section to earth.

Unbalanced or incorrect winding resistances and/or low insulation resistances to earth indicate rewinding of the stator will be necessary. Refer to removal and replacement of component assemblies subsection 7.5.4.

7.5.2 EXCITATION CONTROL TEST

7.5.2.1 AVR STATIC TEST

All types of AVR's can be tested with this procedure:

1. Remove exciter field leads X & XX (F1 & F2) from the AVR terminals X & XX (F1 & F2).
2. Connect a 60W 240V household lamp to AVR terminals X & XX (F1 & F2).
3. Set the AVR VOLTS control potentiometer fully clockwise.
4. Connect a 12V, 1.0A DC supply to the exciter field leads X & XX (F1 & F2) with X (F1) to the positive.
5. Start the generating set and run at rated speed.
6. Check that the generator output voltage is within +/-10% of rated voltage.

Voltages at AVR terminals 7-8 on SX460 AVR or P2-P3 on SX440 or SX421 AVR should be between 170 and 250 volts. If the generator output voltage is correct but the voltage on 7-8 (or P2-P3) is low, check auxiliary leads and connections to main terminals.

Voltages at P2, P3, P4 terminals on MX341 and MX321 should be as given in 7.5.1.

The lamp connected across X-XX should glow. In the case of the SX460, SX440 and SX421 AVRs the lamp should glow continuously. In the case of the MX341 and MX321 AVRs the lamp should glow for approximately 8 secs. and then turn off. Failure to turn off indicates faulty protection circuit and the AVR should be replaced. Turning the "VOLTS" control potentiometer fully anti-clockwise should turn off the lamp with all AVR types.

Should the lamp fail to light the AVR is faulty and should be replaced.

Important ! After this test turn VOLTS control potentiometer fully anti-clockwise.

7.5.3 REMOVAL AND REPLACEMENT OF COMPONENT ASSEMBLIES

METRIC THREADS ARE USED THROUGHOUT

Caution ! When lifting single bearing generators, care is needed to ensure the generator frame is kept in the horizontal plane. The rotor is free to move in the frame and can slide out if not correctly lifted. Incorrect lifting can cause serious personal injury.

7.5.3.1 REMOVAL OF PERMANENT MAGNET GENERATOR (PMG)

1. Remove access cover.
2. Disconnect P2, P3, P4 at the multiway connector inside the access cover.
3. Remove the 4 screws and clamps retaining the stator housing (Frames 4, 5 and 6) or the stator pack (Frame 7).
4. Tap the stator pack or housing out of its spigot.

NOTE:

As the highly magnetic rotor will attract the stator core, care must be taken to avoid a contact which may damage the winding.

5. Remove the exciter rotor securing bolt and stow safely and firmly pull the complete rotor assembly from its location.

N.B.

Keep the rotor clean and avoid contact with metal dust or particles - preferably place in plastic bag.

Important ! The rotor assembly must not be dismantled.

Re-assembly is a reversal of the above procedure having due regard for the notes below:-

1. Ensure rotor magnet assembly is free of metal pieces or particles.
2. Care is needed to avoid winding damage when re-assembling the stator pack, due to strong magnetic attraction.

7.5.3.2 REMOVAL OF BEARINGS

Important ! Position the main rotor so that a full pole face of the main rotor core is at the bottom of the stator bore.

Removal of the bearings may be effected either after the rotor assembly has been removed or more simply by removal of endbracket(s). Refer to subsection 7.5.4.3.

The bearings are a press fit on the shaft and can be removed with standard tooling, i.e. 2 or 3 legged manual or hydraulic bearing pullers.

To remove bearings proceed as follows:

1. Remove 4 screws holding bearing cap.
2. Remove cap.
3. Remove circlip (single bearing generators - non drive end) or wave washer (two bearing generators - drive end).
4. Remove bearing cartridge housing complete with bearing.
5. Remove bearing from cartridge.

If the bearings are to be refitted the bearing(s) and housing(s) must be thoroughly flushed out with clean solvent before re-assembly.

When refitting or replacing bearings they must be refilled with lubricant as follows:-

Recommended lubricant:- Lithium-based Grease Mobilux No. EP2 or Shell Alvania R3.

Temperature range: -30°C. to +120°C.

Quantity:	Frame 4	Drive end	108cm ³
	Frame 4	Non-drive end	108cm ³
	Frame 5	Drive end	108cm ³
	Frame 5	Non-drive end	108cm ³
	Frame 6	Drive end	162cm ³
	Frame 6	Non-drive end	108cm ³
	Frame 7	Drive end	162cm ³
	Frame 7	Non-drive end	162cm ³

One third of the quantity specified above is to be "thumbed" into

the bearing, one third to be placed in the bottom quadrant of the bearing cap cavity and the remaining one third to be placed in the bottom quadrant of the bearing cartridge cavity.

7.5.3.3 MAIN ROTOR ASSEMBLY

SINGLE BEARING MACHINE

NOTE: On single bearing machines, before removal from, or re-assembly to the prime mover, position the rotor, if possible, such that a full pole face is at bottom dead centre.

1. Remove all access covers and terminal box lid.
2. Disconnect exciter leads X and XX and PMG leads P2-P3-P4 at the auxiliary terminals inside the terminal box.
3. Ensure that these leads are free to come away with the non drive end bracket when removed.
4. Remove the 8 bolts holding the drive end adaptor to the frame.
5. With a rope sling around drive end adaptor, tap adaptor out of its spigot location; guide over fan and remove.
6. Remove the 4 bolts retaining the non drive end bearing cartridge in the non drive end endbracket (outer 4 bolts).
7. Remove the 8 bolts securing the non drive end bracket to the frame.
8. Supporting the non drive end bracket with a hoist, insert two M10 bolts in the two holes provided for 'jacking' purposes (on the end bracket horizontal centre line). Screw in the bolts until the end bracket spigot is clear of the locating recess, lower the whole assembly until the main rotor is resting in the stator bore. Still supporting the non drive end bracket, tap the bracket off the non drive end bearing cartridge (taking care that the exciter stator does not foul exciter rotor windings) and remove.
9. To withdraw the rotor from the stator the rotor must be supported by a rope at the drive end and eased out of the stator core until half the main rotor is protruding out of the stator. At this point it is safe to release the weight from the rope sling.
10. Tightly bind a rope sling around the rotor core, and supporting the non drive end of the rotor, guide it clear of the stator.



Warning !

The rope sling may not be at the centre of gravity of the rotor and guidance at the ends of the rotor is essential. As the rotor is fully withdrawn from the stator core, THE FULL WEIGHT OF THE ROTOR GIVEN IN THE TABLE BELOW MUST BE SUPPORTED BY THE CRANE AND SLING. If the rotor core is allowed to drop more than a few millimetres at this point, it will make contact with the stator windings and may damage them.

MINIMUM ROTOR ASSEMBLY WEIGHTS

FRAME	WEIGHT
HC4	473kg.
HC5	681kg.
HC6 - 4 pole	1093kg.
HC6 - 6 pole	1050kg.
HC7 - 4 pole	1592kg.
HC7 - 6 pole	1790kg.

Re-assembly is a reversal of the above procedure.

Before assembly of a single bearing rotor into stator housing check that the drive discs are not damaged or cracked or showing any other signs of fatigue. Also check that holes in the discs for drive fixing screws are not elongated.

Damaged components must be replaced.

When refitting discs ensure that the number and thickness of discs, and the tightening torque of hub bolts is in accordance with the table below.

Refer to engine manual for torque setting of disc to flywheel bolts.

FRAME	NO. OF DISCS	SINGLE DISC THICKNESS	TOTAL THICKNESS	TIGHTENING TORQUE
4	4	1,2	4,8	48kgm
				479Nm
5	4	1,2	4,8	48kgm
				479Nm
6	6	1,2	7,2	84kgm
				822Nm
7	6	1,2	7,2	84kgm
				822Nm

TWO BEARING MACHINES

NOTE:

Position rotor, if possible, such that a full pole face is at bottom dead centre.

The procedure for removal of a two bearing rotor is similar to that outlined for single bearing machines with the exception of Steps 4 and 5 relating to the drive end adaptor.

For removal of this item proceed as follows:-

1. Remove the 8 bolts holding drive end adaptor to frame and 4 bolts retaining bearing cartridge in drive end bracket (outer 4 bolts).
2. With rope sling around the shaft extension, supporting the rotor weight tap the drive end bracket spigot out of its locating recess and lower rotor assembly to rest in the stator bore.
3. Take the weight of the drive end bracket on the sling and tap the bracket off the drive end bearing cartridge, guide over the fan and remove.

Re-assembly is a reversal of the above procedure.

7.6 RETURNING TO SERVICE

After rectification of any faults found, remove all test connections and reconnect all control system leads.

Restart the set and adjust VOLTS control potentiometer on AVR by slowly turning clockwise until rated voltage is obtained.

Refit all terminal box covers/access covers and reconnect heater supply.

Caution ! Failure to refit all guards, access covers and terminal box covers can result in personal injury or death.

SECTION 8

SPARES AND AFTER SALES SERVICE

8.1 RECOMMENDED SPARES

Service parts are conveniently packaged for easy identification. Genuine parts may be recognised by the Nupart name.

We recommend the following for Service and Maintenance. In critical applications a set of these service spares should be held with the generator.

- | | | |
|----|--|----------------------|
| 1. | Diode Set (6 diodes with Surge Suppressors) | |
| | HC4/5 | RSK5001 |
| | HC6/7 | RSK6001 |
| 2. | SX440 AVR | E000-24030 |
| | SX421 AVR | E000-24210 |
| | MX321 AVR | E000-23210 |
| | MX341 AVR | E000-23410 |
| 3. | Bearings | |
| | Drive End | Non-Drive end |
| | Frame 4 | 051-01025 051-01036 |
| | Frame 5 | 051-01035 051-01036 |
| | Frame 6 | 051-01034 051-01025 |
| | Frame 7 | 051-01040 051-01057 |

When ordering parts the machine Serial Number and type should be quoted, together with the part description. The Serial Number is stamped on the nameplate and on the drive end of the shaft.

Orders and enquiries for parts should be addressed to:

Newage International Ltd.,
Nupart Department,
P O Box 17, Barnack Road,
Stamford,
Lincolnshire
PE9 2NB
England.

Telephone: 44 (0) 1780 484000 Telex: 32268 Cables Newage
Stamford
Fax: 44 (0) 1780 66074

or any of our subsidiary companies listed on the back cover.

8.2 AFTER SALES SERVICE

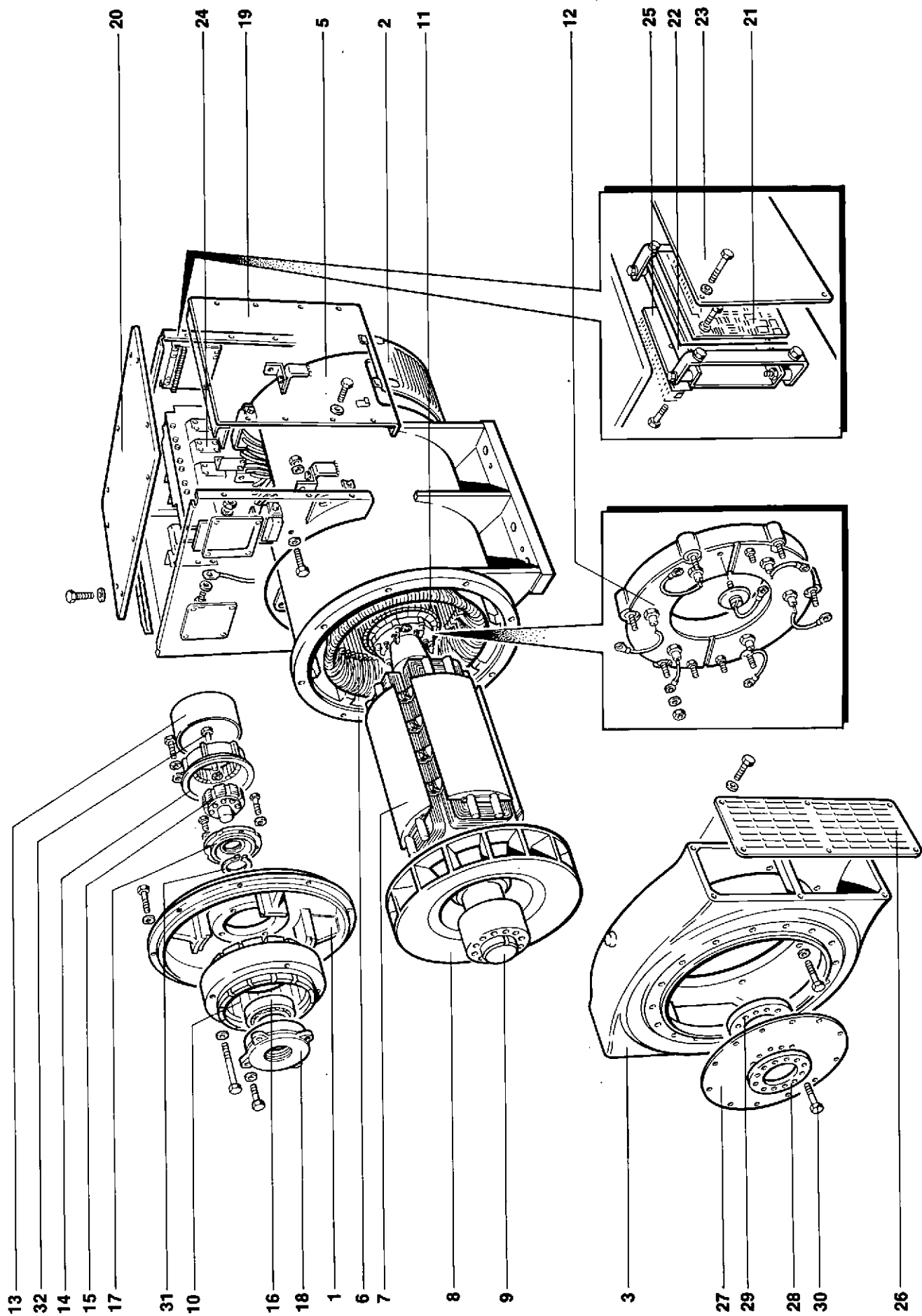
A full technical advice and on-site service facility is available from our Service Department at Stamford or through our subsidiary Companies. A repair facility is also available at our Stamford Works.

PARTS LIST
TYPICAL HC SINGLE BEARING GENERATOR

Plate Ref.	Description	Plate Ref.	Description
1	N.D.E. Bracket	25	Auxiliary Terminal Board
2	N.D.E. Cover	26	D.E. Cover
3	D.E. Bracket	27	Coupling Disc
4	Main Rotor Key (Not illustrated)	28	Coupling Pressure Plate
5	Main Frame	29	Coupling Spacer
6	Main Stator/Bar Assembly	30	Coupling Bolt
7	Main Rotor Assembly	31	Circlip N.D.E.
8	Fan	32	P.M.G. Rotor Stud
9	Shaft		
10	Exciter Stator		
11	Exciter Rotor		
12	Rotating Rectifier Assembly		
13	PMG Cover		
14	PMG Stator Assembly		
15	PMG Rotor Assembly		
16	N.D.E. Bearing		
17	N.D.E. Bearing Cap		
18	N.D.E. Bearing Cartridge		
19	Terminal Box Side Panel		
20	Terminal Box Lid		
21	AVR (Automatic Voltage Regulator)		
22	AVR Mounting Bracket		
23	AVR Cover Plate		
24	Main Terminal Board		

N.D.E.	Non Drive End
D.E.	Drive End
PMG	Permanent Magnet Generator
AVR	Automatic Voltage Regulator

Fig. 11.
TYPICAL HC SINGLE BEARING GENERATOR



PARTS LIST
TYPICAL HC TWO BEARING GENERATOR

Plate Ref.	Description	Plate Ref.	Description
1	N.D.E. Bracket	25	Main Terminal Board
2	N.D.E. Cover	26	Auxiliary Terminal Board
3	D.E. Bracket	27	Bearing D.E.
4	Main Rotor Key (Not illustrated)	28	Wave Washer (Bearing D.E.)
5	Main Frame	29	Bearing Cartridge D.E.
6	Main Stator/Bar Assembly	30	Bearing Cap Outer D.E.
7	Main Rotor Assembly	31	Screen D.E.
8	Fan	32	Drip Proof Louvres (Fitted as option)
9	Shaft	33	Gasket (Fitted as option)
10	Exciter Stator	34	Lifting Lug
11	Exciter Rotor		
12	Rotating Rectifier Assembly		
13	PMG Cover		
14	P.M.G. Rotor Stud		
15	PMG Stator Assembly		
16	PMG Rotor Assembly		
17	N.D.E. Bearing		
18	N.D.E. Bearing Cap		
19	N.D.E. Bearing Cartridge		
20	Terminal Box Side Panel		
21	Terminal Box Lid		
22	AVR (Automatic Voltage Regulator)		
23	AVR Mounting Bracket		
24	AVR Cover Plate		

N.D.E. Non Drive End
D.E. Drive End
PMG Permanent Magnet Generator
AVR Automatic Voltage Regulator

Fig. 12.
TYPICAL HC TWO BEARING GENERATOR

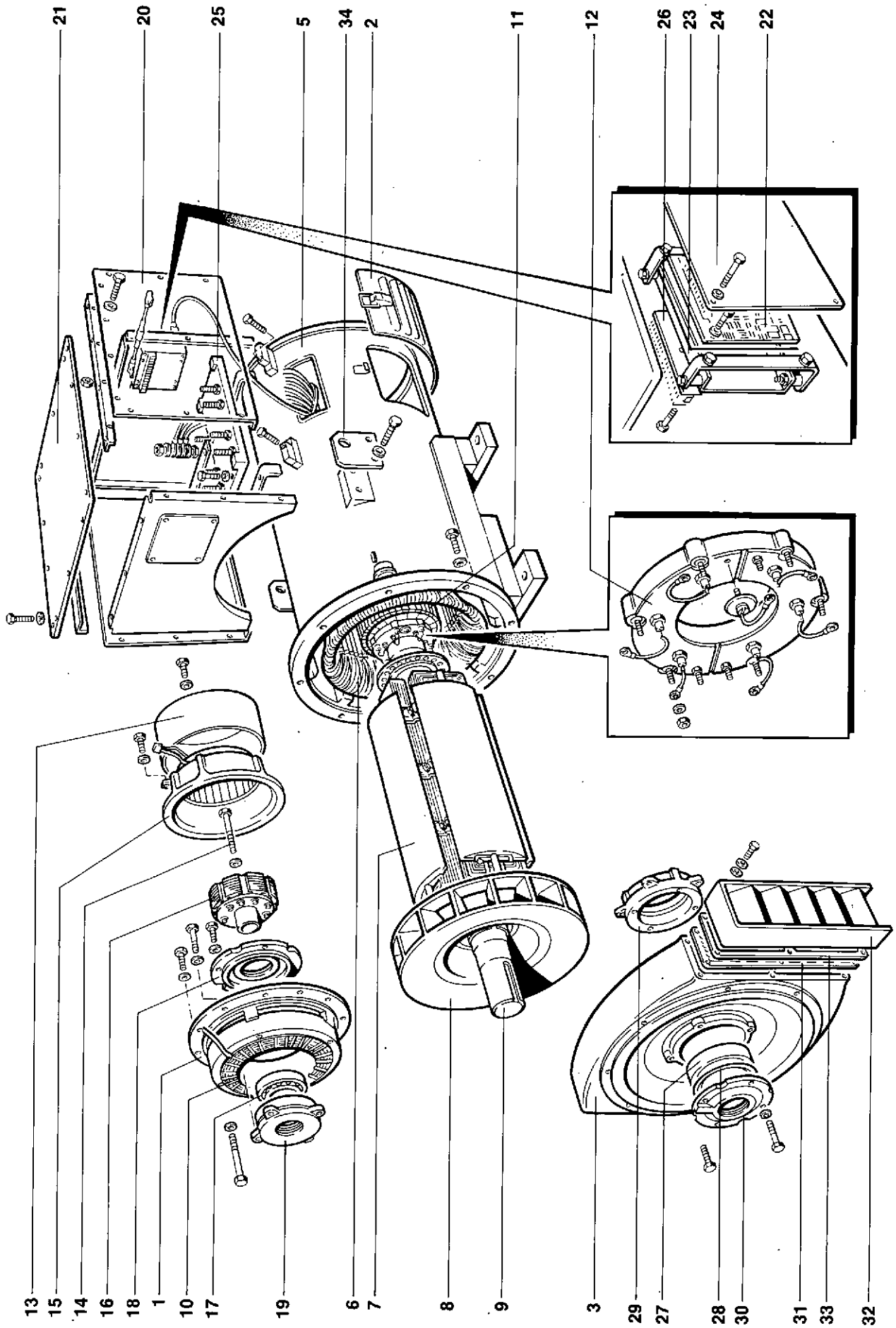


Fig. 13.
ROTATING RECTIFIER ASSEMBLY

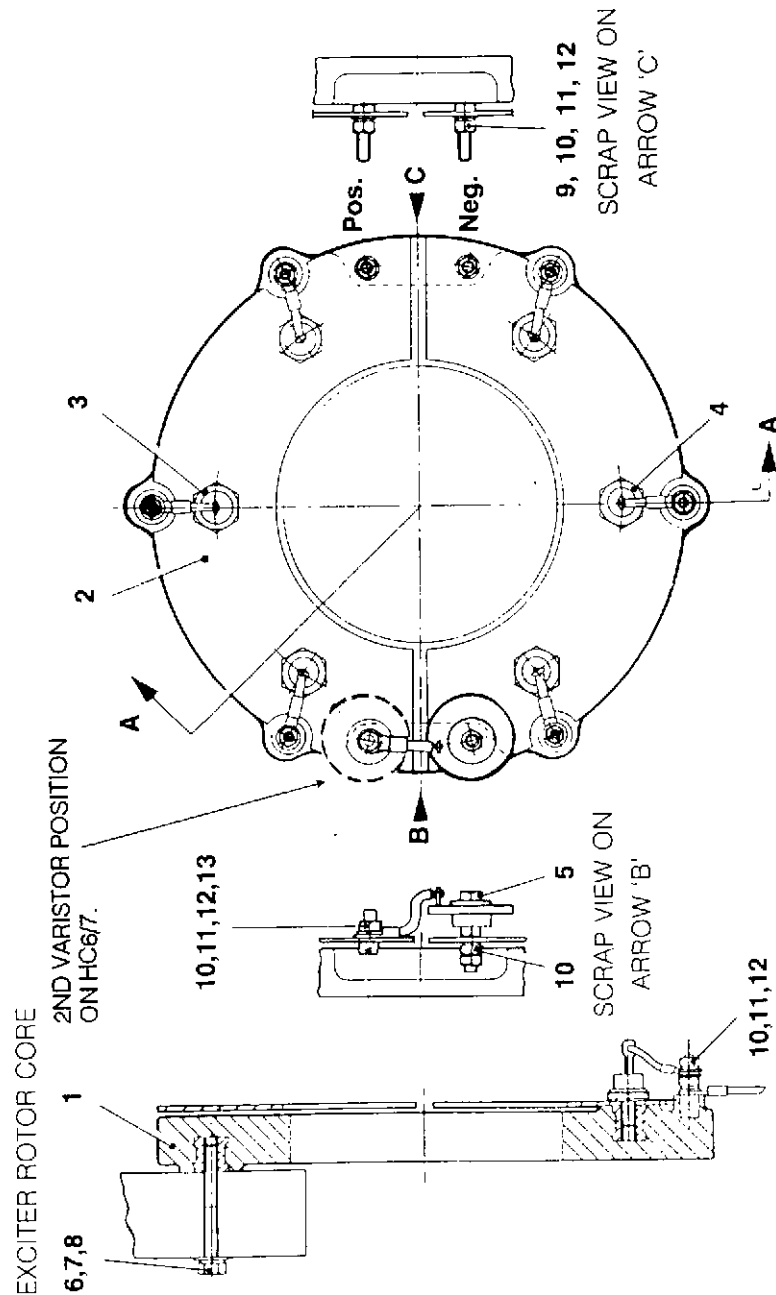


Plate Ref.	Description	Quantity
1	Moulded Base	1
2	Rectifier F in	2
3	Diode (Forward)	3
4	Diode (Reverse)	3
5	Varistor	1
6	Hexagonal Head Bolt M6 X 65	4
7	Plain Washer M6	4
8	S.C. Lock Washer M6	4
9	Hexagonal Head Screw M5 X 20	2
10	Hexagonal Nut M5	17
11	Plain Washer M5	21
12	S.C. Lockwasher M5	15
13	CH. HD. Screw	1

HC4/5 are fitted with one Varistor

HC4/5 are fitted with one Varistor
HC6/7 are fitted with two Varistors (Matched Pair)

1. A rectifier assembly **must** comprise diodes from one manufacturer only.
2. 4 Bolts (Plate ref 6) holding the moulding to the exciter core should be given an application of Loctite 241.
3. When fitting replacement diodes the undersides should if possible be smeared with Midland Silicone Heat Sink compound Type MS2623 or similar (available from our Nupart Dept.) **IMPORTANT** This compound **MUST NOT** be applied to the diode stud threads.
4. Diode tightening torque: 4-4.8N-m (36-42lbf-in).

This manual is available in the following languages on request:
English, French, German, Italian and Spanish.

Denne manual er til rådighed på følgende sprog: engelsk, fransk, tysk, italiensk og spansk.

Denne håndboken er tilgjengelig på de følgende språkene: engelsk, fransk, tysk, italiensk og spansk.

Sur simple demande, ce manuel vous sera fourni dans l'une des langues suivantes: anglais, français, allemand, italien, espagnol.

Dieses Handbuch ist auf Anfrage in den folgenden Sprachen erhältlich: Englisch, Französisch, Deutsch, Italienisch, Spanisch.

Deze handleiding is op verzoek leverbaar in de volgende talen: Engels, Frans, Duits, Italiaans, Spaans.

Este manual pode também ser obtido nas seguintes línguas: inglês, francês, alemão, italiano e espanhol.

Tämä käsikirja on saatavissa pyynnöstä seuraavilla kielillä: Englanti, ranska, saksa, italia, espanja.

Il presente manuale è disponibile, su richiesta, nelle seguenti lingue: inglese, francese, tedesco, italiano e spagnolo.

Este manual también puede solicitarse en los siguientes idiomas: inglés, francés, alemán, italiano e español.

Αυτό το εγχειρίδιο οδηγιών χρήσεως διατίθεται στις ακόλουθες γλώσσες κατόπιν αιτήσεων: Αγγλικά, Γαλλικά, Γερμανικά, Ιταλικά, Ισπανικά.

A.C. GENERATOR WARRANTY

WARRANTY PERIOD:

A.C. Generators: In respect of a.c. generators the warranty period is

- (i) twelve months after the goods have been notified as ready for despatch by us
- OR (ii) provided that the Dealer tests the goods before despatch, twelve months from the date the goods are despatched by the Dealer or eighteen months after the goods have been notified as ready for despatch by us (whichever is the shorter).

DEFECTS AFTER DELIVERY:

We will make good by repair, or, at our option, by the supply of a replacement any fault which, under proper use, appears in any goods manufactured by us within the warranty period and is found on examination by us to be solely due to defective material and workmanship provided that

- (a) We receive notice in writing of the alleged defect within 30 days of its discovery and the defective part is promptly returned, carriage paid, with all identification numbers and marks intact to the Dealer who supplied the goods or, if required by us, to our Works.
- (b) We shall be under no liability for defects in any goods which:
 - (i) have not been stored, installed, used and maintained properly and carefully in accordance with our current recommendations; or
 - (ii) have been used after the defect has been, or ought reasonably to have been discovered; or
 - (iii) have been repaired, adjusted or altered without prior authorisation or by any person except ourselves;

nor in any second-hand goods, proprietary articles or goods not of our own manufacture, although supplied by us, such articles and goods being covered by the warranty (if any) given by the separate manufacturers.

- (c) Our liability shall be fully discharged by either repair or replacement as above, and in any event our liability shall not exceed the current list price of the defective goods.
- (d) Our liability under this clause shall be in lieu of any warranty or condition implied by law as to the quality or fitness for any particular purpose of the goods, and save as expressly provided in this clause we shall not be under any liability, whether in contract, tort or otherwise, in respect of any defect in goods delivered or for any damage or loss (whether direct or consequential resulting from such defect or from any work done in connection therewith).
- (e) Any claim under this clause must contain full particulars of the alleged defect, the description of the goods, the serial number (as shown on the manufacturers identification plate) or, for spares, the order reference, the date of purchase and the name and address of the vendor.
- (f) Our judgement in all cases of claims shall be final and conclusive and the claimant shall accept our decision on all questions as to defects and the exchange of a part or parts. The repaired or replacement part will be delivered by us free of charge ex-Works. We shall not be liable for any expense which may be incurred in removing or replacing any part sent to us for inspection or in fitting any replacement supplied by us.

MACHINE SERIAL NUMBER

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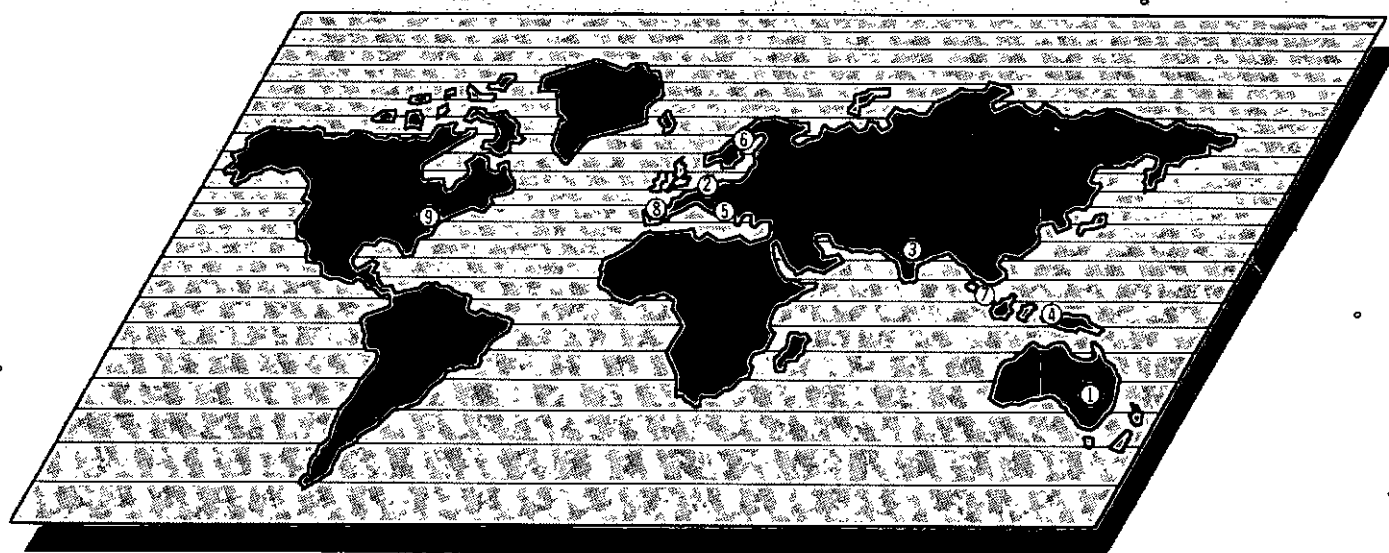
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