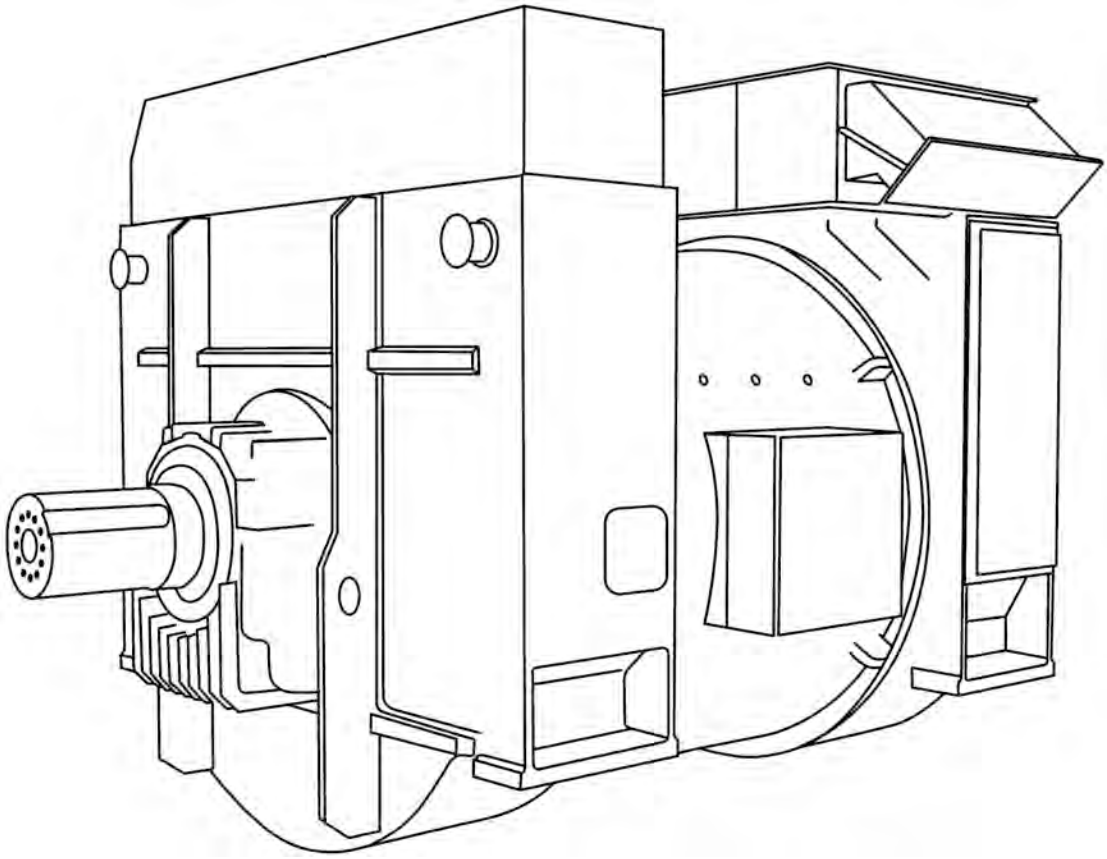
DSG/DIG Generators

Installation, Service and Maintenance



English
Original Instructions

04-2014

ING-WI-0395/A046V044 (Issue 3)

Table of Contents

1 Foreword

1.1 General

This manual forms part of the items supplied and is an important technical guide to the intended use of the generator. It represents an essential source of information for the user and also for managers for the prevention of injuries and damage to the generator.

The generator was manufactured by:

Cummins GeneratorTechnologies GmbH & Co. KG

Bunsenstr. 17

D - 85053 Ingolstadt, Germany

Tel. no.: 0049-(0)841 / 792-0

Fax no.: 0049-(0)841 / 792 250

NOTICE
On the pages that follow the complete name of the company is replaced with the term "manufacturer".

The generator is the intellectual property of Cummins Generator Technologies. The general safety regulations, the specific regulations for the place of use and the precautions described in this document must be followed at all times.

1.2 The Manual

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

Before operating the alternator, 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 alternator. Make sure that the manual is available to all users throughout the life of the alternator.

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 It may be superseded due to our policy of continuous improvement.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.

1.3 Legal

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 emphasize 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/Generator 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 generator 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 Grounding

⚠ WARNING

High Voltage
Will shock, burn or can cause death.
Work on electrical systems must be done by an electrician or instructed persons under the management and supervision of an electrician wearing suitable PPE.

Parts of the machine and system on which inspections, servicing and repair work are done must, if so stipulated, be electrically isolated.

1. Test the electrically isolated parts for electrical isolation using a suitable voltage tester, then ground and short-circuit and also isolate neighboring live parts.

2. In case of work on high-voltage assemblies, after electrically isolating connect the line cable to ground and short-circuit the components, e.g. capacitors, using a grounding bar.

The generator is permanently grounded.

2.6 Noise

⚠ CAUTION

Alternators in operation emit noise. Exposure to noise can cause hearing damage. Wear appropriate ear protection at all times. Maximum A-weighted noise emissions may reach 110 dB(A). Contact the supplier for application-specific details.

2.7 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 alternator 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.

2.7.1 Work on Electrical Equipment

⚠ DANGER

Hazardous voltage.
Will shock burn or cause death.
The colors of electrical cables and connections comply with the applicable regulations (VDI). If the operating organization has agreed different colors with the manufacturer, these colors apply.
Before working on electrical equipment, the entire system must be electrically isolated and grounded.

⚠ DANGER

Hazardous voltage.
Will shock burn or cause death.
Faulty electrical components can be live and as a result life-threatening. Any defects found in electrical systems, assemblies, equipment must be rectified without delay. If there is an acute risk until rectified, the system or the assembly must not be used in the defective state.

⚠ WARNING

Magnetic field.
Generator has a powerful magnetic field that can interfere with implanted medical devices such as heart pacemakers.
Do not approach the generator if you have an implanted medical device.

Work on electrical cables is to be done in accordance with local or national electrical safety regulations applicable for the voltage as well as the safety regulations applicable on the site.

Each generator is built in accordance with the applicable regulations. The electrical control system is compliant with the VDE regulations, VBG 4 and EN 60204.

- Only use approved protective equipment
- In case of malfunctions in the supply of electrical power, immediately shut down the unit (exception: if used as an emergency power generator).

2.8 Lock Out/Tag Out

⚠ WARNING

Risk of serious injury or death
Alternators can retain mechanical and electrical energy
Isolate the alternator from all sources of mechanical and electrical energy before starting service or maintenance work. Adopt a suitable lock-out/tag out process.

2.9 Lifting

⚠ WARNING

Improper lifting can cause serious injuries to persons or can cause death.
Do not use the alternator lifting points to lift the complete generator set (alternator coupled to motive power source)
The lifting points provided are designed for lifting the alternator only.
Do not remove the lifting label attached to one of the lifting points.

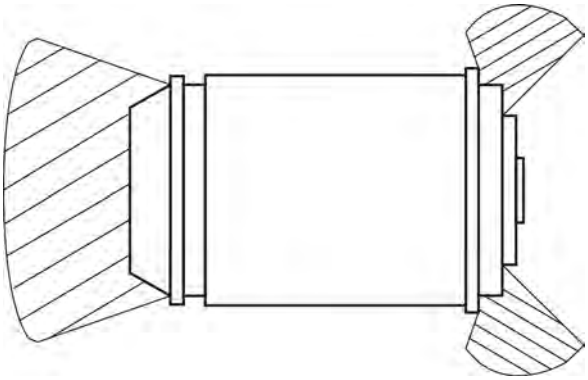
2.10 Alternator Operating Areas

⚠ WARNING

Flying debris

In the event of catastrophic failure, debris may be ejected from the alternator air inlet/outlet and may cause severe injury or death.

Avoid access to these areas while the alternator is operating.



Always wear suitable PPE when working in hatched areas or directly in-line with any air inlet/outlet.

Make sure this consideration is captured in your risk assessment.

2.11 Safety Information Signs

Safety information signs are provided on the equipment to indicate hazards and emphasize instructions. Become familiar with the signs and the meaning before operating the equipment. To avoid injury, always take the necessary precautions. Sample signs are shown in **Table 1 on page 6**.

TABLE 1. SAFETY SIGN EXAMPLES

				
Warning	Electrical Hazard	Rotating Parts	Mandatory (Example: Lifting)	Protective Conducter

2.11.1 Hazard Warning Labels

⚠ WARNING

Hazard warning labels show the type and source of potential hazards. Observe the safety labels to avoid risk of injury. The generator set manufacturer is responsible for fitting the self-adhesive hazard warning labels supplied with the alternator. Labels must be fitted at the locations shown on the back of the label sheet supplied with the alternator manual.

Replace labels that are missing, damaged or painted over.

2.12 Oils and Grease

⚠ CAUTION
Hazardous Substances ***Misuse of oils, grease or other chemical substances can lead to serious injury*** ***When handling oils, greases and other chemical substances pay attention to the safety regulations, appropriate PPE and environmental regulations that apply.***

2.12.1 Solvents and Substances Containing Solvents

NOTICE
Pay attention to the safety regulations on handling solvents. Ask the manufacturer of the solvent for safety data sheets and first aid measures in case of emergency! The safety data sheets must be available before using the solvent.

On handling solvents or substances containing solvents always wear protective equipment such as safety glasses, safety shoes, hard hat, protective gloves and suitable protective clothing to protect the skin. Always use barrier cream.

Only use solvents in well-ventilated areas. To keep the exposure and hazards as low as possible, you should:

1. Seal solvent containers immediately after use
2. Ensure that solvent and its vapors are not inhaled.

   Solvents are combustible and flammable! A flame is not necessarily required for ignition, ignition can also be triggered by hot objects at temperatures above the ignition temperature of the solvent, or by electrical sparks (pay attention to electrostatic charging).
3. Do not bring organic solvents into contact with oxidizing agents (risk of explosion).

4. Ensure adequate ventilation!

   Solvent vapors are heavier than air and can collect on the ground or in hollows. There is a risk of asphyxiation and explosion!

First aid:

After inhaling larger quantities: copious fresh air, seek medical attention.

After contact with the skin: rinse thoroughly with water.

In case of contact with the eyes: rinse using eye bath and seek medical attention from an ophthalmologist.

After swallowing: Seek medical attention

2.13 General Guidance

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

2.13.1 General Safety Instructions

- Only use the generator in correct working condition as well as in the manner intended, with due consideration for safety and hazards while following the documentation and the local health and safety regulations.
- Correct any malfunctions without delay that may affect safety or have them rectified by our service organization.
- Always store this documentation with the generator.
- Regularly check that personal work with due consideration for safety and hazards and follow the documentation.
- Use appropriate personal protective equipment at all times
- Follow all information on safety and hazards on the generator and maintain in legible condition.
- On the occurrence of safety-related changes on the generator or in its operating behavior, immediately shut down the generator and correct malfunction without delay.
- Do not make any changes, additions or modifications to the generator. This statement also applies to installation and the settings for safety features.
- Do not circumvent or bypass any safety features. Before opening doors or covers for which the use of a tool is required, the generator must be shut down, electrically isolated and grounded.
- Service parts must comply with the technical requirements defined by the manufacturer. This aspect is only ensured with genuine branded service parts. On the use of other service parts, liability by the manufacturer is excluded.
- Do not make any changes to the program (software) in the programmable control system. Changes to the program must only be made by appropriately trained personnel.
- Comply with stipulated intervals or intervals defined in the documentation for regular inspections and servicing work.
- Use only appropriate tools for undertaking maintenance measures.

- Pay attention to fire alarm and firefighting procedures; pay attention to location and operation of fire extinguishing systems (see **Section 9.8 on page 74**).
- Only allow trainees, apprentices or personnel under instruction or personnel undergoing general training to work on the generator under the constant supervision of an experienced person.
- Only task trained, experienced persons with the attachment of loads and signaling to crane drivers. The person providing the signals must be visible for the operator.
- During installation work above head height, climbing aids and working platforms intended for this purpose with appropriate safety features must be used. Do not use generator components and attachments as climbing aids! During servicing work at heights, wear fall arresting equipment.
- Keep all grips, steps, railing, pedestals, platforms, ladders free of debris and dirt.
- The generator electrical equipment is to be checked regularly; loose connections or burnt, damaged cables must be rectified immediately.
- If work is necessary on electrically live parts, involve a second person who can provide immediate assistance in case of an emergency. Cordon off working area with a red-white safety chain and a warning sign. Only use electrically insulated tools. Follow the local safety regulations, e.g. VDE 0105

2.13.1.1 Safety Instructions for Normal Operation

- Refrain from all unsafe forms of working.
- Only operate the generator if all protective devices and safety-related devices, e.g. detachable protective devices, emergency stop devices, are fitted and functional.
- Inspect daily the generator for externally visible damage and defects. Immediately report any changes that have occurred (including changes in operating behavior) and immediately shut down and secure the generator.
- In case of malfunctions, immediately shut down and secure generator. Correct malfunction without delay.
- Follow the documented procedures for switching on and switching off.
- Before switching on/placing in operation the unit, make sure no-one will be placed at risk by the starting machine.

2.13.1.2 Safety Instructions for Special Tasks

Observe adjustment, servicing and inspection activities and intervals stipulated in the documentation including information on the replacement of parts/assemblies. Service and maintenance procedures and tasks should only be carried out by experienced and qualified engineers, who are familiar with the procedures and equipment.

- Before starting special tasks and maintenance work, inform the operators. Nominate supervisor.
- During all work related to the operation, the adjustment for production, the conversion or the adjustment of the generator and its safety-related features as well as inspection, servicing and repair, pay attention to switching on and switching off procedures as per the documentation and instructions on maintenance work.
- Mark and cordon off maintenance area as far as necessary.
- When the generator is completely switched off for servicing and repair work, it must be secured against unintended switching back on using Lock out / Tag out:
    - Cordon off switch panel and attach a lock and tag to the main switch.

- Make sure individual parts, as well as larger assemblies, are fastened to lifting equipment and secured on replacement so that they can cause no harm. Only use suitable lifting equipment in correct working order with adequate load bearing capacity. Do not stand or work under suspended loads.
- At the start of servicing / repair, clean generator of dirt and residue of anti-corrosion agents. Do not use aggressive cleaning agents. Use fluff-free cloths for cleaning.
- After cleaning, check all oil, compressed air lines for leaks, loose connections, chafing and damage. Correct any defects found immediately.
- If it is necessary to remove safety features during set-up, servicing and repair, the safety features must be re-fitted and checked immediately on completion of the servicing and repair work.
- Ensure any materials used are disposed of safely with due consideration for the environment.

2.13.2 General Guidance for Use

⚠ DANGER

Incorrect handling, hazardous voltages, rotating parts and hot surfaces will shock, burn or cause loss of limbs or death.
Adhere to all safety instructions.

Generators have dangerous, live and rotating parts and hot surfaces. All work in relation to transport, storage, installation, connection, commissioning, operation and servicing must be done by authorized, trained specialist staff. National standards, e.g. EN 50 110-1 / DIN VDE 0105 / IEC 60364 are to be followed in the specific case.

It is forbidden to place the unit in operation until the end product is compliant with local regulations (follow in particular local safety and installation regulations, e.g. EN 60204).

These machines comply with the IEC EN 60034 series of standards. It is forbidden to use them in potentially explosive atmospheres.

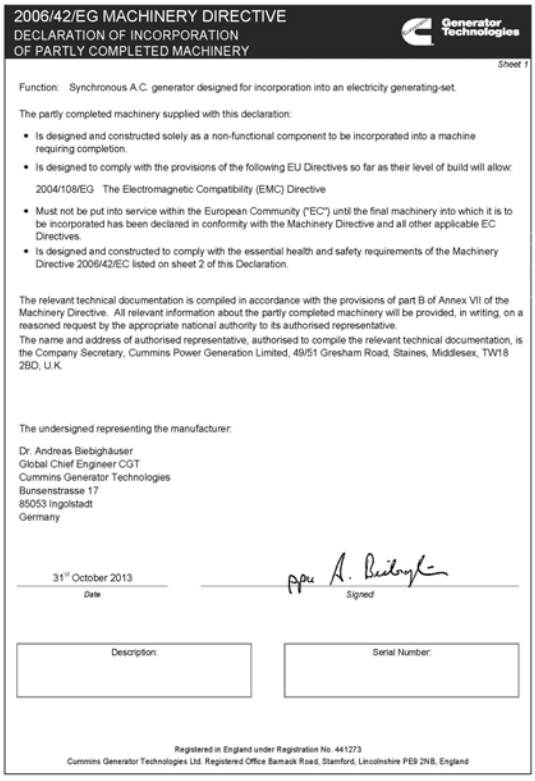
Under no circumstances use a degree of protection ≤ IP23 outdoors or in dusty environments. Standard Air-cooled models are suitable for ambient temperatures from -15 °C to +40 °C and altitudes of ≤ 1000 m above sea level. The ambient temperature for air/water-cooled models must not be less than +5 °C without additional precautions. For generators with sleeve bearings, the ambient temperature must not be lower than 0° C. The oil temperature must be at least 15 °C for the start. (For generators with sleeve bearings also see the documentation from the bearing manufacturer). Pay attention to any differing information on the rating plate. The conditions in the place of operation must match all agreed information on the rating plate and in the specification.

In cases where there is a contradiction between the content of this manual and the machine supplied, contact the manufacturer.

3 Safety Directives and Standards

AVK generators comply with European safety regulations as well as national and international regulations on generators issued in the EC. The generator must be used in accordance with the standards and intended use within the limits stated on the rating plate.

3.1 Machinery Directive: Declaration of Incorporation of partly completed Machinery



2006/42/EG MACHINERY DIRECTIVE
DECLARATION OF INCORPORATION
OF PARTLY COMPLETED MACHINERY

Generator Technologies

Sheet 1

Function: Synchronous A.C. generator designed for incorporation into an electricity generating-set.

The partly completed machinery supplied with this declaration:

- Is designed and constructed solely as a non-functional component to be incorporated into a machine requiring completion.
- Is designed to comply with the provisions of the following EU Directives so far as their level of build will allow:

  2004/108/EG The Electromagnetic Compatibility (EMC) Directive

- Must not be put into service within the European Community ("EC") until the final machinery into which it is to be incorporated has been declared in conformity with the Machinery Directive and all other applicable EC Directives.
- Is designed and constructed to comply with the essential health and safety requirements of the Machinery Directive 2006/42/EC listed on sheet 2 of this Declaration.

The relevant technical documentation is compiled in accordance with the provisions of part B of Annex VII of the Machinery Directive. All relevant information about the partly completed machinery will be provided, in writing, on a reasoned request by the appropriate national authority to its authorised representative.
The name and address of authorised representative, authorised to compile the relevant technical documentation, is the Company Secretary, Cummins Power Generation Limited, 49/51 Gresham Road, Staines, Middlesex, TW18 2BD, U.K.

The undersigned representing the manufacturer:

Dr. Andreas Biebighäuser
Global Chief Engineer CGT
Cummins Generator Technologies
Bunsenstrasse 17
85053 Ingolstadt
Germany

31st October 2013
Date

ppa A. Biebighäuser
Signed

Description:	Serial Number:

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

2006/42/EG MACHINERY DIRECTIVE
DECLARATION OF INCORPORATION
OF PARTLY COMPLETED MACHINERY

Generator Technologies

Sheet 2

ESSENTIAL HEALTH AND SAFETY REQUIREMENTS RELATING TO THE DESIGN AND CONSTRUCTION OF PARTLY COMPLETED MACHINERY

1.1	**General Remarks**	
	1.1.2	Principles of safety integration
	1.1.3	Materials and products
	1.1.6	Design of machinery to facilitate its handling
1.3	**Protection Against Mechanical Hazards**	
	1.3.1	Risk of loss of stability
	1.3.2	Risk of break-up during operation
	1.3.3	Risks due to falling or ejected objects
	1.3.4	Risks due to surfaces, edges or angles
	1.3.7	Risks related to moving parts
	1.3.8.1	Moving transmission parts
1.4	**Guarding**	
	1.4.1	Guards - General requirements
	1.4.2.1	Fixed guards
1.5	**Other Hazards**	
	1.5.2	Static electricity
	1.5.3	Energy supply other than electric
	1.5.4	Errors of fitting
	1.5.6	Fire
	1.5.13	Emissions of hazardous materials and substances
1.7	**Information**	
	1.7.1	Information and warnings on the machinery
	1.7.4	Instructions

LEGEND

1. Essential Health and Safety Requirements not shown are not considered applicable for this Partly Completed Machinery or must be fulfilled by the assembler of the Machinery.
2. Essential Health and Safety Requirements shown are considered applicable for this Partly Completed Machinery and have been fulfilled by the manufacturer to the extent possible, subject to the build requirements of the Machinery assembler, the information contained in the assembly instructions and Cummins bulletins.

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

DIG generators are supplied with a "Declaration of Incorporation of Partly Completed Machinery" 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.

3.2 Low Voltage Directive: Declaration of Conformity

2006/95/EG LOW VOLTAGE DIRECTIVE

DECLARATION OF CONFORMITY

Generator Technologies

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/EG	Low Voltage Directive
2004/108/EG	The Electromagnetic Compatibility (EMC) Directive

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

EN 61000-6-2:2005	Electromagnetic compatibility (EMC). Generic standards - Part 6-2: Immunity for industrial environments
EN 61000-6-4:2007+A1:2011	Electromagnetic compatibility (EMC). Generic standards - Part 6-4: Emission standard for industrial environments
EN ISO 12100:2010	Safety of machinery - General principles for design - Risk assessment and risk reduction
EN 60034-1:2010	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 name and address of authorised representative, authorised to compile the relevant technical documentation, is the Company Secretary, Cummins Power Generation Limited, 49/51 Gresham Road, Staines, Middlesex, TW18 2BD, U.K.

Dr. Andreas Biebighäuser
Global Chief Engineer CGT
Cummins Generator Technologies
Bunsenstrasse 17
85053 Ingolstadt
Germany

31st October 2013
Date

ppa A. Biebighäuser
Signed

Description:	Serial Number:

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

DSG generators are supplied with an EC Declaration of Conformity. It is the responsibility of the generating set manufacturer to ensure that the complete generating set complies with EC Directives and standards.

4 Introduction

4.1 Serial Number

Each generator is marked with a unique serial number. It is marked on the rating plate on the generator. (See Section 4.2 on page 15)

The serial number is to be stated in any future correspondence related to the generator, as it is the only information that is used to identify the specific generator.

4.2 Rating Plate

⚠ WARNING

Overheating
Can cause catastrophic failure and serious injury from ejected debris.
Always operate the generator within the rated parameters specified on the rating plate .

A rating plate is permanently attached to the generator and must not be removed. The rating plate provides information on manufacture, identification, electrical and mechanical aspects.

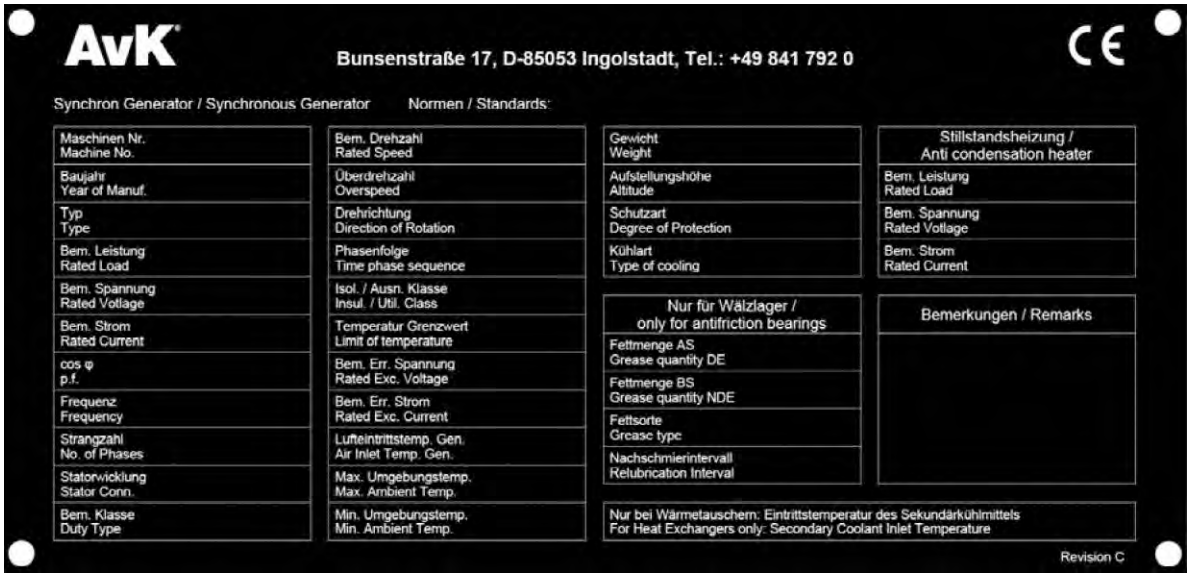


FIGURE 1. RATING PLATE

4.3 Important Remarks

NOTICE

In any areas of contradiction, the specific order-related documents take presidence.

In cases where there is a contradiction between the content of this manual and the generator supplied, contact the manufacturer.

- The safety measures that are listed in the safety instructions in the manual must be observed at all times.

Safety in the workplace is dependent on the alertness, care and common sense of all persons who operate and service the machines. Along with the safety precautions recommended here, caution is always required in the vicinity of machines: Pay attention to your safety!

NOTICE
The installation must comply with the instructions and regulations for health and safety. This statement applies for general safety regulations in the related country, specific agreements made for the related works, safety instructions included in this manual, and separate safety instructions supplied with the generator.

4.4 Liability, Warranty and Guarantee

All data and information in this documentation are provided based on our past experience and knowledge.

The technical information and data described in this documentation relate to the situation at the date of publication. We reserve the right to make changes in the context of technical further development without changing this documentation. It is therefore not possible to derive any claims from the data and descriptions in this documentation.

We accept no liability for damage or interruptions to operation due to operating errors, failure to follow the instructions, improper servicing or repair. The manufacturer is not liable under any circumstances for direct, indirect, specific, accidental or consequential damage, irrespective of its nature, that results from the application of this document; the manufacturer is also not liable for accidental or consequential damage that results from the use of the generator.

We specifically highlight that service parts and accessories not supplied by us must be approved by the manufacturer of the generator.

Any additional liability for damage resulting from the use of service parts and accessories that have not been approved by the manufacturer is excluded by the manufacturer.

Liability covers manufacturing and material defects.

Liability for damage caused by improper storage, incorrect installation or incorrect operation of the generator is excluded, as are the resulting injuries to the personnel or third party damage.

The installation and the use of third-party products will degrade the design features of the electrical machine and impair the safety of people, the system or other property.

Any unauthorized modifications or changes to the generator are not allowed for safety reasons and exclude liability on the part of the manufacturer for resulting damage. If attachments/parts provided by the customer are to be installed in or on the generator, this action must be done in consultation with the manufacturer.

Warranty and liability conditions in the manufacturer's general terms and conditions are not expanded by the above statements.

NOTICE
Claims cannot be made under the warranty if the operating conditions of the generator have been changed, changes have been made to the design of the generator or repair work has been done on the generator without prior written agreement from the manufacturer.

4.5 Intended Use

4.5.1 Operating Conditions

4.5.1.1 Vibration Analyses

NOTICE
Serious damage (for example, destruction of the bearings, or cracks in the structure) may be caused if the vibration allowed in the standard ISO 8528-9 or ISO 10816-3 is exceeded. Serious damage (for example, destruction of the crankshaft, or destruction of the shaft) may be caused if the torsional vibration is exceeded (e.g. ABS, LRS|). Ensure that the limits of the Standards are adhered to.

It is the responsibility of the generating set builder to undertake the calculation, measurement and evaluation of mechanical vibration in the power generating set (refer to standards ISO 8528-9 and ISO 10816-3).

It is imperative the rotational vibration calculation is made and checked.

4.5.1.2 Purpose

⚠ WARNING
Improper use. ***Can cause hazards that could result in death or serious injury.*** ***Always a operate in an accordance with the operation instructions.***

NOTICE
Consult the manufacturer if you want to use the generator in a different manner to that described in the order documents.

The generator is designed for onshore or maritime applications as per the order documentation.

4.5.1.3 Impermissible Forms of Operation

Do not operate the generator:

- With operating data different to the data stated on the rating plate.
- With machine features modified by the operating organization.
- Outside the agreed specification

4.5.1.4 Permissible Forms of Operation

NOTICE
The generator must only be used for the purpose stated in the order documentation. It must be operated in accordance with the information in the documentation.

It is only allowed to operate the generator

- In accordance with the procedures described in this documentation and
- If this documentation has been read and understood.

Any other use, as well as use involving hazardous or harmful substances is considered incorrect use.

NOTICE
Damage caused by operation otherwise than as intended or by incorrect operation is not covered by the manufacturer's warranty and guarantee obligations. The risk is borne solely by the user.

We recommend that operating hours, malfunctions, inspections, servicing and repairs are documented in a log.

If malfunctions or damage cannot be rectified by the operating organization's specialist personnel, please contact our customer service department.

Address:

Cummins Generator Technologies Germany GmbH

Bunsenstr. 17

85053 Ingolstadt, Germany

Telephone: +49 841 / 792-0

Fax: +49 841 / 792-195

4.6 Documentation

4.6.1 Additional Information

NOTICE
Some customer-specific elements may not be included in this user manual. Additional documentation can be found in the Appendix. If the information in this manual does not match the information in the Appendix, the data in the supplementary documentation in the Appendix applies.

In addition to this manual, each set of documentation is supplied with a dimension drawing and rotor drawing, an electrical circuit diagram as well as data sheets that state, among others, the following order-specific information:

1. External dimensions of the generator
2. Generator weight
3. Moment of inertia of the rotor
4. Position of the lifting eyes on the generator
5. Instrumentation and position of additional equipment
6. Requirements on bearing oil and lubricants
7. Main and ancillary connections.

4.6.2 Information Not Included in the Documentation

This user manual does not contain any information on starting, protection or rotational speed control features as this is not part of our delivery scope.

5 Transportation, Storage and Corrosion Protection

5.1 Transportation and Packaging

5.1.1 General

The generator is supplied on a transport frame with a transport lock.

The following protective measures are taken in the factory before the delivery of the generator. If the generator is moved subsequently, the same protective measures are to be taken:

1. Protect machined surfaces

   e.g. the seat for the drive coupling, are protected against corrosion using an anti-corrosion coating.

5.1.2 General Information for Anti-friction bearings

Ball bearings and roller bearings are lubricated using a lubricant in the factory. The lubricant is stated on the rating plate.

The first filling of the bearings with lubricant is adequate until the first re-lubrication interval, provided the generator is not stored.

5.1.3 General information for sleeve bearings

The sleeve bearings are drained after the generator test run; they are therefore delivered wet with oil. All oil inlets and oil outlets as well as oil pipes are sealed. This method provides adequate protection against corrosion. Sleeve bearings must be filled with oil during commissioning before operating the generator. The sleeve bearings must always be transported wet with oil but not filled with oil.

5.1.4 General Information for Air-Water Coolers

Air-water coolers are drained and the inlets and outlets on the cooler are sealed using protective caps.

5.1.5 Packaging

Packaging depends on the mode of transport (truck, ship, air freight).

The generator is packed using environmentally-friendly materials (blocks of wood, wooden crates, plastic sheet) that comply with the IPPC regulations.

- For transport by ship, the generator must be packed for a maritime environment to protect against splashes of salt water, moisture and vibration damage during loading, transport and unloading
- For long transport routes, on customer request the generator will be sealed with air- and dust-tight plastic sheet with desiccant.

5.1.6 During Transport (All DSG and DIG 120/130)

To avoid damage to the bearings:

- The generator must be transported and moved using a suitable transport frame.

The generator must be transported and unloaded by persons who are familiar with the lifting equipment and related ancillary equipment. All lifting equipment and tackle must be suitable for the weight of the generator and must comply with local safety regulations. Secure transport routes. Lifting fixtures (for example, lifting eyes) must only be used to lift the item to which they are attached. Always use the lifting features on the base frame to lift the complete generating set.

The transport eyes on the generator are only to be used to transport the individual generator, (not for lifting a complete generating set).

NOTICE
Do not transport using a trolley over uneven surfaces (e.g. rails).

- The generator must be stored in a vibration-free room.
- The transport markings (pictograms) on the generator packaging must be observed during transport.
- The generator must only be supported at its feet. Support at other parts is not allowed.

If vibration is to be expected, the generator must be isolated from vibration by placing suitable vibration elements under the generator feet.

The following information on transport is given in the generator:

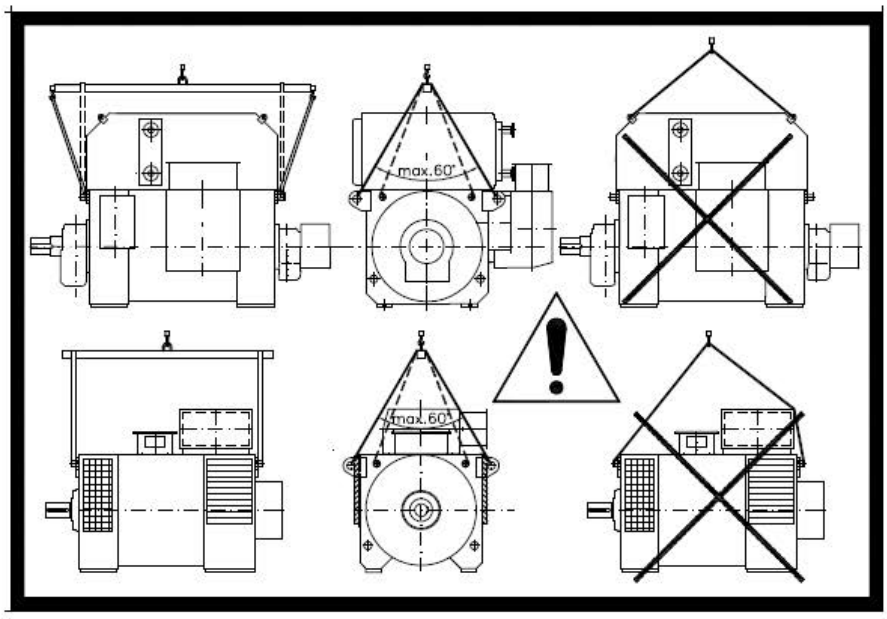


FIGURE 2. TRANSPORT INFORMATION - DSG AND DIG 120/130

5.1.7 During Transport (DIG 142)

To avoid damage to the bearings:

- The generator must be transported and moved using a suitable transport frame.

The generator must be transported and unloaded by persons who are familiar with the lifting equipment and related ancillary equipment. All lifting equipment and tackle must be suitable for the weight of the generator and must comply with local safety regulations. Secure transport routes. Lifting fixtures (for example, lifting eyes) must only be used to lift the item to which they are attached. Always use the lifting features on the base frame to lift the complete generating set.

The transport eyes on the generator are only to be used to transport the individual generator, (not for lifting a complete generating set).

NOTICE
Do not transport using a trolley over uneven surfaces (e.g. rails).

- The generator must be stored in a vibration-free room.
- The transport markings (pictograms) on the generator packaging must be observed during transport.
- The generator must only be supported at its feet. Support at other parts is not allowed.

If vibration is to be expected, the generator must be isolated from vibration by placing suitable vibration elements under the generator feet.

The following information on transport is given in the generator:

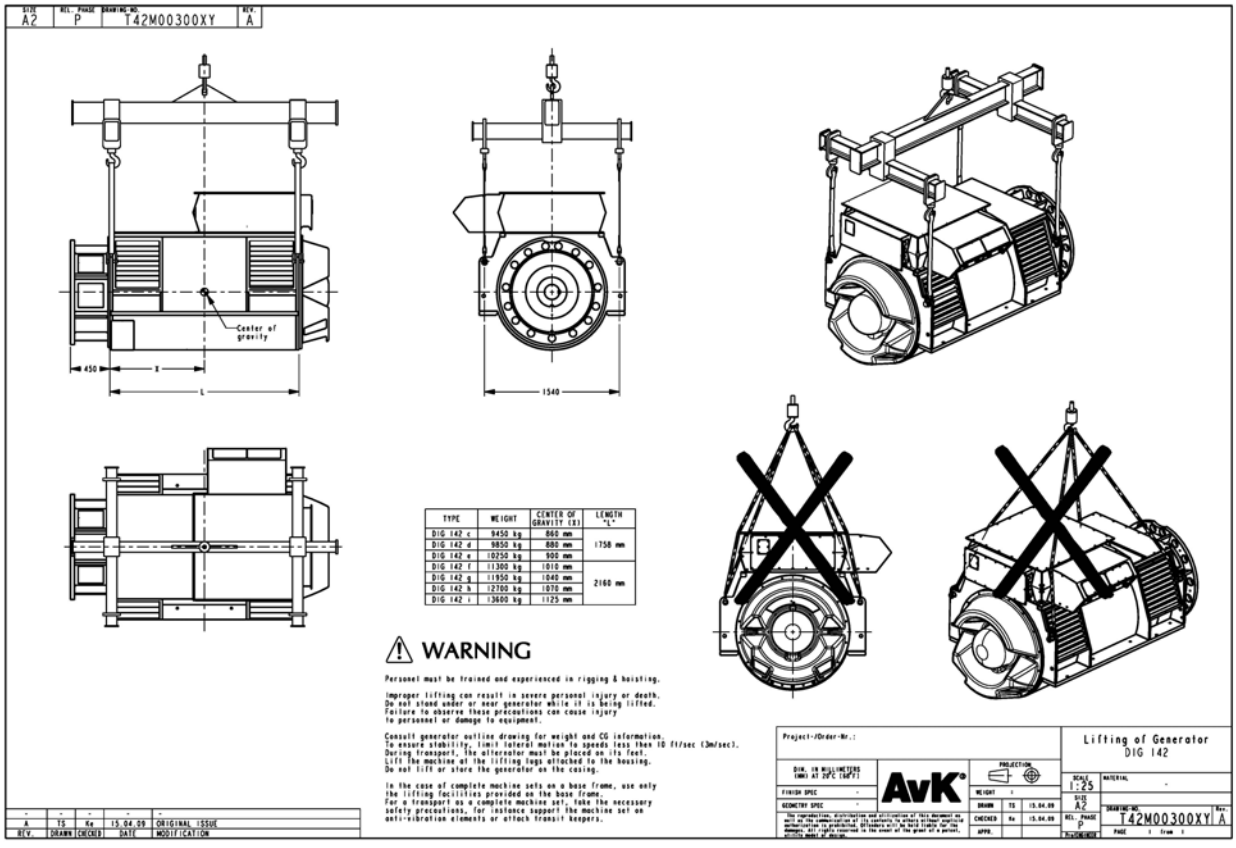


FIGURE 3. TRANSPORT INFORMATION - DIG 142

5.1.8 During Transport (DIG 140/150/156/163/167/183)

To avoid damage to the bearings:

- The generator must be transported and moved using a suitable transport frame.

The generator must be transported and unloaded by persons who are familiar with the lifting equipment and related ancillary equipment. All lifting equipment and tackle must be suitable for the weight of the generator and must comply with local safety regulations. Secure transport routes. Lifting fixtures (for example, lifting eyes) must only be used to lift the item to which they are attached. Always use the lifting features on the base frame to lift the complete generating set.

The transport eyes on the generator are only to be used to transport the individual generator, (not for lifting a complete generating set)

NOTICE
Do not transport using a trolley over uneven surfaces (e.g. rails).)

- The generator must be stored in a vibration-free room.
- The transport markings (pictograms) on the generator packaging must be observed during transport.
- The generator must only be supported at its feet. Support at other parts is not allowed.

If vibration is to be expected, the generator must be isolated from vibration by placing suitable vibration elements under the generator feet.

The following information on transport is given in the generator:

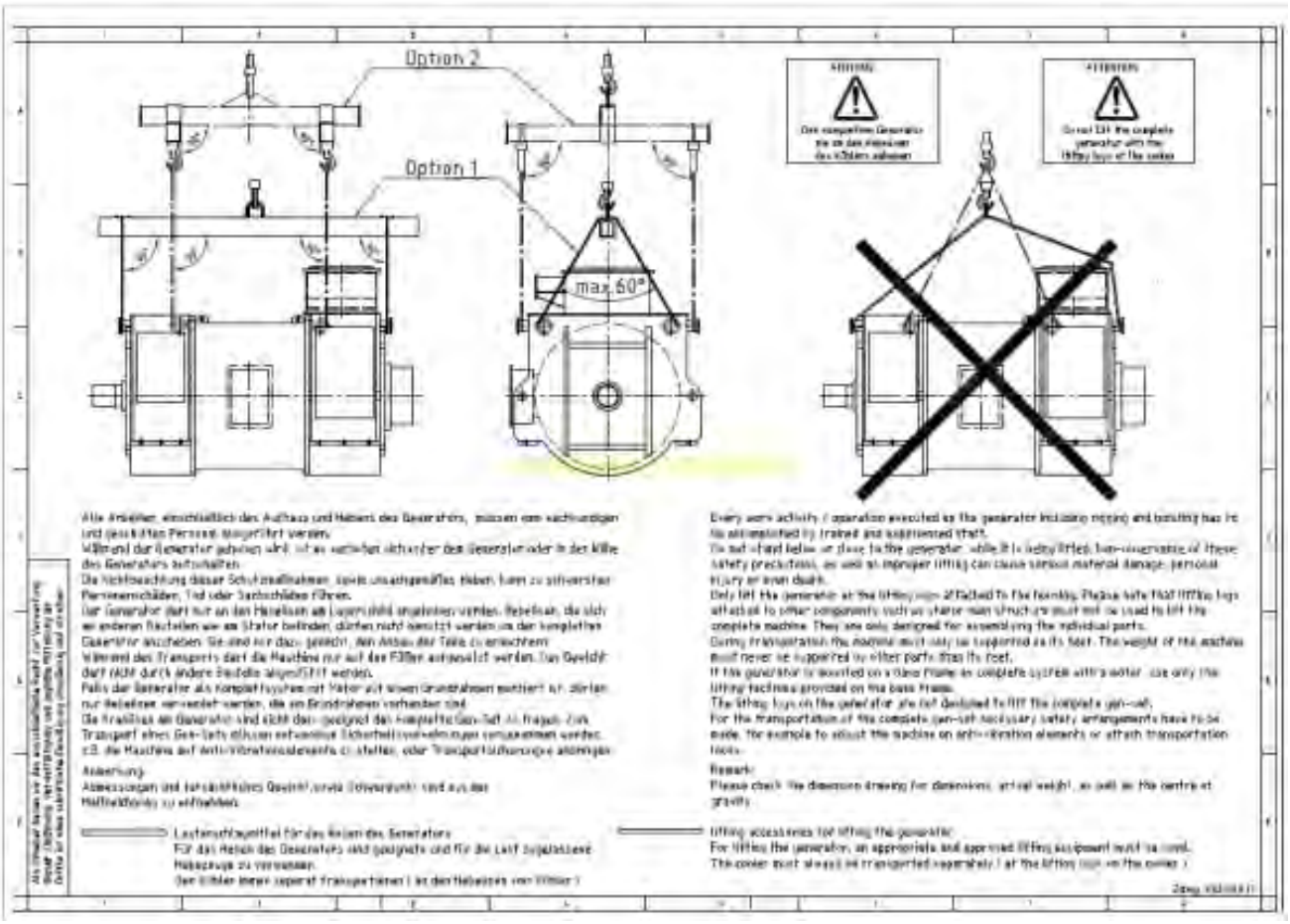


FIGURE 4. TRANSPORT INFORMATION

5.1.9 Unpacking Checks/Items supplied

Check that the items supplied correspond to the order specification and the delivery note. We refer to our terms and conditions of sale and supply.

5.1.10 Inspection on Arrival

Check the generator and all supplied parts immediately it arrives. Check for evidence of improper handling. Any transport damage must be photographed and reported to the freight carrier and the supplier within seven days, so a claim can be made against the transport insurance.

If the generator is not to be installed immediately do not leave it to stand without further protection. For further details see **Section 5.2 on page 25**.

5.1.11 Inspection on Unpacking

Place the generator on a flat surface free of vibration. Ensure there is sufficient access to the generator and associated components.

Remove the packaging and check that the generator is not damaged. Compare the delivery with the delivery note enclosed to check that additional items are present. If damage is suspected or an item is missing, take photographs that clearly show the problem and contact the freight carrier and the supplier immediately.

Refer to **Section 13.4 on page 124** for the correct disposal and recycling of the packaging material.

5.2 Storage

5.2.1 Storage in a Suitable Room (Less Than 6 Months)

⚠ CAUTION

Fire Hazzard
Will burn, cause personal injury or could cause death
Make sure no highly flammable or flammable objects are stored in the vicinity of the anti-condensation heateror generator packaging.

Suitable conditions are:

- Stable temperature conditions between 10 ºC (50 ºF) and 50 ºC (120 ºF).
- the generator must not exceed 50 °C (120 ºF)
- The ambient air must be clean and free of dust and corrosive gases or salt-laden aerosols.
- Low atmospheric humidity (below 75%) is required. The generator temperature must be maintained above the dew point to prevent condensation in the generator.
- If the generator has an anti-condensation heater, the heater must be switched on and its function checked regularly. The temperature of the generator is also to be monitored.
- If there is no anti-condensation heater, or it cannot be switched on, use an alternative heat source to protect the generator against condensation.
- A stable surface free of vibration, protected against knocks. If vibration is expected, isolate the generator by placing suitable vibration elements under the feet.
- All bare surfaces on the generator are protected on delivery. Check the protection regularly and:

  1. Clean any rust film and other dirt from bare surfaces (ends of shaft, flange, screws etc.).

  2. Seal the cleaned surfaces using a complete layer of protective lacquer or protective wax (Tectyl 511M or 846K).

  3. If the period of storage/idle exceeds two months, Tectyl 511 or equivalent should be sprayed through the filler opening into the sleeve bearing.

5.2.2 Storage in a Suitable Room (Longer than 6 Months)

⚠ WARNING

Fire Hazard
Will burn, cause personal injury or could cause death
Make sure no highly flammable or flammable objects are stored in the vicinity of the anti-condensation heater or generator packaging.

Suitable conditions are:

- Stable temperature conditions in the range from 10 ºC (50 ºF) to 50 ºC (120 ºF). The generator temperature must be kept above the dew point to prevent condensation in the generator.
- A dust-free, dry environment with low atmospheric humidity (below 75%) is required. If this requirement cannot be met, the generator is to be stored welded in plastic sheet with desiccant.

- The ambient air must be clean and free of dust and corrosive gases or salt-laden aerosols.
- If the anti-condensation heaters are switched on and the temperature of the ambient air is above 50 ºC, the generator must not heat up to above 50 ºC (120 ºF)
  - If the generator has an anti-condensation heater, the heater should be switched on and its function checked regularly.
  - If there is no anti-condensation heater, or it is not possible to place it in operation, an alternative method is to be used to protect the generator against condensation.
- Make sure the generator sits on a stable surface free of vibration and protected against knocks. If vibration is to be expected, the generator must be isolated by placing suitable vibration elements under the generator's feet.
- All bare surfaces on the generator are protected on delivery. Regularly check the protection and proceed as follows in case of damage:
  1. Clean any rust film and other dirt from bare surfaces (ends of shaft, flange, screws etc.).
  2. Cover cleaned surfaces using protective lacquer or protective wax (Tectyl 511M or 846K).
  3. Ensure the layer of lacquer provides a seal!
  4. Sleeve bearings are to be protected against corrosion in accordance with the information from the sleeve bearing manufacturer and their protection regularly checked.
  5. Additionally, Cummins recommends to add a drying agent to the sleeve bearing housing.

  By storage longer than 18 months, the bearing shelves of sleeve bearings must be replaced.

5.2.3 Storage in Unsuitable Conditions For Less Than 2 Months

Protect the generator against insects and other small animals. Prevent corrosion, moisture or the formation of condensation in and on the generator. For temporary outdoor storage during transport or if suitable store room conditions are not available, the generator must not be left unprotected in the transport packaging. The following measures are to be taken in addition to the measures in **Section 5.3.3 on page 28**:

1. Fully protect the generator from rain. The cover must be well ventilated to permit the circulation of air around the generator. If the generator is left in the transport packaging, ventilation openings must be made in the packaging
2. Place generator with transport frame on blocks so that no moisture can enter the generator or the transport frame from below. The transport frame and the generator must be at least 100 mm (4 inch) off the ground.
3. Make sure the generator is well ventilated.

5.2.4 Storage under Unsuitable Conditions longer than 2 Months

By storage under unsuitable conditions longer than 2 months, the warranty will expire immediately unless an exception has been granted by contacting the supplier in writing.

5.3 Protect Against Corrosion

5.3.1 Bare Surfaces

List the corrosion protection measures taken, check their effectiveness with the manufacturer and check them regularly. Correct any malfunctions and treat corrosion immediately.

1. Make sure the lacquer or wax seals the part to protect it
2. The ambient air must be clean and free of dust and corrosive gases or salt-laden aerosols
3. All bare surfaces on the generator are protected with Tectyl or protective lacquer on delivery. Regularly check the protection and proceed as follows in case of damage:
    a. In case of damage, clean any rust film and other dirt from bare surfaces (ends of shaft, flange, screws etc.).
    b. Cover cleaned, damaged surfaces using protective lacquer or protective wax (Tectyl 511M or 846K).

5.3.2 Sleeve Bearings

NOTICE
If the transport lock is re-tightened to a higher torque, the bearing will be damaged. In case of questions please contact the manufacturer.

Refer to an Appendix for documentation from the sleeve bearing manufacturer. If the instructions in the Appendix vary from those in this manual, the instructions in the Appendix apply.

To protect the sleeve bearings against corrosion take the following measures:

- Fittings on the sleeve bearings are sealed in the factory and sealing lacquer applied.
    1. If the sleeve bearing has already been filled with oil (e.g. after test run on the unit), drain this oil.
    2. Spray Tectyl 511 or equivalent with a compressed air tool through the filler opening into the bearing. Repeat this corrosion protection treatment every six months for two years. For this purpose it is recommended to open the packaging at the bearings.
    3. Check the compatibility of synthetic oil with bearing materials, corrosion protection materials and oil filling.
    4. Remove the sight glass for the oil ring, remove the oil and open the oil drain (see Figures 2&3).
    5. Spray corrosion protection agent into the openings using compressed air.
    6. The parts of the bearing must be fully covered with lubricant to prevent corrosion during the storage period.
    7. Seal the sight glasses and the oil drain.
    8. Repeat the procedure on the second bearing.
    9. After protection against corrosion, carefully re-seal the packaging to prevent corrosion due to external effects.

Generators with sleeve bearings are fitted with a transport lock to protect the bearing against damage during transport and storage.

Check the transport lock for bolt tightness regularly.

5.3.3 Anti-friction Bearings

After storage for more than 2 years the bearings and the grease must be replaced before commissioning the generator.

If the transport lock is re-tightened to a higher torque, the bearing will be damaged. In case of questions please contact the manufacturer.

To prevent brinelling of anti-friction bearings during storage:

1. Pre-load the bearing using the transport lock.
2. Remove the transport lock and Turn the rotor monthly so that the position of the rolling elements changes. The rotor must rotate at least 420°.
3. Fill the entire bearing chamber with grease.

5.3.4 Air-air Cooler

Check the effectiveness of the corrosion protection measures annually. Or more frequently in particularly unfavorable ambient conditions. Renew the corrosion protection measures if necessary.

1. Clean the entire cooling path by blowing out with dry air.

5.3.5 Air-water Cooler

Check the effectiveness of the corrosion protection measures annually. Or more frequently in particularly unfavorable ambient conditions. Renew the corrosion protection measures as necessary.

1. Drain the existing cooling water.
2. Clean the cooling water pipes and flush using clean, clear water.
3. Dry the cooler with warm, pre-dried air.

5.3.6 Customer Connection Openings

Clean the Cooler and pipes and blow through warm, dry air to dry them. Seal the Openings through which cables are not yet connected to terminal boxes or flanges that are not yet connected to pipes.

5.4 Remove Corrosion Protection

NOTICE
Do not remove the anti-corrosion coatings using emery paper.

Before operating a corrosion-protected generator, remove the measures taken and logged for storage and establish the state required to commission the generator.

- Remove any drying agent that may have been placed in the generator.
- Remove the anti-corrosion coatings using cleaner´s solvent or a similar oil-based solvent.
- Ensure that all necessary fluids (e.g. oil, grease, water) are added in the correct amount to the generator before it is taken into operation.

5.4.1 Anti-friction Bearings

Check which measures were applied for protection against corrosion, remove as appropriate.

The amount of grease in the bearings for long-term storage must be reduced to the specified amount for operating the generator. Open the bearing chamber, remove the excess grease and re-seal the bearing chamber. In case of questions related to the amount of grease, please contact the manufacturer with the machine number.

NOTICE
An excessive amount of grease or old grease in the bearings during operation will result in serious bearing damage! Pay regard to the storage time and the grease amount.

Check the amount of grease in the attachments. If necessary contact the manufacturer for information on the first filling.

5.4.2 Sleeve Bearings

The removal of the protection against corrosion in the sleeve bearings and further steps are described in the operating instructions for the sleeve bearings.

After extended storage, check the bearings for corrosion damage.

1. Clean the bearing housing from the exterior. Dust and dirt will hinder the dissipation of heat from the bearing.
2. Remove any drying agent that may have been placed in the bearing housing.
3. Re-tighten the joint screws and the flange screws as follows.

Take the torques from the documentation from the manufacturer of the sleeve bearing or contact the manufacturer with the machine number.

1. Check that the sight glass is correctly seated.
2. Check the sight glass for the oil ring on the top of the bearing. This should be tightened hand-tight (12-16 Nm)
3. Tighten all plugs to the required tightening torque.

5.4.3 Cooler

Follow the operation and maintenance instructions supplied by the cooler manufacturer.

5.4.3.1 Air-water Cooler

Fill and operate the water circuit according to the operating and maintenance instructions from the cooler manufacturer. You will find these instructions in the Appendix.

5.4.3.2 Air-air Cooler

Operate the air-air cooler according to the operating and maintenance instructions from the cooler manufacturer. You will find these instructions in the Appendix.

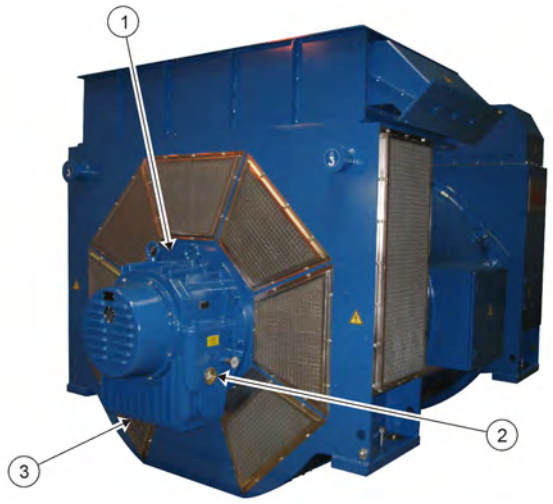
5.4.4 Condensed Water Drain

⚠ DANGER
Harzardous Voltage ***Will shock, burn or cause death.*** ***In case of condensed water, do not operate the generator without the repairs and inspections described in Chapter 10 on page 77.***

Check whether condensed water has formed in the generator. If there is condensed water present, open the drain plug at the lowest point on the generator and close again after draining the condensed water.

5.5 Oil Drain Points

TABLE 2. NON DRIVE END



No	Description
1	Oil Ring Sight Glass
2	Oil Sight Glass
3	Oil Drain

TABLE 3. DRIVE END

No	Description
1	Oil Ring Sight Glass
2	Oil Sight Glass
3	Oil Drain

This page is intentionally blank.

6 Installation and Alignment

6.1 General

⚠ DANGER

Hazardous voltage and rotating parts.
Will shock, burn, or cause loss of limbs or death.
Prevent unintentional operation of the generator and accidental damage caused when work is done nearby.

Follow general and local health and safety instructions during installation.

Good planning and comprehensive preparations before installation are necessary for malfunction-free, reliable and safe operation of the generator

Follow the standards for connections and use of electrical equipment, in particular national standards, for the installation of the equipment (e.g. see standard IEC 60079-14 or EN 60204).

When welding, do not use generator as (earth) ground.

6.2 Preparation of the Generator

Prepare the generator as follows before installation:

1. Measure the insulation resistance of the windings as described in **Section 7.4.4 on page 48**.
2. If necessary, remove the transport lock. Keep it in a safe place for future use. To prevent bearing damage the transport lock must always be attached to the generator if the generator is moved, or placed in storage. See **Section 5.1.1 on page 19**.
3. Remove the anti-corrosion coating from the end of the rotor shaft and the generator feet using white spirit or a similar oil-based solvent.

6.2.1 Generators with Anti-friction Bearings

Generators with two bearings must be connected to the prime mover using elastic couplings to ensure continuous free axial movement between the coupling halves due to thermal expansion of the generator shaft without bearing damage.

The non-drive end bearing is always fixed. The axial thermal expansion of the rotor is calculated as described in **Section 6.4.3 on page 39**. If in doubt, contact the manufacturer.

- Make sure the grease is compliant with the specification on the rating plate and make sure the bearing is filled with the correct amount of grease. See **Section 5.4 on page 28**.

NOTICE

An excessive amount of grease or old grease in the bearings during operation will result in serious bearing damage. Pay regard to the storage time and the grease amount.

6.2.2 Generators with Sleeve Bearings

1. The drive-end bearing is always fixed. Fill the sleeve bearing with oil. For this purpose refer to the outline drawing for the viscosity of the oil. If a lubricant is not stated on the outline drawing, use the lubricant recommended by the sleeve bearing manufacturer.

6.2.3 Recommendations for Coupling Assembly

6.2.3.1 Balance Condition of the Rotor

Balance the rotor coupling half corresponding to the rotor balancing. A standard rotor is dynamically balanced using half keys. The type of balancing is marked on the end of the rotor shaft:

H = Half key

F = Whole key

N = No key

6.2.3.2 Assembly

⚠ WARNING

Rotating Parts.
Will cause severe injury. The coupling is to be protected with a guard. There is a hazard in operation due to rotating parts.
In operation, be careful of rotating parts.

⚠ WARNING

Hot parts.
Cause serious burns.
Prevent skin contact with hot parts using PPE.

1. Follow the general instructions from the coupling manufacturer
2. The coupling can be heavy. Use suitable lifting equipment
3. Clean the anti-corrosion coating from the coupling seat on the shaft and compare the dimensions of the end of the shaft and the coupling with the outline drawing provided.
4. Make sure that the key slots in the coupling and the shaft are clean, free of burrs and undamaged.
5. Smear the shaft and the hub bore with a thin layer of resin-free oil to ease the assembly of the coupling half.

   Never smear mating surfaces with molybdenum disulfide (MoS_2) or similar products.
6. On mounting a feature on the bores and threads in the shaft, consult with the manufacturer.
7. If it is necessary to heat the coupling to ease fitting, follow the temperature information from the coupling manufacturer.

To prevent damage to the bearings, do not put additional forces on the bearings while assembling the coupling half.

6.3 Mounting Design

6.3.1 General

The mounting design and construction is the responsibility of the customer or a third-party. The mounting design must ensure safe operating conditions and good access for servicing and monitoring. Cooling airflow must be unhindered to and from the generator. Nearby machines or equipment must not heat the cooling air for the generator or its attachments, such as the bearings.

The mounting must be stable, stiff and free of external vibration. Check for resonance; the natural frequency of the mounting with mounted generator must not lie within ±20% of the operating frequency.

The mounting must be designed to support the weight of the generator and include air, water, oil and cable ducts. The dimensions of the connection features must match the corresponding dimensions on the outline drawing provided.

The mounting must be designed to accomodate all the manufacturing tolerances.

6.3.2 Mounting Forces

The mounting and the fastening screws must withstand mechanical moments that occur during generator starting, operation and transient events. Refer to the technical data sheet for the loads.

The calculation of the mounting forces is not included in the items supplied, for this reason the customer or a third-party is responsible for this task. If necessary, calculation can be agreed in the project planning phase.

6.3.3 Mounting on Ships

6.3.3.1 General Requirements

The classification and design requirements of the certification authority apply to the design and implementation of mountings on ships.

6.3.3.2 Calculations

Check and calculate during the project phase

1. The natural frequency of vibration in the overall system in 6 degrees of freedom.
2. Calculate the static displacements in x, y and z directions on all elastic components. Take into account all loads effective at nominal power output due to the inherent weight of the motor, the motor nominal torque (or output torque for flange-mounted gearboxes), and ship pitch and roll motion.
3. Compare the displacement values calculated with the values allowed for the electrical components.
4. Calculate the forced damped vibration.

The result must conform to the specifications for the ship classification and be agreed with the manufacturer of the component

6.3.3.3 Fastening to the Mounting

Only screw joints must be used for fastening the drive systems to the ship-borne mounting.

To keep settling to a minimum, the number of joints in the screw joints is to be limited to a minimum.

The contact surfaces for screw heads and nuts must be flat and machined parallel.

Do not tack weld generator mounting screws and nuts.

The screw joint must be designed for the maximum possible load that can occur.

The required pre-load on the mounting screws is to be defined in agreement with the manufacturer of the prime mover or the manufacturer of the related system component.

The preferred fastener type is a cap screw, installed so that the screw pre-load can be checked at any time.

6.3.3.4 Requirements

Follow the manufacturer's installation regulations during the mechanical mounting of the individual components on the foundation.

Design of the mounting must be agreed with the certification authority.

Make sure the assembly and inspection openings on the drive systems provided for maintenance measures remain accessible.

Final fastening must be done after alignment done. Consider the operation-related thermal expansion and the dynamic behavior of the system components (coupling, gearbox etc.) during alignment.

Make sure that the alignment of the individual system components to each other does not change during mechanical work on the mounting.

All welding work in the area of the mounting must be completed before mounting the generator.

During the design of an elastic mounting, consider the aging and natural wear of the mounting elements. Check and log the settling rates at intervals specified by the manufacturer. Replace the elastic mounting when the maximum allowed amount of settling occurs.

6.3.4 Installation on Concrete Foundations

6.3.4.1 Items Supplied

The installation shims, fastening screws and mounting pads or bed plates are not included in the normal items supplied with the generator. These can be supplied to special order.

6.3.4.2 Calculations

Check and calculate during the design phase

1. The natural frequency of vibration for the overall system in 6 degrees of freedom.
2. Calculate the forced damped vibration.
3. Calculate the mounting forces and screw joints

The results must conform to the specifications and be agreed with the manufacturer of the related system component.

6.3.4.3 Prepare the Foundation and the Holes in the Foundation

Mounting pads in accordance with DIN 799 or bed plates can be used to anchor the generator in a concrete foundation.

Take into account the following points during the preparation of the foundation:

- Compare the position of the holes in the foundation and the height of the foundation with the related dimensions on the outline drawing.

6.3.4.4 Prepare the Mounting Pads or the Bed Plates

If required, shims and mounting pads are supplied as separate parts for fitting on site.

To ensure the firm seating of the mounting pads in the concrete, they must be unpainted and free of dirt and dust.

1. Lift the generator with a crane to assemble the mounting pads or bed plates to the generator.
2. Clean the parts that are cast in the concrete.
3. Clean parts protected with an anti-corrosion coating using solvent.
4. Only screw greased alignment screws into the mounting pads or bed plates.

Make sure that clearances and fasteners are free of concrete.

6.3.4.5 Install the Generator

Lift the generator carefully and, together with the coupling half and bed plates or mounting pads, fit it into the holes that have been made on the existing foundation. The coupling is fitted in accordance with the specifications from the coupling manufacturer.

6.3.4.6 Position the Mounting Pads or the Bed Plates

The bed plates or mounting pads must either be positioned together with the generator or separately, so that the generator can be aligned afterwards within the range of its adjustment features.

6.3.4.7 Cementing

NOTICE
Cracks in the concrete or poor fastening to the concrete foundation can loosen the generator.
Fill the holes in the foundation completely and avoid cavities.
Cementing the generator in the foundation is a very important part of the installation. Follow the instructions of the concrete manufacturer.
Use high-quality concrete that is not subject to shrinkage to prevent problems during cementing.

6.3.4.8 Final Installation and Inspection

1. After the concrete has hardened, re-tighten the foundation bolts.
2. Lock the nuts using approved locking generators (e.g. DIN).
3. Tighten the fastening screws.
4. Check and correct the alignment to ensure the generator runs with the permissible vibration.
5. Complete the installation by fitting dowel pins.

6.3.5 Installation on Steel Foundation

6.3.5.1 Items Supplied

Installation shims or fastening screws are not included in the normal items supplied. These can be supplied to special order.

6.3.5.2 Inspect the foundation

Before lowering the generator onto the foundation:

1. Clean the foundation thoroughly
2. Check that the foundation is flat and level (parallel error maximum 0.1 mm (4.0 mil))
3. Check that the foundation is free of external vibration.

6.3.5.3 Install the Generator

Lift the generator carefully and, together with the coupling half, fit it on the existing foundation. The coupling is fitted according to specifications from the coupling manufacturer.

6.3.5.4 Coupling Cover and Enclosures

Before fitting enclosures and operating the generator but after installing and aligning the generator, make sure that there are no tools or foreign bodies left inside the generator or the enclosures

⚠ WARNING
Rotating parts. ***Can cause loss of limbs or death.*** ***The coupling must be protected with a guard. In operation, be careful of rotating parts.***

Keep the alignment and installation equipment together with the transport lock for future use

6.4 Align the Prime Mover and Generator

6.4.1 General

To ensure a long, satisfactory service life for both the prime mover and the generator, both must be correctly aligned. This means that the radial and angular offset between the two shafts on the machines must be minimized.

Be sure to complete an alignment report. Claims relating to damage can only be considered if an alignment report is available. Before starting the alignment work, remove all transport locks and rotor fastenings. Undertake alignment with great care, as alignment errors will result in bearing and shaft damage. Even small alignment errors will result in uneven running of the machines and bearing damage.

6.4.2 Theory of Alignment

The accuracy of alignment is related to the tools used for the alignment (dial gauges, laser measuring instrument).

- A laser measuring instrument is most accurate.

One of the two machines to be coupled is defined as the reference point. On power generator sets this reference point is generally the prime mover.

- Fine alignment is dependent on the design of the machine, as follows:

TABLE 4. ALIGNMENT OFFSET AND SPEED

Nominal speed:	Maximum radial offset:
1800 revs/min	0.05 mm / 1.96 mil
1500 revs/min	0.06 mm / 2.36 mil
1000 revs/min	0.08 mm / 3.15 mil
750 revs/min	0.09 mm / 3.54 mil
600 revs/min	0.11 mm / 4.33 mil
375 revs/min	0.15 mm / 5.90 mil

General figure for the angular offset: ≤ 0.05 mm / 100 mm (0.5 mil / 1 inch)coupling diameter

General figure for the coupling distance: ≥ 3 mm / 0.118 inch.

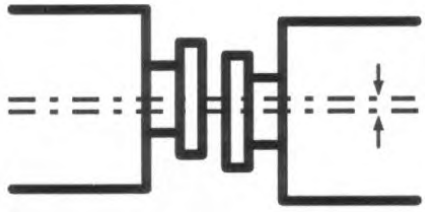


FIGURE 5. RADIAL OFFSET

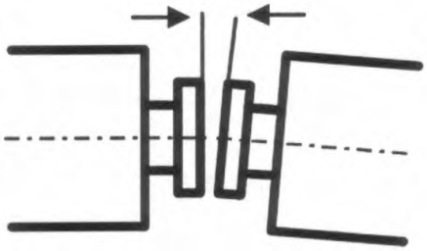


FIGURE 6. ANGULAR OFFSET

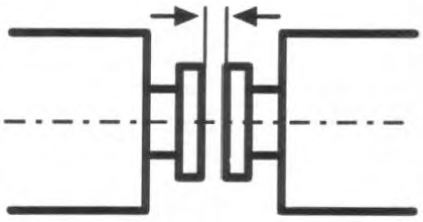


FIGURE 7. AXIAL OFFSET

On alignment with the machines cold it is to be taken into consideration that generator, gearbox and prime mover may have different thermal expansion. This situation will result in different height changes on the parts when warm.

6.4.3 Compensate for Thermal Expansion

Operating temperatures have a significant effect on alignment and must be taken into account. The temperature of the generator under operating conditions is higher than during installation. The center of the shaft will be higher during operation, i.e. further away from the base than at rest due to thermal expansion.

Thermally-compensated alignment may be necessary depending on the operating temperature of the generator, the type of coupling, the distance between the two machines etc.

6.4.3.1 Vertical Thermal Expansion

Vertical thermal expansion is always to be taken into account.

The thermal expansion of the generator can be calculated approximately using the distance between the base and the center of the shaft:

$\Delta H = \alpha \times \Delta T \times H$

Where

ΔH= Thermal expansion [mm]

$\alpha = 10 \times 10\text{-}6\ K^{-1}$

ΔT= Temperature difference between alignment temperature and operating temperature to be expected [°K]

H= Shaft height [mm] (see outline drawing)

Take into account the thermal expansion of the generator in relation to the prime mover to determine the overall thermal expansion.

6.4.3.2 Axial Thermal Expansion

Axial thermal expansion is always to be taken into account.

The calculation is made from the fixed bearing on the generator to the end of the shaft on the drive side (see rotor drawing in the Appendix).

The fixed bearing is on the B end (NDE - non-drive end) of the generator for anti-friction bearings and on the A end (DE - drive end) of the generator for sleeve bearings. In case of queries related to the fixed bearing and the thermal expansion please contact the manufacturer.

The thermal expansion can be calculated approximately using the distance between the fixed bearing and the other end of the rotor shaft:

$\Delta L = \alpha \times \Delta T \times L$

Where

ΔL= Thermal expansion [mm]

$\alpha = 10 \times 10\text{-}6\ K^{-1}$

ΔT= Temperature difference between alignment temperature and operating temperature to be expected [°K]

L= Distance from the fixed bearing to the AE of the shaft [mm]

Make sure that continuous free axial movement is possible between the coupling halves (except fixed couplings) to permit axial thermal expansion of the generator shaft and prevent bearing damage.

6.4.4 Assemble the Coupling Halves

The coupling halves are assembled in accordance with the requirements from the coupling manufacturer. The coupling halves on the prime mover and generator are placed together loosely so that they can move freely in relation to each other during the alignment.

6.4.4.1 Run-out on the Coupling Halves

NOTICE
Do not turn generator rotor using the fan. The fan will not withstand such forces and will be damaged.

The alignment process starts with the measurement of the run-out on the coupling halves. This measurement provides an indication of any inaccuracy on the shaft and/or the coupling halves.

The run-out on the coupling halves is measured in relation to the generator bearing housing. Fit the dial gauges as shown in **Figure 8 on page 41**. Rotate the rotor shaft with a simple lever. Check the run-out of the coupling half on the prime mover in relation to the bearing housing.

Fill sleeve bearings with oil before rotating. The permissible run-out error is less than 0.05 mm (1.9 mil).

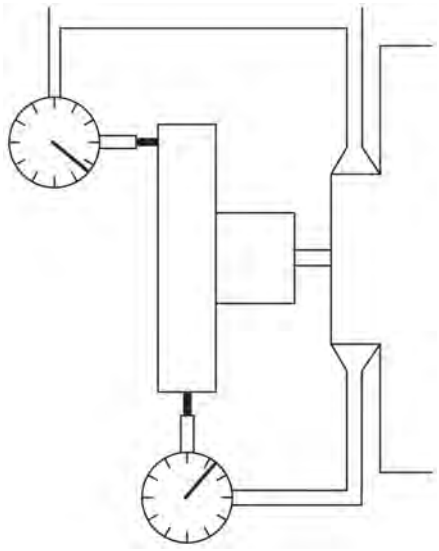


FIGURE 8. MEASUREMENT OF THE RUN-OUT ON THE COUPLING HALF

The alignment must be performed with great care. Otherwise, the prime mover and the generator can be seriously damaged by heavy vibration. Measure alignment performed according to instructions from the coupling manufacturer. Parallel, angular and axial alignment of the generator is required.

6.4.5 Coarse Alignment

For ease of alignment and the fitting of shims, alignment screws are fitted to the generator base.

The generator stands on the alignment screws. Please note that the generator must stand on all feet (screws) in a plane with a maximum of 0.1 mm (4.0 mil) parallel error. If this is not the case, the generator will twist or distort, which will result in bearing damage and other damage.

- Make sure the generator is leveled vertically, horizontally and axially. Make the necessary adjustments by, e.g., placing alignment elements or shims under the feet.

6.4.6 Final Alignment

Sleeve bearings are to be filled with oil before rotating.

NOTICE
Do not turn generator rotor using the fan. The fan will not withstand such forces and will be damaged.

The generator is aligned as follows:

1. The generator must stand on its alignment screws.
2. Turn the rotor with a simple lever and check the axial play.
3. Fit the alignment equipment.
4. If dial gauges are used, their scale must be adjusted so that about half the scale is available in both directions. Check the strength of the dial gauge holder to prevent possible bending, see **Figure 9 on page 42**.

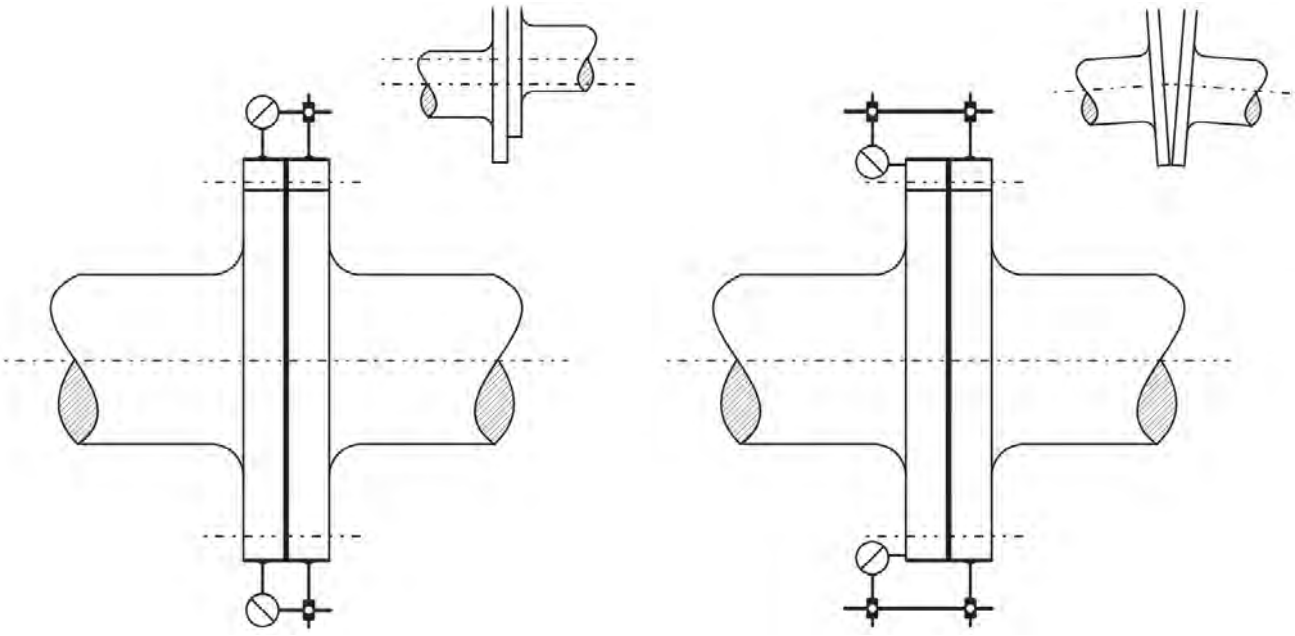


FIGURE 9. ALIGNMENT USING DIAL GAUGES - 1: RADIAL ALIGNMENT, 2: ANGULAR ALIGNMENT

5. Measure and note the values for radial, angular and axial offset in four different positions: top, bottom, right and left, i.e. every 90°, while the coupled shafts are rotated at the same time. Record the values.
6. Align the generator vertically by turning the alignment screws or by lifting using hydraulic lifters. For ease of radial alignment, alignment screws are fitted to the generator feet. The expansion of the base frame due to thermal action can affect the accuracy of the alignment (see **Section 6.4.3 on page 39**).
7. If no alignment elements (e.g. Vibracon) are used, please proceed as follows:
   a. Measure the distance between the underside of the generator feet and the base frame and fabricate appropriate solid blocks, or have the necessary quantity of shims available.
   b. Place the solid blocks or shims under the generator feet. Loosen the alignment screws and tighten the fastening screws.
8. Check alignment again and correct, as required.
9. Re-tighten the nuts and secure them using approved (DIN) locking elements.
10. Fasten the generator feet using dowel pins to simplify the possible future re-installation of the generator; see **Section 6.5 on page 44**

6.4.6.1 Permissible Offset

Definitive alignment tolerances cannot be stated, as there are too many factors that play a role. Excessively large tolerances will cause vibration and may result in bearing damage or other damage. For this reason it is recommended to keep the tolerances as low as possible.

The tolerances stated by the coupling manufacturer only apply to the coupling, not to the alignment of the prime mover and load machine. They can only be used as general figures for the alignment if they are lower than the maximum values stated in **Section 6.4.2 on page 38**.

6.4.6.2 Align a Generator with Axial Play

In case of generators that permit axial play in the fixed bearing, an adjustment indicator is fitted and there is a marking on the shaft that indicates the operating center point. The rotor is operated in the correct position if the pointer is aligned with the groove on the shaft. This so-called operating center point does not necessarily match the magnetic center point of the generator. The fan and magnetic forces can pull the rotor out of the generator's geometric center point. Pay attention to any adjustment indicator fitted and its position.

6.4.6.3 Align a Two Bearing Generator

During the alignment of two-bearing generators the following errors can occur:

1. Radial offset
2. Angular offset
3. Axial offset

If aligning when the generating set is cold, consider that the height of generator, gearbox and prime mover is different when warm due to differences in thermal expansion.

- Align the coupling (minimum axial offset) according to the instructions from the coupling manufacturer. During this process consider the linear expansion of the shafts when reaching the operating temperature.
- Use suitable alignment aids, e.g. dial gauges or a laser instrument, for the fine radial alignment of the generator.

6.4.6.4 Align a Single Bearing Generator

The objective of the alignment on one-bearing generators is to keep the air gap between the rotor and stator equal all round so that the rotor is exactly aligned radially.

For the axial alignment the distances on the B end (non-drive end) must be met.

Refer to the illustration in the Appendix for the dimension that defines the axial center position of the rotor.

To align the generator, proceed as follows:

1. Remove the radial transport lock.
2. Roughly align the generator on the base frame or the bed plates. (See **Section 6.5 on page 44**)
3. Couple the prime mover and generator without using force.

Pay attention to the following points:

- Crankshaft clearance on the combustion engine.
- Air gap between rotor and stator.
- Axial dimension as per sketch in the Appendix.

- Check the radial alignment accuracy by measuring the distance between the shaft and the machined inside diameter of the bearing plate.

6.4.6.5 Alignment of Generators with Flange-mounted Gearbox

Follow the documentation from the gearbox supplier to align a generator with a flange-mounted gearbox done.

6.5 Fit the Dowel Pins

The generator does not have any bores for dowel pins in its feet. Cummins recommends fitting tapered pins (DIN 258) to maintain exact alignment and to permit easier re-installation of the generator if removed.

6.6 Measures for Delayed Commissioning

External vibration will damage all types of bearings and shorten the service life of the bearings.

If the generator is not operated for an extended period after installation, follow the measures described in **Section 5.2 on page 25**. In addition, rotate the shaft 10 turns at least every 3 months and the fill the self-lubricating bearings with oil. If the generator is subject to external vibration, the generator must be un-coupled.

7 Mechanical and Electrical Connections

7.1 General

Do not drill additional holes and threads. The generator will be damaged.

Mechanical and electrical connections are made after installation and alignment. Mechanical connections can include the connection of air ducts, water pipes and/or an oil supply system.

Electrical connections include the connection of line cables and additional cables, ground cables and optionally external fan motors.

7.2 Mechanical Connections

7.2.1 Cooling Air Connections

7.2.1.1 Connect Air Ducts

Clean the air ducts thoroughly before you connect them to the generator and make sure there are no obstructions in the ducts. Seal the joints using suitable seals. After connecting the air ducts, make sure that there are no leaks.

Generators that are designed for the possible connection of air ducts have connection flanges shown in the outline drawing.

7.2.1.2 Connect a Cooler to the Generator

Generators that are equipped with a heat exchanger for their cooling have a cooling air seal on the heat exchanger.

If the heat exchanger or parts of the cooling system are supplied separately, they must be installed on site as follows:

1. Lift the cooler or the individual parts only by the lifting eyes using suitable lifting equipment.
2. Make sure all connection components are free of dust and dirt.
3. Refer to the outline drawing in the Appendix for the correct installation positions.
4. Lift the cooler parts at the point provided and fasten them using the hardware provided.
5. Make sure all seals are fitted correctly.

7.2.1.3 Connect an External Fan Motor

The external fan motor is generally an asynchronous three-phase motor. The terminal box for the fan motor is on the motor housing. The rating plate on the external fan motor indicates the voltage and frequency to be used. The direction of rotation of the fan is marked with an arrow.

NOTICE
Check the direction of rotation of the external fan motor (fan) visually before you start the generator. If the fan motor runs in the wrong direction, its phase sequence must be changed.

7.2.2 Connect Cooling Water

7.2.2.1 Air-water Cooler

Generators that are equipped with an air-water heat exchanger have connection flanges. Connect the flanges and seal the joints using suitable seals. Refer to the outline drawing in the Appendix for the size of the connection flanges.

- Ensure that the water circuit has no leaks, before starting the generator.

7.2.2.2 Connect Cooling Water to Sleeve Bearings

Make the connections, make sure they are secure and there are no leaks in the system. Refer to the outline drawing in the Appendix for the size of the connections. After the generator has run for a time it is necessary to check the cooling system. Make sure the coolant can circulate freely.

7.2.3 Oil Supply for the Sleeve Bearings

Generators with external lubrication are equipped with oil pipe flanges and optionally pressure limiters and flow indicators.

1. Install all the necessary oil lines and connect the oil supply.
2. Install the oil supply in the vicinity of the generator so that the pipes to each bearing are of similar length.
3. Test the oil supply before the pipes are connected to the bearings using flushing oil.
4. Check the oil filter and clean or replace if necessary. A replacement filter is not included in the items supplied
5. Install the oil inlet pipes and connect them to the bearings.
6. Install the oil outlet pipes underneath the bearings with a minimum angle of 15°, which corresponds to a fall of 250 - 300 mm/m (3-3,5 inch/foot).

The oil level in the bearings will increase if the fall on the pipes is inadequate; the oil flows too slowly back to the oil tank from the bearings. This will result in malfunctions in the oil flow or even oil leaks. Fill the oil supply with clean oil of the correct type and the correct viscosity. Always use oil of the correct viscosity, stated on the outline drawing. If the type of oil is not clear from the outline drawing, refer to the oil types in the lubricant list from the sleeve bearing manufacturer.

1. Switch on the oil supply and check the oil circuit for any leaks before starting the generator.
2. The normal oil level is reached between one third and half of the oil sight glass. Check the oil level only at standstill and at ambient temperature.

NOTICE
The bearings are supplied without lubricant. If the generator is operated without lubricant, immediate bearing damage will result. **Do not drill additional holes and threads. The generator will be damaged.**

7.2.3.1 Hydrostatic System

Make sure that the hydrostatic system is running and functional before starting or coasting down the generator.

On the connection of the pipe to the hydrostatic connection for the bearing it must be ensured that the connection on the bearing is not rotated. This connection must be locked using a suitable tool during the installation of the pipe.

Sleeve bearings with hydrostatic lifting are used in critical cases To prevent damage due to metal contact on the bearing surfaces, hydrostatic systems ensure low bearing wear where the generator starts at low speeds, or with frequent starts/stops, high starting load or very long coast-down times. For these application conditions, the use of hydrostatic systems is strongly recommended by the manufacturer.

The maximum load bearing capacity of the system is defined by the maximum pump pressure. The hydrostatic pump pressure is normally limited to 200 bar. Due to small lubrication gap at the shaft surface in case of metal-on-metal contact, the pump pressure is highest at the start of lifting. Lifting is associated with a noticeable pressure surge. As the lubrication gap increases in size after lifting the shaft, the pressure drops as a function of the bearing geometry and the volume of lubricant. The static pump pressure for supporting the shaft should be around 100 bar.

Refer to the order-specific documentation for the minimum speed for operating a generator without a hydrostatic system.

7.3 Connect Vibration Sensors

7.3.1 Anti-friction Bearings

Standard Generators with anti-friction bearings are equipped with bores for the connection of SPM vibration sensors.

7.3.2 Sleeve Bearings

Standard Generators with sleeve bearings do not have any preparation for vibration sensors. These can be supplied to special order.

7.4 Electrical Installation

7.4.1 General Information

⚠ DANGER
Hazardous voltage. ***Will shock burn or cause death.*** ***Before installation make sure that the supply cables are disconnected from the power system and that the cables are grounded.***

The safety information in **Chapter 2** must be observed at all times

Plan the electrical installation thoroughly before implementation. Read the Circuit diagrams supplied with the generator thoroughly before starting the installation work. It is important that the line voltage and frequency for all electrical equipment correspond to the values stated on the related rating plate or in the circuit diagram.

The line voltage and the frequency must lie within the limits stated in the related standard. The data must correspond to the data on the rating plate and be connected according to the circuit diagram.

7.4.2 Safety

Electrical work must be done by appropriately qualified specialist personnel. The following safety instructions must be followed:

1. Switch off all units including ancillary equipment
2. Provide securing features to prevent unintentional switching back on
3. Make sure all parts are disconnected from their related power supply
4. Short all parts to protective ground and short-circuit the switching circuits
5. Cover all live parts and cordon off the surrounding area
6. If the secondary circuit is expanded with a current transformer, make sure that an open circuit does not occur during use.

7.4.3 Moisture

The ability of air to absorb water is temperature-dependent. If the air temperature drops below the saturation point, condensation may form on the winding insulation, as a result the electrical resistance will drop. Further protective measures are necessary in a humid operating environment!

7.4.4 Insulation Resistance

Measure the insulation resistance of generators that have been stored or have not been operated for an extended period, before initial commissioning.

1. Ground all parts to which the measuring voltage is not applied.
2. Before measuring the insulation resistance of the winding, disconnect all connections (primary connection, measuring connection, connections to the control system, safety circuit and interference suppression circuit).
3. During insulation measurements, measuring equipment and measuring wires must be disconnected.
4. Before commissioning, measure the insulation resistance on the stator winding from phase to phase and from phase to ground, and also measure the rotor winding to ground.
5. The measurement is to be done using 1 kV DC on low-voltage generators (< 1 kV) or using 5 kV on high-voltage generators (≥ 1 kV).

Due to the capacitive charging of the winding, the measuring instrument only indicates the correct value for the insulation resistance after 60 seconds.

- The winding section is to be grounded immediately after switching off the measuring voltage

For excessively low insulation values:

1. Check insulation on the terminals for soiling and moisture.
2. Clean and dry terminals as necessary.
3. Repeat the insulation resistance measurements.
4. Damp windings can result in leakage currents, flashover or breakdowns. Damp windings must be dried.

For low-voltage generators with nominal voltage < 1 kV, as well as in the rotor winding, the insulation resistance must be 5 MΩ at 25 °C.

For medium and high-voltage generators with nominal voltage ≥ 1 kV the necessary insulation resistance in MΩ is to be calculated using the equation

$R \geq 3 + 2 \times U_N$ U_N

Where U_N is the nominal voltage of the generator in kV.

- As the windings are connected at the pillars or bars, these must be checked during the insulation test and measurement.

NOTICE
On all secondary connections and measuring connections, the maximum test voltage is 500 V DC. The insulation resistance must not be less than 5 MΩ

- The secondary connections, such as measuring connections to transducers, all connections to the control system, safety circuits and interference suppression circuits must be checked separately.
- Each of these connections must be checked separately on the terminal strip. During this process the insulation resistance of the terminal strip must be measured.

If the insulation resistance on new, cleaned or repaired windings is less than 5 MΩ, the winding must be dried.

7.4.5 Main Terminal Box

The inside of the main terminal box must be free of dirt, moisture and foreign bodies. The box itself, the cable glands and unused cable entries must be sealed.

The main terminal box is attached to the top or side of the generator. In the standard version three of the four terminals are used for the power outputs U1, V1 and W1; the fourth is used for forming the star point for the three ends of the windings U2, V2 and W2. In case of factory-fitted current transformers, a copper bar forms the fourth terminal (N).

A connection feature for low-voltage connections such as a control system, temperature sensor, heating or similar item is, depending on the size of the generator, either on the bearing plate on the B end or in a separate auxiliary terminal box on the stator housing.

7.4.6 Auxiliary Terminal Boxes

Auxiliary terminal boxes are attached to the generator to suit the additional equipment and customer needs; See the positions on the outline drawing.

The auxiliary terminal boxes are equipped with terminal blocks and cable glands. As standard, the maximum cross-section of the conductors must not exceed 1.5 mm² (0.0024sq. in.) and the voltage to 500 V. Existing cable glands are suitable for cables with a diameter of 10-16 mm (0.4 inch-0.6 inch).

7.4.7 Isolation Distances for the Primary Line Connections

The connections for the primary line cables must be designed in accordance with the operating conditions.

To ensure lasting, trouble-free operation, the isolation distances and the creep path distances must be adequately dimensioned. The minimum isolation distances and creep path distances must comply or exceed the requirements defined by:

- Local regulations
- Standards
- Classification regulations
- Hazard zone classification

7.4.8 Primary Line Cables

⚠ DANGER

Hazardous voltage.

Will shock, burn or cause death.

Fasten the primary line cable connections correctly to ensure reliable operation. Prevent vibration on the primary line cable connections. If necessary, use additional supports approved by the manufacturer. Provide the manufacturer with the related information during project planning.

⚠ DANGER

Hazardous voltage.

Will shock, burn or cause death.

Before installation of the generator, make sure that the power cables are disconnected from the supply system and that the cables are connected to the protective ground.

The dimensions of the power cables must be designed for the rated current and comply with local standards. The cable terminating fittings must be of a suitable type and be of the correct size. Check the connections on all equipment.

Standard stator terminals are marked in accordance with IEC 60034-8 using the letters U, V and W. The neutral terminal is marked with N. Insulation stripping, connecting and insulating high-voltage cables must be done in accordance with the instructions from the cable manufacturer.

Fasten the cables so that the bus bar in the terminal box is not placed under mechanical load.

Compare the phase sequence with the circuit diagram and rating plate.

- Seal unused cable glands in the terminal box and generator against the ingress of dust and moisture so they cannot loosen.
- Re-tighten all contact screws and nuts to the specified torque.
- If sudden loads or generator vibration are to be expected, fasten cables using cable clips or cable racks.
- Make sure there is enough play at elastically mounted equipment.

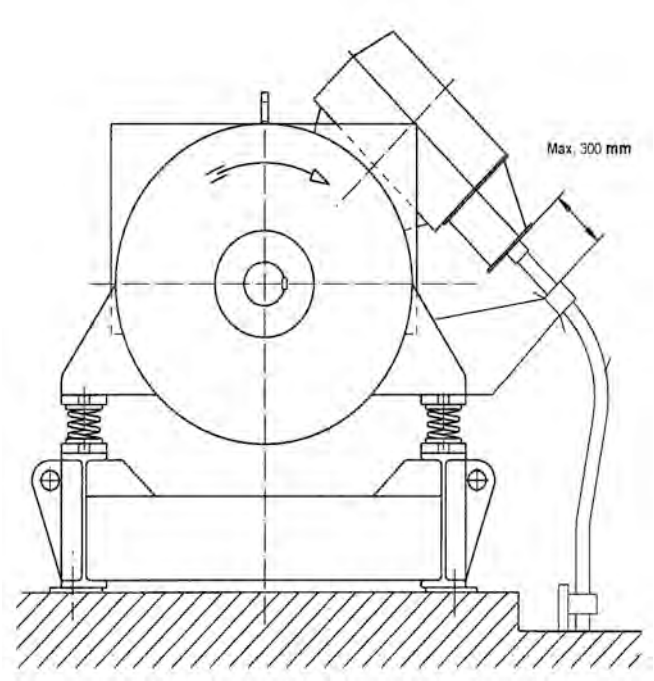


FIGURE 10. VIBRATION DAMPERS ON BASE FRAME. ENSURE FREE CABLE LENGTH.

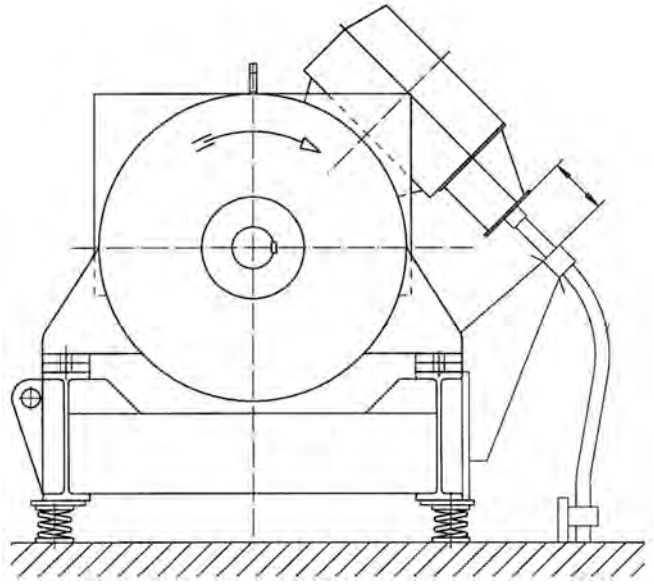


FIGURE 11. VIBRATION DAMPERS ON FOUNDATION. ENSURE FREE CABLE LENGTH.

7.4.8.1 Recommendation for Power Cable Connection to the Customer's System

- Connect the cables in accordance with DIN 46200
- Use approved screw locking elements for cable fastenings and only fit these to the connection on one side of the clamped conductor

The other side of the clamped conductor is reserved for carrying the electrical power. Only use washers or locking plates made of copper-zinc alloys (brass). Materials with equivalent electrical and mechanical properties are also allowed.

7.4.8.2 Recommendation for Bus Bar Connection to the Customer's System

- Bus bar connection in accordance with DIN 46200
- Use approved screw locking elements for the bus fastenings and only fit these to the connection on one side of the clamped conductor. The other side of the clamped conductor is reserved for carrying the electrical power, for this reason it is only allowed to use washers or locking plates made of copper-zinc alloys (brass).
- Materials with equivalent electrical and mechanical properties are also allowed.

Fasten the bus bar connections to the customer's system correctly to ensure reliable operation. Prevent vibration on the bars. If necessary, use additional supports and decoupling approved by the manufacturer. Provide the manufacturer with the related information during project planning.

7.4.8.3 Transducer Installation

Do not operate the generator until any required transducer is installed.

7.4.8.4 Interference Suppression

The generators comply with the requirements of interference suppression class "N" in accordance with VDE 0875.

For good interference suppression, pay attention to correct grounding with an appropriate protective ground conductor with the stipulated minimum conductor length.

7.4.8.5 Connection of Additional Equipment and Instruments

Mark the terminals of additional equipment if they are live while the generator itself is switched off.

Connect the instruments and the additional equipment as per the circuit diagram.

Refer to the circuit diagram supplied with the generator before connecting the cables. The connection and function of the additional equipment must be checked before commissioning.

7.4.8.5.1 Grounding Connections

Connect grounding according to local regulations before the generator is connected to the supply voltage.

The generator and related equipment must be connected to protective ground. The connections to protective ground must be able to protect the generator against damaging or dangerous electrical potentials (voltage).

The manufacturer's liability does not cover damage as a consequence of incorrect grounding or incorrect cabling in the customer's installation.

7.5 Criteria That Affect the Output Power

7.5.1 Design Criteria

The following criteria are used during design:

- Coolant temperature
- Installation altitude
- Degree of protection
- Type of cooling
- Power factor
- Ship classification

7.5.2 Effect of Coolant Temperature

Do not increase the output power above the rated output power specified in the order.

The limit temperature of the winding is definitive.

- If the cooling air temperature drops, the output power increases.
- If the cooling air temperature increases, the output power drops.

The parameters for the specific generator selected, e.g. reactances, apply in general for the rated output power defined (SN).

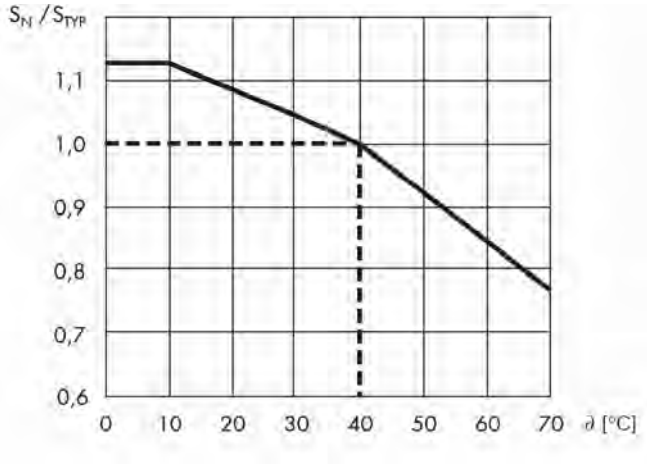


FIGURE 12. DEPENDENCY OF THE OUTPUT POWER ON THE COOLANT TEMPERATURE (STYPE FOR KT=40 °C)

7.5.3 Effect of Installation Altitude

As the density of air drops with increasing altitude, the ability of the air to absorb heat falls. The output power must be reduced or a larger generator must be selected.

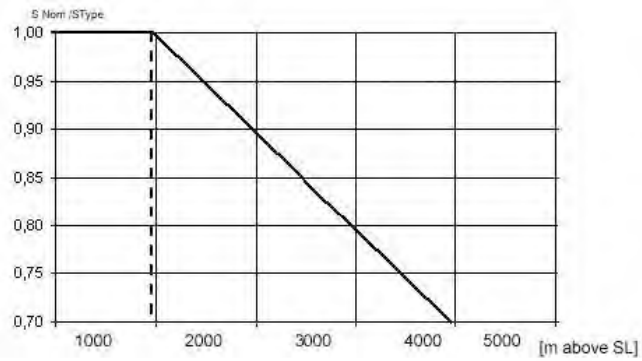


FIGURE 13. DEPENDENCY OF THE OUTPUT POWER ON THE INSTALLATION ALTITUDE

- Figure Figure 12 on page 53 and Figure 13 on page 54 apply to SType: KT=40 °C, installation altitude ≤ 1000 m, IP23, IC01)

7.5.4 Effect of Power Factor Cos Phi

The under-excited range from cos phi 0 to 1 is limited in case of:

- Individual operation due to the maintenance of the rated voltage by the voltage regulator.
- Operation in parallel with the line system due to stability against loss of synchronism.

The over-excited range is limited from:

- cos phi = 1 to the rated power factor by the output power of the prime mover
- cos phi = rated power factor to 0 by the permitted rotor heating

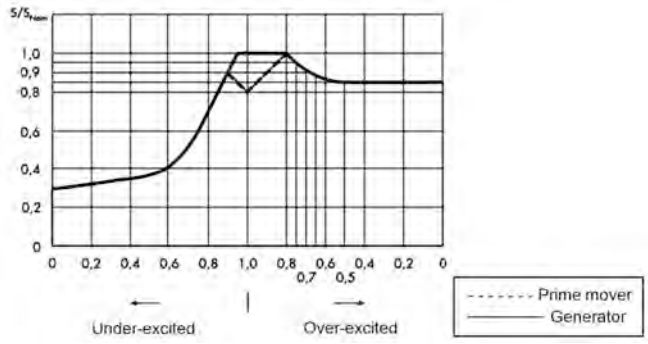


FIGURE 14. DEPENDENCY OF THE OUTPUT POWER ON THE POWER FACTOR

7.6 Electrical Behavior

7.6.1 Principle of Operation

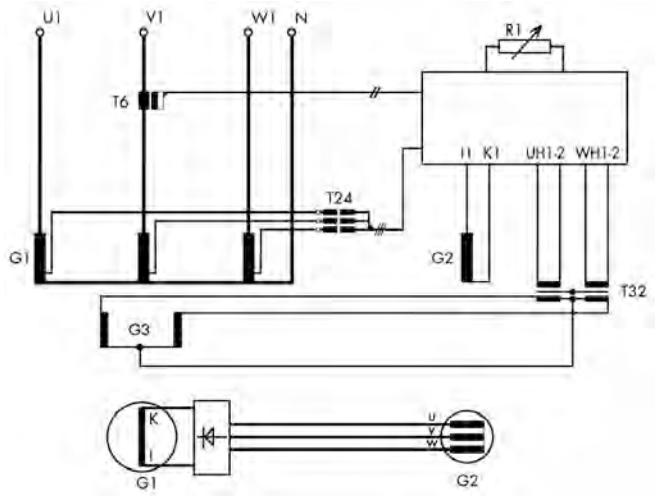


FIGURE 15. BLOCK DIAGRAM OF GENERATOR WITH AUXILIARY WINDING

G1	Primary machine
G2	Excitation machine
G3	Auxiliary windings
T6	Static transforme
T24	Measuring transformer
T32	Isolating transformer
R1	Set point adjuster

The auxiliary windings G3 supply the excitation winding of the brushless three-phase AC exciter G2 with power via the control element of the voltage regulator.

The voltage generated in the three-phase winding in the excitation rotor is rectified in a B6 bridge circuit and fed to the rotor in the generator G1.

The voltage of the primary generator is controlled with changing loads by the voltage regulator changing the excitation current in winding G2.

7.6.2 Voltage Regulator

The following voltage regulators can be installed in the generator, depending on customer requirements:

- Cosimat N+
- Basler DECS 100; 125, 200
- AVK Stamford DM110
- ABB Unitrol 1000; 1010, 1020
    - It is also possible to procure the generator without a voltage regulator.
    - The description of the voltage regulator is in the Appendix.

7.6.3 Self-excitation, De-excitation

7.6.3.1 Self-excitation

The following options are available:

- For generators with auxiliary windings, self-excitation is provided by permanent magnets in the excitation machine.
- In special cases, excitation can also be initiated using an external voltage of approx. 10 VDC.

Do not switch on external excitation when the generator is stationary.

7.6.3.2 De-excitation

⚠ DANGER

Hazardous voltage.
Will shock, burn or cause death.
When working on electrical systems be cautious because of the voltages. The value of the residual voltage is above the permitted physical contact voltage. Ensure that you adhere to the circuit diagram and use appropriate PPE.

The interruption must always be made on the regulator supply side (see order-specific documentation). For de-excitation the current in winding J1K1 on the excitation machine G2 must be reduced to zero.

- Disconnect power supply to the regulator by removing the jumpers or using a switch as per the circuit diagram.
- The switch contacts must be designed for 10 A and 230 V AC.

Follow the information in the related circuit diagram. After de-excitation the generator continues to generate a residual voltage of approx. 15% of U_N at the rated speed.

7.6.4 Voltage and Frequency

The generator is built to a maximum 15 kV for 50 or 60 Hz.

As standard the voltage and frequency range is defined in accordance with IEC 60034-1 zone A.

7.6.4.1 Voltage Adjustment Range

Depending on the voltage regulator used, the generators can be supplied with set point control for installation in the switch panel.

7.6.4.2 Static Voltage Behavior

The voltage accuracy is ± 0.5% to ± 1% under the following conditions:

- No-load to nominal load cos phi 0.1 …1
- Cold and warm machine
- Speed drop of 3%

7.6.4.3 Transient Voltage Behavior

The voltage change on a sudden load fluctuation depends on the reactance voltage drop of the generator G1.

The magnetic circuit and the winding are designed for low transient voltage changes.

External disturbance variables for the transient voltage change are:

- The relative current transient
- The power factor

With a basic load the transient voltage change is slightly lower than on the generator with no load.

On the application of full load with cos phi 0.8 the transient voltage change is approx. 18 to 25%.

- Refer to the order-specific data sheet for the exact values.

The time constants of the generator G1, the excitation machine G2 and the control system used, along with the dynamic speed drop as an external effect define the change in the voltage over time.

Up to the rated voltage, the excess excitation provided by the supply equipment is effective on switching in loads. As a result the generously dimensioned excitation system achieves short stabilization times.

This aspect affects the control properties.

The thermal design for continuous operation is for cos phi rated power factor. The normal operating range is from cos phi (rated power factor normally = 0.8) to cos phi=1.

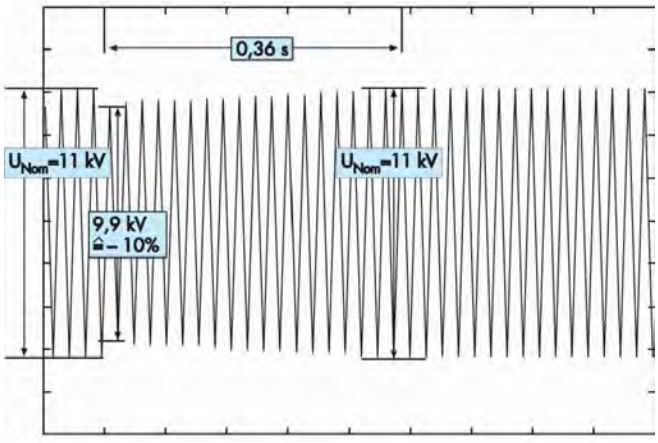


FIGURE 16. GENERATOR DIG 150I/8; 3300 KVA; 11 KV; 50 HZ; 750 MIN-1 SWITCHING IN 1000 KVA; COS φ = 0.1

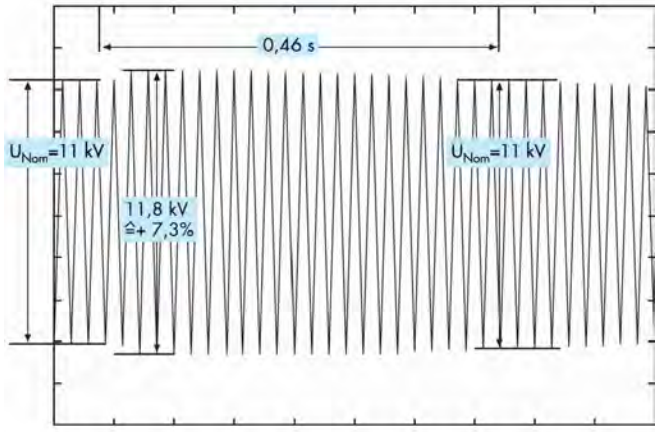


FIGURE 17. GENERATOR DIG 150I/8; 3300 KVA; 11 KV; 50 HZ; 750 MIN-1 SHUTTING DOWN 1000 KVA; COS φ = 0.1

7.6.4.4 Voltage Waveform Shape

The design of the magnetic circuit, the stator winding, the rotor contour and the form of the air gap result in a sinusoidal voltage waveform.

The definitions for the evaluation of the waveform shape are:

- Telephone Harmonic Factor "THF"
- Total Harmonic Distortion "THD"

  Here the requirements as per IEC 60034 are reliably met.

7.6.5 Currents

7.6.5.1 Asymmetrical Loading

The electrical design of the generator also permits asymmetrical loading.

For an asymmetrical load without loading on the other phases, the following are allowed as per IEC 60034-1.

1. I2/IN ≤ 8% continuous, where no stator current exceeds the rated current.
2. $(I2/IN)^2*t \leq 20$ s for transient processes.

7.6.5.2 Overload

- The generator is sized for 1.5 times rated current for 30 s duration.
- In line with the specifications for combustion engines, an overload of 1.1 times rated current for 1 hour is permitted once within 6 hours.
- The excitation system permits a brief overload up to 1.8 times rated current for approx. 10 s.

  This short-term overload capability is available, e.g. for starting currents for asynchronous motors.

7.6.5.3 Short-circuit Behavior

The generators are designed so that the transient voltage behavior is compliant with the requirements provided to the manufacturer. This behavior then defines the short-circuit behavior.

- Depending on the size of the generator, the current decays to the sustained short circuit current within 0.3 to 0.6 s

The primary components are sized so that the generator is able to supply 2.5-3 times the rated current for 5 s in case of a three-phase terminal short circuit.

- For a two-phase short circuit the sustained short circuit current is a factor of 1.4 to 1.7 times higher. In this way protective devices for the reliable selective isolation of the line system can be allocated.

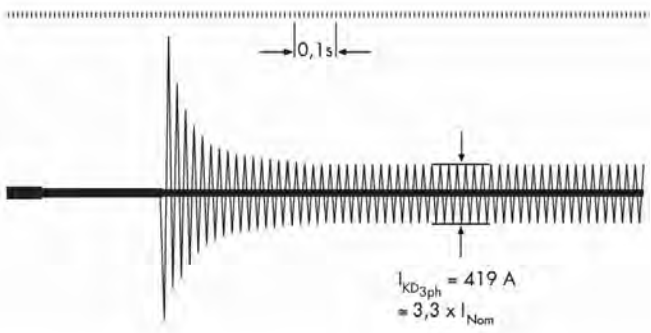


FIGURE 18. INSTANTANEOUS SHORT CIRCUIT CURRENT

7.6.5.4 Harmonic Load

Loads with non-linear load currents (e.g. rectifiers) cause harmonics on the voltage waveform.

The total harmonic distortion on the voltage waveform must be kept as low as possible to reduce the losses that occur as a result in the generator and in the system, and to ensure the correct function of the electrical equipment connected.

7.6.5.5 Standby Regulator

For increased reliability if the electronic voltage regulator fails, it is possible to manually or automatically switch the generator using a standby regulator.

The entire regulator unit, including:

1. Main regulator
2. Standby regulator
3. Manual or automatic change-over circuits must be installed in the switchgear.

7.6.5.6 Star Point Treatment of Neutral Conductor Current

Generators can be operated with a solidly grounded star point or with an ungrounded star point. The type of star point grounding is defined by the protection concept and not by the generator.

Different possibilities for star point grounding (neutral conductor grounding):

- Low impedance (solid) grounding
- High impedance grounding
- Ungrounded star point

NOTICE
A double ground fault behaves in all circumstances like a short circuit.

7.6.5.6.1 Low Impedance (Solid) Grounding

Differential protection for fast detection is stipulated. On grounding several star points high equalization currents occur due to harmonics; these currents place high thermal loads on the windings and above all on the neutral conductor.

- To reduce these currents, neutral conductor chokes are required.

Very high currents can occur for an earth fault on a phase.

- The high earth fault currents cause burning in the core and damage to the generator winding.

7.6.5.6.2 High Impedance Grounding

In case of high impedance grounding the fault current is limited by an appropriately dimensioned neutral conductor grounding resistor. The maximum possible ground current is to be limited to 5 A by grounding resistors. As neutral conductor grounding resistors are mostly designed for brief operation, selective protective devices must be provided.

In the worst case the winding insulation in the generator is loaded with a voltage to ground increased by the factor √3. Do not sustain a fault current longer than 2 hours, or accelerated aging of the winding insulation will occur.

7.6.5.6.3 Ungrounded Star Points

In case of a ground fault in ungrounded line systems a fault current does not occur.

The winding insulation in the generator is the loaded with a voltage to ground higher by the factor √3.

Do not sustain a fault current longer than 2 hours, or accelerated aging of the winding insulation will occur.

If the generator is to be operated in these conditions for an extended period, the winding must be designed with a higher insulation class.

7.7 Parallel Operation

7.7.1 General

The parallel operation of the required number of units enables good efficiency and optimal utilization.

The reliability is increased. In case of a failure of one unit and appropriate configuration, the other units can take over the output power.

7.7.2 Parallel Switching Conditions

The generators to be switched in parallel and line system must comply with the synchronization conditions, i.e. the generators must be the same in relation to the following criteria:

1. Voltage
2. Frequency
3. Phase sequence
4. Phase position

Permissible tolerances before connecting are:

1. Voltage difference taking into account the phase position: maximum 2% of U_N
2. Frequency difference: maximum 0.6% of f_N

To avoid incorrect synchronization, a synchronization control unit in the switch panel should only enable the circuit breaker once the synchronization conditions described are met. After switching in parallel the effective and reactive load distribution must be balanced.

7.7.3 Island Parallel Operation

- The prime movers define the effective load distribution.
- The voltage behavior of the generators defines the reactive load distribution.

The following methods of reactive load distribution are to be used:

1. Voltage droop
2. Power factor regulation

7.7.3.1 Voltage Droop

Terminal voltage is reduced as a function of the reactive current.

The distribution of the reactive load proportional to the rated output power of the generators requires the same voltage droop.

- For adjustment to other makes the voltage droop can be continuously adjusted from 0% to a maximum of 6% of the nominal voltage.
- For stable parallel operation the voltage droop is set in the factory to 3% at nominal current and cos phi 0.1.

This basic setting results in the following voltage droop curve:

TABLE 5. VOLTAGE DROOP

0%	at cos phi = 1
1.3%	at cos phi = 0.9
1.8%	at cos phi = 0.8
3%	at cos phi = 0.1

7.7.4 Operation in Parallel with the Line System

As the line system has a much higher short circuit power than the generators in the majority of cases, the number of units operating in parallel is irrelevant. As a result there is no significant effect as a result of this configuration.

Voltage fluctuations emanate largely from the line system.

In case of operation in parallel with the line system a power factor regulator is to be used.

As a result the power factor set remains constant in case of line voltage fluctuations as well as with varying generator loads.

If a specific power factor is required at the line transition point, the current transformer for the power factor regulator must be arranged at this point.

7.7.4.1 Power Factor Regulation

This process is used for operation in parallel with the line system. For the Cosimat N+, an additional regulator for power factor regulation controls the generator voltage regulator. This additional regulator, in the generator or in the switchgear, is used to maintain the power factor set point.

- For digital voltage regulators (e.g. DECS, Unitrol 1000) the power factor regulator is integrated.

As a result, the generator current has also to be monitored at the generator terminals as a function of the power factor.

This page is intentionally blank.

8 Commissioning and Starting

8.1 General

The commissioning report is an important document for future servicing and maintenance of the generator as well as any troubleshooting. Commissioning can only be considered complete once an adequate commissioning report has been prepared and archived.

It is imperative that the commissioning report is submitted on making claims under the warranty. For contact information see **Section 12.2 on page 122**.

8.2 Check the Mechanical Installation

1. Before commissioning check the alignment of the generator.
2. Review the alignment report and make sure that the generator is aligned in accordance with the manufacturer's alignment specification (see **Section 6.4 on page 38**)
3. The alignment report must always be included with the commissioning report. Make sure the generator is correctly anchored on the foundation.
4. Check the foundation for cracks and its general condition.
5. Make sure the fastening screws are tightened to the correct torque.
6. Check the direction of rotation of the generator, looking at the generator shaft DE.
7. Make sure the lubrication system is operational and running before the rotor is turned.
8. On generators with anti-friction bearings turn the rotor by hand (before the generator has been coupled) and make sure it rotates freely and no abnormalities, e.g. scraping or grating noises can be heard.
9. Check the installation of the main terminal box and the cooling system.
10. Check the ambient conditions and the function of the cooling system.
11. Check the connections for the oil and cooling water lines and check them for leaks during operation.
12. Check the pressure and the flow of oil.
13. Check the pressure and the flow of cooling water.

8.3 Check the Electrical Installation

Before the generator is started for the first time, after an extended period at standstill or during general servicing work, measure the insulation resistance, see **Section 7.4.4 on page 48**.

8.4 Controller and Protective Equipment

8.4.1 General

If the generator shuts down or in the event of an alarm, the reason must be found and corrected before re-starting the generator. The generator is equipped with several temperature sensors (PT100) in order to avoid overheating of the generator. These sensors must be connected to a temperature monitoring and protection system.

The temperature alarm level for resistive temperature sensors must be set as low as possible. The level can be determined based on test results or the operating temperature measured. The temperature alarm can be set 5 - 10 K (11 - 20 °F) higher than the operating temperature of the generator with maximum load at the highest possible ambient temperature.

If a temperature monitoring system with two functions is used, the lower level is normally used as the alarm level and the higher level as the shutdown level.

8.4.2 Stator Winding Temperature

Standard stator windings are manufactured in accordance with temperature rise class F. This class has a temperature limit of 155 °C (300 °F). A high temperature will result in the insulation aging more quickly and shortening the service life of the windings. Take this into account when defining the limits for alarm triggering and thermal shut down.

8.4.2.1 Maximum Temperature Setting

Carefully consider the application environment when setting the shutdown values during commissioning. After a test run at nominal load for approx. 3-4 hours, the temperature sensors must be set approx. 5 K above the values measured. During this process make sure that the maximum possible cooling air temperature is taken into account.

This statement applies in particular to the temperature monitoring for the anti-friction bearings/sleeve bearings, as a temperature increase is normally indicative of a bearing damage. Warning and shut down levels must be set close to the nominal temperature.

Do not exceed the temperatures stated in **Table 6 on page 64**.

8.4.2.2 Maximum Settings for the Stator Temperature - Class F

TABLE 6. WARNING TEMPERATURES AND SHUTDOWN TEMPERATURES FOR STATORS

Insulation class	Warning °C	Shutdown °C
Heating to B	125	130
Heating to F	140	145
Heating to H	155	160

8.4.3 Monitoring the Bearing Temperature

8.4.3.1 General

The bearings can be equipped with temperature sensors to monitor the bearing temperatures. The viscosity of the grease or oil used reduces at a higher temperature. If the viscosity becomes too low, it is no longer possible to form a film of lubricant in the bearing and the bearing will be damaged which in turn will damage the shaft.

If the generator is equipped with resistive temperature sensors, monitor the temperature of the bearings continuously. If the temperature of a bearing starts to increase unexpectedly, the generator must be shut down immediately, as the temperature increase may be indicative of a bearing failure.

8.4.3.2 Maximum Temperature Settings for Bearings

If not stated otherwise on the outline drawing, the following warning and shutdown limits apply.

TABLE 7. WARNING TEMPERATURES AND SHUTDOWN TEMPERATURES FOR BEARINGS

Bearing class	Warning °C	Shutdown °C
Anti-friction bearings	75	90
Sleeve bearings	85	90

8.4.3.3 Maximum Temperature Settings for Bearings - DIG 167

If not stated otherwise on the outline drawing, the following warning and shutdown limits apply for the sleeve bearings in the generator series DIG 167.

TABLE 8. WARNING TEMPERATURES AND SHUTDOWN TEMPERATURES FOR GENERATORS DIG 167

Bearing class	Warning °C	Shutdown °C
DIG 167 c/d/e	103	105
DIG 167 f/g/h	107	110
DIG 167 i/k	117	120

- These warning values and shutdown values can only be achieved by using the synthetic oils stated on the outline drawing.

8.4.3.4 Protective Systems

The generator must be protected against malfunctions, failures and overloads that could damage the generator. The protection must comply with the requirements and regulations in the specific country in which the generator is used. The manufacturer of the generator is not responsible for the adjustment of the protective systems.

8.5 First Run

8.5.1 General

The first test start is a standard procedure after installation and alignment, making mechanical and electrical connections, commissioning and activation of protective systems. The first start must be made without load.

8.5.2 Before Starting

Before the first test start the generator and its equipment are visually inspected. Make sure that all the necessary work, checks and settings have been made.

Before the first test start the following checks and measures prior are to be made:

1. Check the coupling and the coupling guard for correct assembly and loose parts.
2. Check that any fitted grounding brushes are free to move and are in contact with the shaft.
3. The sleeve bearings and, if required, the oil supply system must have been filled with the stipulated oil to the correct level. Then switch on the oil supply system, if necessary.
4. In case of water-cooled generators, place in operation the water cooling circuit. Check the flanges and cooling unit for leaks.
5. Compare the wiring and the bus bar connections with the circuit diagram.
6. Check grounding connections and grounding systems.

7. Check start, stop, protective and alarm relays in each system.
8. Check the insulation resistance of the windings and other equipment.
9. Fit the covers to the generator.
10. Clean generator and surrounding area.
11. Check that no loose parts (bolts etc.) are in the terminal box. If so, these must be removed.
12. Check the fan rotation direction.
13. Check the rotating parts do not touch any fixed components.

8.5.3 Starting

First check the direction of rotation of the generator on starting for the first time. If external fan motors are installed, check the direction of rotation. Check that the rotating parts do not touch any fixed components.

If the generator does not have a fixed bearing and the generator is started with a flexible coupling, it is normal for the shaft to move axially before it stabilizes. If installed, check the adjustment indicator and correct the alignment in case of errors (see **Section 6.4 on page 38**).

8.5.4 Direction of Rotation of the Generator and External Motors

The generator must be operated with the direction of rotation stated on the rating plate.

Check the direction of rotation of the generator based on the outline drawing.

Check the direction of rotation of any external motors installed (pumps, fans etc.). The direction of rotation is given by an arrow near the motor.

8.5.5 Ground Fault Monitoring

- Check the function of the ground fault monitoring.
- If the generator has a brush lifting device, check its position and function. Refer to **Section 10.8.7.1 on page 104**.

8.6 Operate the Generator for the First Time

8.6.1 Monitoring During Operation

During operation for the first time check whether the generator is functioning correctly. Constantly monitor the amount of vibration, the temperature of the windings, bearings and regulators.

- Check the operating load on the generator by comparing the load current with the value stated on the generator rating plate.

8.6.1.1 Check the Excitation

1. Check voltage rise during automatic operation.
2. Check regulation range of the automatic voltage regulation.
3. Check regulation range of the voltage with manual excitation.
4. Check switching from voltage regulation to current regulation with manual excitation.

8.6.1.2 Check the Synchronization Chain

The synchronization check is made in 2 stages.

1st stage:

The two measuring circuits in the synchronization chain are supplied from the same source. Check the following points:

1. The zero point for the synchronoscope
2. The zero indication on the differential voltmeter
3. The frequency meter

2nd stage:

One measuring transformers is supplied from the generator and the other from the line system to compare the related rotating fields.

8.6.1.3 Full Load Test

After stabilization, the following must be measured:

1. Stator winding
2. Cold air - warm air
3. Bearing on coupling end AS (DE)
4. Bearing on opposite end to the coupling BS (NDE)
5. Vibration measurement on the generator bearings (see **Section 10.5 on page 88**).

8.6.1.4 High-speed De-excitation

High-speed de-excitation is only necessary in case of certain malfunctions. For example, false synchronisation or if the generator is suddenly separated from the mains.

De-excitation switches are not included in the items supplied.

8.7 Check the Generator in Operation

During the initial days of operation, it is important to monitor the generator carefully for changes in vibration, temperature or abnormal noises.

8.7.1 Bearings

8.7.1.1 Generators with Anti-friction Bearings

- Do not re-grease the generator during commissioning.
- If the generator has been protected against corrosion, remove the corrosion protection before starting for the first time.

The type of grease used originally is stated on the rating plate on the generator. Refer to the allowed grease types in **Section 10.6.2.4 on page 94**, types of greases.

The temperature of the bearings increases at the start due to excess grease. After a few hours the excess grease is driven out and the temperature of the bearing drops to the normal operating level. See **Section 10.6.2.4 on page 94**

Adhere strictly to the re-lubrication interval. The interval between two lubrication intervals must not exceed 12 months under any circumstances. After the generator has been operated for several hours, measure the vibration and record the values for subsequent reference.

8.7.1.2 Generators with Sleeve Bearings

Make sure that no rotating parts rub on fixed parts. For self-lubricating bearings, check the oil level in the oil sight glass at standstill and at ambient temperature. It must be in the area from one third to half of the oil sight glass (see **Figure 21 on page 92**).

Continuously check the temperature and oil level in the bearings at the start. This is particularly important with self-lubricating bearings. If the temperature of the bearing suddenly increases, the generator must be stopped immediately and the cause of the temperature increase corrected, before the generator is started again. If no logical reason is found using the measuring equipment, open the bearings and check their state.

During the warranty period the manufacturer is always to be informed before measures are taken.

For self-lubricating bearings, check the rotation of the oil lubrication ring through the inspection window on the top of the bearing. If the oil lubrication ring is not rotating, stop the generator immediately to avoid bearing damage.

In case of generators with external lubrication, the oil supply is provided by external units. See documentation on the oil supply.

The use of higher supply pressures and increased flow rates will not provide any advantage and may result in leaks. The viscosity of the oil, the flow rates and the maximum oil inlet temperature are stated on the outline drawing.

The lubrication system must be designed so that the pressure in the bearing corresponds to atmospheric pressure (external pressure). Air pressure that enters the bearing via inlet or outlet pipes will result in oil leaks.

8.7.2 Vibration

You will find a detailed description of the vibration in **Section 10.5 on page 88**.

8.7.3 Temperature Level

Check the temperatures of the bearings, stator windings and cooling air with the generator running. (See **Section 8.4.2.1 on page 64**)

The winding and bearing temperatures only reach a stable temperature after several hours at maximum load.

The temperature of the stator winding depends on the load on the generator. If it is not possible to achieve full load during or just after commissioning, the actual and temperature values must be recorded and noted in the commissioning report.

1. Record the temperatures at the temperature sensors for the windings and if necessary for the bearings.
2. Check the temperature frequently to ensure it remains below the limits.
3. Continous temperature monitoring is required.

8.7.4 Heat Exchanger

- Before starting, make sure the connections are secure and there are no leaks in the system.

After the generator has run for a time it is necessary to check the cooling system.

- Make sure the coolant and, if necessary, the air can circulate without hindrance.

8.8 Shut Down the Generator

The procedure to shut down the generator depends on the application. Before commissioning clarify the concept for the shutdown procedure with the manufacturer of the drive unit and the switchgear.

However, it is recommended to:

1. Reduce, if necessary, the load in the load system
2. Disconnect the generator from the line system
3. Make sure there is no condensation in the generator.
4. Switch on any anti-condensation heaters, if these are not switched automatically by the switchgear.
5. For water-cooled generators, interrupt the flow of cooling water to prevent condensation inside the generator.

This page is intentionally blank.

9 Operation

9.1 General

⚠ CAUTION
Hot Surfaces. ***Will burn.*** ***Use PPE and measure the temperature of the surfaces before touching them.***

NOTICE
Generator overload can result in serious damage.

NOTICE
Always observe the safety precautions.

To ensure trouble-free operation, the generator must be carefully serviced and monitored.

Before starting the generator, ensure the following:

1. Check the sleeve bearings for the correct oil and oil level according to the technical data and the outline drawing
2. All cooling systems are operating
3. Check the generator and all attachments for leaks, soiling or damage
4. Check that there is no servicing work in progress
5. The operators and the system are ready for the machine start.

In case of deviations from the normal operating state, e.g. raised temperatures, noise or vibration, shut down the generator and find the cause. If in doubt, contact the manufacturer.

9.2 Normal Operating Conditions

The generator is designed for operation in normal operating conditions according to the order specification and manufacturer's internal regulations.

9.3 Number of Starts

The number of starts and shutdown processes in succession depends on the design of the generator. If in doubt, contact the manufacturer for this information.

Use a counter to check the number of starts. The servicing intervals are based on the related operating hours, see **Chapter 10 on page 77**.

9.4 Monitoring

Check the generator at regular intervals. Abnormal operating conditions must be investigated.

The objective of monitoring inspection is to make operating personnel familiar with the system. This aspect is very important for the timely identification and rectification of deviations and malfunctions. Normal operational monitoring includes logging the operating data such as load, temperatures and vibration.This data form a useful basis for servicing and maintenance.

During the initial operating period (up to 200 hours) monitor the generator particularly intensively. Check the temperature of the bearings and windings, the load, the current, the cooling, the lubrication and vibration several times a day.

In the subsequent weeks and months (200-1000 hours) a daily check is sufficient. Record the results of the check in the inspection report and archive it at the operating organization. Subsequently, the interval between the inspections can be further extended if operation is continuous and stable.

9.4.1 Bearings

Monitor bearing temperatures (see **Section 8.4.3 on page 64**) and lubrication (see **Section 10.6 on page 91**).

9.4.2 Vibration

Monitor the vibration level in the generator. See **Section 10.5 on page 88**.

9.4.3 Stator Temperatures

Check the temperatures of the stator windings and cooling air with the generator running. (See **Section 8.4.2 on page 64**)

9.4.4 Heat Exchangers

Make sure the connections are secure and there are no leaks in the system. Make sure the coolant and, if necessary, the air can circulate freely. (See **Section 10.9.3 on page 106**).

9.4.5 Slip Ring Units

Monitor the wear on the carbon brushes and replace them before the wear limit is reached. (See **Section 10.8.7 on page 103**).

9.4.6 Documentation of Operation

The documentation of operation includes logging the operating data including the load, temperatures and vibration. This data form a useful basis for servicing and maintenance.

9.5 Shutting Down

⚠ WARNING
Hazardous volatge. ***Will shock, burn or cause death.*** ***Use appropriate PPE and make sure that no voltage is present. There may be electrical power present in the auxiliary terminal box for the anti-condensation heater.***

See **Section 8.8 on page 69**.

9.6 Anti-condensation Heaters

Anti-condensation heaters increase the air temperature in the area of the windings to prevent the formation of condensation. Ideally the anti-condensation heater switches on automatically when switching off the generator.

9.7 Flashover Pressure Protection

NOTICE
If a flashover pressure event occurs in the terminal box, it is imperative that the entire generator is inspected without delay.

It is not sufficient to simply renew the flashover protection. A protective system for pressure relief is installed in Cummins generators; this system limits the extent of damage due to an event in the terminal box. A pressure event can occur if a fault causes flashover in the terminal box. During this process air and other materials suddenly expand to several times their initial volume due to the extremely high temperature.

Flashover protection attempts to reduce the pressure caused by this reaction in a defined manner using predetermined breaking points so that the effects of the event can be minimized. The objective is to exclude a hazard for personnel.

For this purpose a predefined breaking point for pressure relief is integrated into the sleeve on the terminal box. This feature consists of four individual plates that are arranged to form a square plate, or a metal film. The flashover protection is mounted pointing towards the generator to prevent harm to any person nearby and to minimize any debris thrown out.

The flashover protection must be sealed so that the required degree of protection is achieved, but the pressure relief function is not affected.

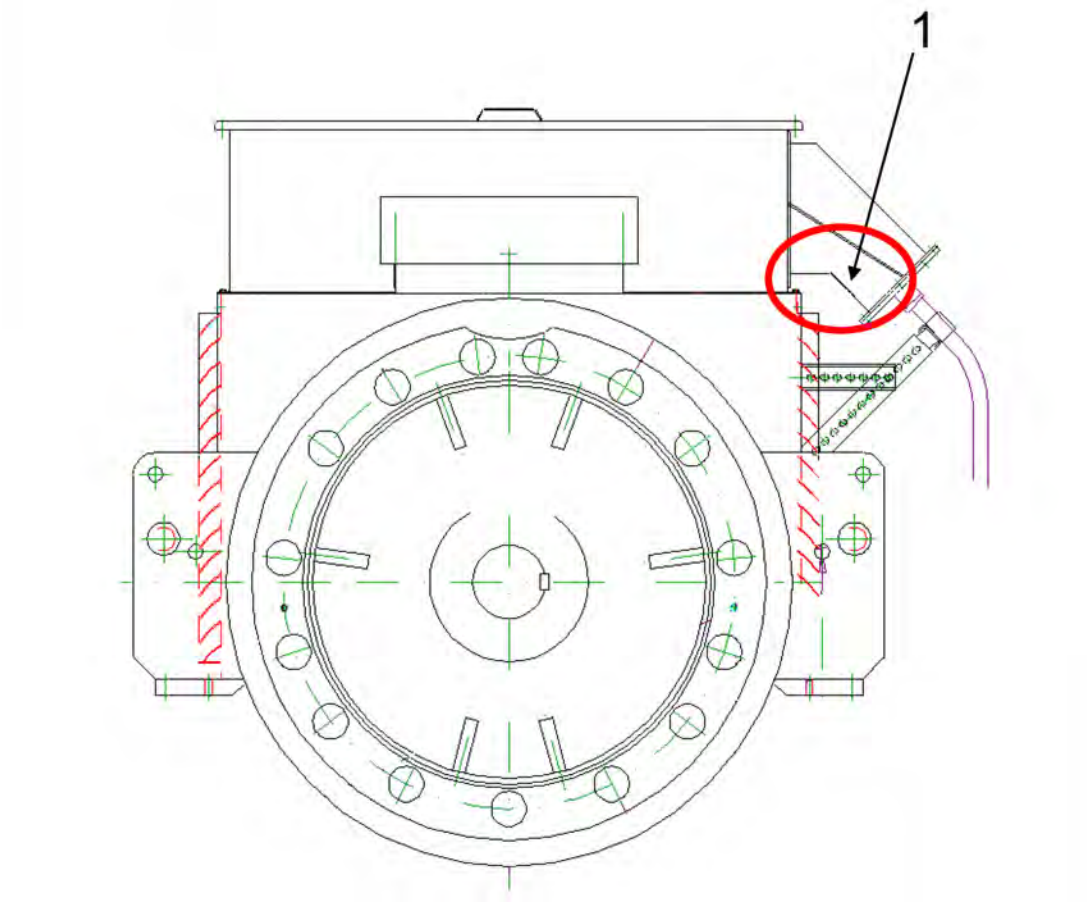


FIGURE 19. PROTECTION DEVICE (1)

9.8 Firefighting and Extinguishing Agents

9.8.1 General

NOTICE
If a flashover pressure event occurs in the terminal box, it is imperative that the entire generator is inspected without delay.

Pay attention to the generally applicable and national safety distances to electrical systems, e.g. DIN VDE 0132 (Fire-fighting in the area of electrical systems). Make sure regular inpection and tests are done.

Pay attention to the generally applicable and national health and safety regulations.

During extinguishing tasks in electrical systems and in their vicinity, take precautions to prevent an electric shock hazard for the fire fighters or operators.

This requirement also involves:

- The use of suitable tools and equipment, e.g.
  - Insulated tools
  - Grounding rods
  - Short circuiting devices
  - Insulating covers

- Insulating protective trim panels

The minimum distances required between extinguishing agent outlet opening and live parts of the electrical system are intended to protect the personnel undertaking the extinguishing task against the direct effects of electrical power during the extinguishing task.

9.8.2 Extinguishing Agents

The following can be used as extinguishing agents:

- Water
- Foam
- Powder
- Carbon dioxide

Select the extinguishing agents taking into account their suitability and use limitations.

While taking into consideration the disadvantages for fighting the fire as well as for the general public, shutdowns are only to be made with the agreement of the operating organization.

Extinguishing agents must only be used in the area of live electrical systems if the minimum distances to be maintained have been determined by the operating organization as a preparatory measure.

9.8.2.1 Extinguishing Agent - Water

Fires in the area of electrical systems are to be fought using a spray jet as far as possible.

In case of water containing other substances, such as wetting agents or elements that increase the conductivity, such as sea water and the like, conductive coatings on insulators are possible.

9.8.2.2 Extinguishing Agent - Foam

Low voltage systems:

Foam must only be used on electrically isolated systems; neighboring systems are also to be electrically isolated, if necessary. The use of type-tested extinguishing equipment approved for use in electrical systems is excluded from this limitation.

High voltage systems:

Foam must only be used on electrically isolated systems, without exception; neighboring parts of systems are also to be electrically isolated, if necessary.

9.8.2.3 Extinguishing Agent - Powder

Coatings of extinguishing foam can be conductive in higher electrical field strengths, created by high voltage (voltage above 1 kV) under the effect of temperature, moisture and humidity, and currents similar to short circuits can flow. The resulting arc faults represent a mortal danger for persons in the vicinity and hazard for the system. For this reason extinguishing powders must only be used if these systems are dry.

Avoid indirect hazards, to the persons in the vicinity and the high voltage system itself, due to conductive coatings.

Only use extinguishing powder that does not form coatings that are difficult to clean (e.g. vitrifiable coatings with ABC powder) on the parts of the system. Avoid the use of extinguishing powder in the area of system sensitive to dust (such as measuring and control systems, distribution cabinets with contactors and relays etc.

9.8.2.4 Extinguishing Agent - Carbon Dioxide (CO2)

⚠ WARNING

Suffocation by carbon dioxide.
Carbon dioxide is heavier than air and causes asphyxiation from 8% by volume.
Caution on use in small, poorly ventilated rooms. Pay attention to the warning information on the extinguishing equipment.

Carbon dioxide is not electrically conducting and does not leave any residue. It can be used on live systems without restriction.

9.8.3 Cleaning After Fire-fighting

Never place generators or systems back in operation that have not been cleaned adequately and their function fully checked.

NOTICE

Extinguishing agent residue can have a highly corrosive effect on parts of the generator. Contact the manufacturer of the extinguishing agent for information on suitable measures to counteract this effect and regularly check their effectiveness.

After all necessary measures for firefighting, immediately start to remove extinguishing agent residue.

Also check if parts of a system not directly affected by a fire may have been damaged or soiled by extinguishing agent.

The manufacturer does not provide any warranty on generators and their attachments if these are soiled by extinguishing agent.

10 Service and Maintenance

10.1 Preventive Servicing

A generator is often an important element of a larger installation.

If the generator is correctly monitored and serviced, the generator will function correctly and reliably for a long time.

The purpose of the servicing is therefore:

- To ensure that the generator operates reliably and without anomalies or interruptions
- To be able to plan the necessary maintenance work in advance to minimize the downtimes.

The normal monitoring during operation includes the recording of operating data, e.g. load, temperature and vibration, as well as checking for correct lubrication and measuring the insulation resistances.

During the first days and weeks after commissioning or undertaking maintenance measures, the generator must be monitored intensively. The temperature of the bearings and windings, the load, the current, the cooling, the lubrication and vibration are to be checked regularly.

This section contains recommendations in relation to a servicing schedule as well as instructions for normal servicing tasks. These instructions and recommendations are to be read carefully and used as the basis during the planning of the servicing schedule. Please note that the servicing recommendations stated in this section represent a minimum. More intensive maintenance and monitoring will increase the reliability and service life of the generator. The servicing should be intensified if there are local conditions with high requirements or extreme reliability is required. Cummins Service will be pleased to assist you in case of questions on the specific requirements categorization or servicing recommendations.

The data recorded during the monitoring and servicing will make it easier to foresee and plan further measures. If you detect anomalies, the instructions in troubleshooting will assist you in the location of the causes.

We recommend the use of checklists (in the Appendix) for the preparation of servicing schedules. The actual servicing as well as any troubleshooting must be done by specialist personnel. Cummins Service will be pleased to provide assistance with this task. You will find the related contact information at the start of the documentation.

A key element of the preventive servicing is the availability of a selection of suitable service parts. To be able to have quick access to crucial service parts in case of need, you should keep a basic range in stock.

10.2 Safety Precautions

⚠ DANGER

Hazardous voltage, will shock, burn or cause death.

When the generator rotor turns, the exciter generates a voltage.

Prevent the rotor turning before you open the terminal box. Never open the terminal box or touch the unprotected terminals while the generator rotor is rotating. Follow safety instructions at the start of the manual. See Chapter 2 on page 3.

⚠ WARNING

Hazardous voltages, rotating parts and hot surfaces will shock, burn or cause loss of limbs or death.

Before starting work on the unit, it is to be shut down and locked. During the work make sure that a potentially explosive atmosphere is not produced and is not present.

Qualified, specialist personnel trained in the necessary servicing procedures and tests are to be tasked with the servicing of the electrical system and the installation.

For general safety information, see safety instructions at the start of the manual. See **on page 3**. Before starting any work on electrical systems, take general electrical safety precautions and follow local regulations to prevent injuries. This action should be taken in accordance with the instructions from the operating organization's safety personnel.

Safety rules before starting work:

1. Switch off
2. Lock out
3. Check all lines and equipment are dead
4. Ground and short-circuit phases
5. Cover, partition and screen off adjacent line sections.

10.3 Recommended Servicing Schedule

This section represents a recommended servicing schedule. The servicing should be intensified if there are local conditions with extreme requirements or extreme reliability is required. It is also highlighted that even on following this servicing schedule, the normal monitoring and observation of the state of the generator are required.

Please note that in the servicing schedule below, accessory parts may be mentioned that are not present on all generators, even though the schedules have been adapted to this generator.

The servicing schedule is based on four servicing intervals; the related intervals are dependent on the operating hours. The amount of effort required and the downtimes vary:

Servicing interval 8000 operating hours

This servicing interval includes visual inspections and minor servicing work. The purpose of the servicing is to check whether problems are developing before they result in failures and unplanned interruptions for servicing. The service inspection also identifies further measures.

The servicing is dependent on the type and the installation of the generator as well as the feasibility of undertaking the inspection. The tools for this servicing work are normal servicing tools.

The servicing is to be done after an interval of 8,000 equivalent operating hours or one year after commissioning or servicing at the latest.

Servicing interval 25000 operating hours

This servicing interval can require the removal of generator components. The purpose of this servicing is to check inaccessible components to safeguard long-term operation.

The servicing is dependent on the type and the installation of the generator as well as the feasibility of undertaking the inspection. The tools for this servicing include special servicing tools.

The servicing is to be done after an interval of 25,000 equivalent operating hours or three years after commissioning or servicing at the latest.

Servicing interval 50000 operating hours

This servicing interval can require the removal of generator components. The purpose of this servicing is to check inaccessible components to safeguard long-term operation.

The servicing is dependent on the type and the installation of the generator as well as the feasibility of undertaking the inspection. The tools for this servicing include special servicing tools.

The servicing is to be done after an interval of 50000 equivalent operating hours or 6 years after commissioning at the latest.

Servicing interval 100000 operating hours

This servicing interval requires a complete generator overhaul.

The purpose of this servicing is to equip the generator for continued long-term operation.

The servicing is dependent on the type and the installation of the generator. The servicing can only be done by appropriately qualified personnel.

The servicing is to be done after an interval of 100000 equivalent operating hours after commissioning.

10.3.1 Generator

	SERVICING WORK		TYPE					Servicing Intervals			
System	X = required * = if necessary O= see rating plate/documentation	Generator in operation	Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
General	Machine operation - Starting, shutting down, vibration measurement	*	X	X	*		X	X			
	General overhaul					*					X
	Coupling and foundation - Specially cracks, rust, alignment	*	X	X			X	X			
	Paint finish - Rust, condition		X		X		X		X		
	Screw joints - Strength of all screw joints		X	X			X	X			
	Foundation screws - Fastening, condition		X	X			X	X			
	Grounding - Connection, function		X	X			X	X			
	Vibration	X		X			X	X			

10.3.2 Main Electrical Connections

	Servicing Work		Type					Servicing Intervals			
System	**X = required** *** = if necessary** **O= see rating plate/documentation**	Generator in operation	Visual inspection	Test and measure	Clean	Repair or replace	During commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Main electrical connections	Main electrical cables - Wear, fastening		X	X			X	X			
	Main electrical cables - Oxidation, fastening, cracks, screw joints		X	X			X	X			
	Main electrical connections - Insulation, resistance		X	X			X	X			
	Main electrical cables - Strain relief		X	X			X	X			
	Regulator - Function	X		X			X	X			
	Current transformers, voltage transformers, isolators - General condition, fastening, connections		X	X			X	X			
	Cable routes - Condition of the cables to the generator and in the generator		X	X			X	X			

10.3.3 Stator and Rotor

	SERVICING WORK		TYPE					Servicing Interval			
System	X = required * = if necessary O= see rating plate/documentation	Generator in operation	Visual inspection	Test and measure	Clean	Repair or replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Stator and rotor	Stator - Fastening, cracks, weld seams		X				X	X			
	Insulation of the stator winding - Wear, cleanliness, insulation resistance,		X	X	*		X	X			
	Stator winding assembly - Damage to insulation		X		*		X	X			
	Exciter stator - rotor Resistance			X			X	X			
	Rectifier carrier - Fastening, cable, diodes, varistors		X	X	*		X	X			
	Auxiliary windings - Resistance measurement			X			X	X			
	Stator slot wedges - Movement; firm seating		X						X		
	Stator terminals - Fastening, insulation		X	X			X	X			
	Instrumentation - Condition of the cables and cable ties		X				X	X			
	Rotor winding insulation - Wear, cleanliness, insulation resistance		X	X	*		X	X			
	Anti-condensation heaters - Operation, insulation resistance		X	X	*		X	X			
	Shaft position axial alignment		X	*			X	X			
	Connections on the rotor - Fastening, general condition		X				X	X			
	Grounding brushes - Operation and general condition	*	X				O				
	Fan - Soiling, condition		X				X	X			

10.3.4 Accessories

System	SERVICING WORK X = required * = if necessary O= see rating plate/documentation	Generator in operation	TYPE Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Servicing Intervals Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Accessories	PT-100 elements (stator, air cooling, bearings) - Resistance	*		X			X	X			
	Auxiliary terminal box **-** General condition, terminals, condition of wiring		X	X	*		X	X			

10.3.5 Slip Ring Units

System	SERVICING WORK X = required * = if necessary O= see rating plate/documentation	Generator in operation	TYPE Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Servicing Intervals Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Slip Ring Units	Assembly - Fastening, insulation, connections	*	X		*	*	X	X			
	Brush holder - Alignment, function		X	X	*	*	X	X			
	Brushes - Wear, function		X	X		*	X	X			
	Slip ring wiring		X				X	X			
	Slip rings - Wear, roundness, patina		X				X	X			

10.3.6 Lubrication System and Anti-friction Bearings

	SERVICING WORK		TYPE					Servicing Intervals			
System	X = required * = if necessary O= see rating plate/documentation	Generator in operation	Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Lubrication system and anti-friction bearings	Bearings - During operation; general condition, noise, vibration	X	X	X		X	X				
	Bearing condition analysis - SPM measurement	X		X			X	X			
	Surplus grease - Condition and discharge		X		X			X			
	Lubrication system - freedom from leaks and function		X		*	*		X			
	Seals - Freedom from leaks		X			*		X			
	Grease - paint and condition		X			*		X			
	Re-lubrication interval	X					O				
	Bearing insulation - insulation resistance		X							X	

10.3.7 Lubrication System and Sleeve Bearings

	SERVICING WORK		TYPE					Servicing Intervals			
System	X = required * = if necessary O = see rating plate/documentation	Generator in operation	Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Lubrication system and sleeve bearings	Bearing assembly -Fastening, general condition, soiling		X	X	*		X	X			
	Oil - oil level		X			*	O				
	Bearing shells -General condition, wear		X		*					X	
	Loose lubrication ring - Condition, abraded material		X		*					X	
	Loose lubrication ring -Function		X			X	X				
	Gaskets and seals -Freedom from leak		X	X		*	X	X			
	Bearing insulation -Condition, insulation resistance		X			*				X	
	Operation - Freedom from leaks, operation		X	X		*	X	X			
	Oil -Change interval					X	O				
	Oil - Type, quality, quantity, flow rate, pressure		X	X		*		X			
	Oil lubrication - Function, amount of oil		X				X	X			
	Flow rate regulator - Function		X	X			X	X			
	Oil tank - Cleanliness, freedom from leaks		X		*		X	X			
	Additional units - Operation		X	X	*		X	X			
	Oil cooler / oil heating -Oil temperature		X	X	*		X	X			

10.3.8 Cooling System

	SERVICING WORK		TYPE					Servicing Intervals			
System	X = required * = if necessary O = see rating plate/documentation	Generator in operation	Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Generator cooling	Fan - Operation, condition		X		*		X	X			
	Generator inlet air Hindrance - amount		X				X	X			
	Filter - Cleanliness, operation		X		*	*	O				
	Air paths - Cleanliness, operation		X		*		X	X			
Air-air cooling	Fans - Operation, condition		X		*		X	X			
	Pipes - Cleanliness, operation		X		*		X	X			
	Ducts - Cleanliness, operation		X		*		X	X			
	Metal ribs - General condition		X		*		X	X			
	Vibration dampers **-** Condition and function		X			*	X	X			
Air-water cooling	Heat exchangers -Freedom from leaks, operation, pressure		X				X	X			
	Cooler condensate drain - Function, cleanliness		X		*		X	X			
	Pipes - Cleanliness, corrosion, freedom from leaks		X		X				X		
	Ducts - Cleanliness, operation		X		X				X		
	Cooler housing - Freedom from leaks, condition		X		*		X	X			
	Gaskets and seals -Freedom from leaks, condition, cracks		X			*		X			
	Metal ribs - General condition		X		*				X		
	Vibration dampers - Condition and function		X			*	X	X			
	Check for leaks		X	X	X	*	X	X			

10.3.9 Safety

	SERVICING WORK		TYPE					Servicing Intervals			
System	X = required * = if necessary O= see rating plate/documentation	Generator in operation	Visual inspection	Test and Measure	Clean	Repair or Replace	During Commissioning	Every 8,000 hours or 1 year	Every 25,000 hours or 3 years	50,000 hours or 6 years	100,000 hours
Safety	Alarm system - Function and correctness			X			X	X			
	Warning and shutdown temperatures - Correct adjustment, function			X			X	X			
	Overcurrent shutdown Function		X	X			X	X			
	Check differential protection		X	X			X	X			

10.4 Servicing - General Structure

To ensure a long service life of the general structure of the generator, the exterior of the generator is to be kept clean and is to be regularly checked for rust, leaks and other faults. Soiling on the external parts of the generator will subject the generator to corrosion and can affect its cooling.

10.4.1 Strength of Screw Fasteners

NOTICE
Loose fastenings on these parts can result in sudden and serious damage. Check and re-tighten the fastenings regularly.

The strength of the screw fasteners is to be checked regularly. In particular attention is to be paid to the base fastening and the screws for the attachments; these screws must always be correctly tightened.

See the general values for tightening torques in **Table 9**.

TABLE 9. GENERAL TIGHTENING TORQUES (STEEL - STEEL)

Thread size	Property class	Tightening torque Nm	Tightening torque (foot-pound)
M4	8.8	3.0	2.2
	10.9	4.6	3.4
	12.9	5.1	3.8
M5	8.8	5.9	4.4
	10.9	8.6	6.3
	12.9	10.0	7.4
M6	8.8	10.1	7.4
	10.9	14.9	11.0
	12.9	17.4	12.8
M7	8.8	16.8	12.4
	10.9	24.7	18.2
	12.9	28.9	21.3
M8	8.8	24.6	18.1
	10.9	36.1	26.6
	12.9	42.2	31.1
M10	8.8	48	35
	10.9	71	52
	12.9	83	61
M12	8.8	84	62
	10.9	123	91
	12.9	144	106
M14	8.8	133	98
	10.9	195	144
	12.9	229	167
M16	8.8	206	152
	10.9	302	223
	12.9	354	261
M18	8.8	295	218
	10.9	421	311
	12.9	492	363
M20	8.8	415	306
	10.9	592	437
	12.9	692	363
M22	8.8	567	418
	10.9	807	595
	12.9	945	697
M24	8.8	714	527
	10.9	1017	750
	12.9	1190	878

Thread size	Property class	Tightening torque Nm	Tightening torque (foot-pound)
M27	8.8	1050	774
	10.9	1496	1103
	12.9	1750	1291
M30	8.8	1428	1053
	10.9	2033	1499
	12.9	2380	1755
M33	8.8	1928	1422
	10.9	2747	2026
	12.9	3214	2371
M36	8.8	2482	1831
	10.9	3535	2607
	12.9	4136	3051
M39	8.8	3208	2366
	10.9	4569	3370
	12.9	5346	3943

NOTICE

The values in the table General tightening torques are of a general nature and do not apply to components such as diodes, auxiliary isolators, bearings, cable terminals or pole fastenings, bus bar terminals, overvoltage arrestors, current transformer fastenings, rectifiers or varistors or other electrical connections, or if another value is stated in this manual or in the manufacturer's documentation.

10.5 Vibration

High or increasing vibration levels are indicative of changes in the condition of the generator. Normal levels vary widely as a function of the use, the type and the generator foundation. Typical causes of high vibration levels are:

- The alignment has changed
- Bearing wear or bearing damage
- Vibration is occurring on machines connected or the vibration has changed
- Fastening or foundation screws have loosened
- Rotor imbalance has changed
- Couplings are worn

The following instructions are part of the following two ISO standards:

ISO 10816-3 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts: Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ

ISO 8528-9 Reciprocating internal combustion engine driven alternating current generating sets: Part 9: Measurement and evaluation of mechanical vibrations.

10.5.1 Measuring Methods and Operating Conditions

10.5.1.1 Measuring Equipment

The measuring equipment must be able to measure the effective broadband vibration with a linear frequency response from at least 10 Hz to 1000 Hz. Depending on the vibration criteria this aspect can require measurements of displacement or velocity or a combination of the two. The lower limit for the frequency range with a linear frequency response must, however, not be less than 2 Hz for machines with speeds of 600 rev/min and below.

10.5.1.2 Measuring Points

Measurements are normally made on accessible parts of the generator. Make sure that the measurements appropriately reflect the vibration in the bearing housing and do not contain any local resonances or amplification. The locations and directions of the vibration measurements are to be selected so that they offer appropriate sensitivity for the generator dynamic forces. Typically this aspect requires two orthogonal radial measuring points on each bearing, as shown in **Figure 20 on page 89**. The transducers can be applied at any angular position on the bearings. Generators are measured in vertical, axial and horizontal directions. The measuring points and measuring directions are to be noted together with the measured values.

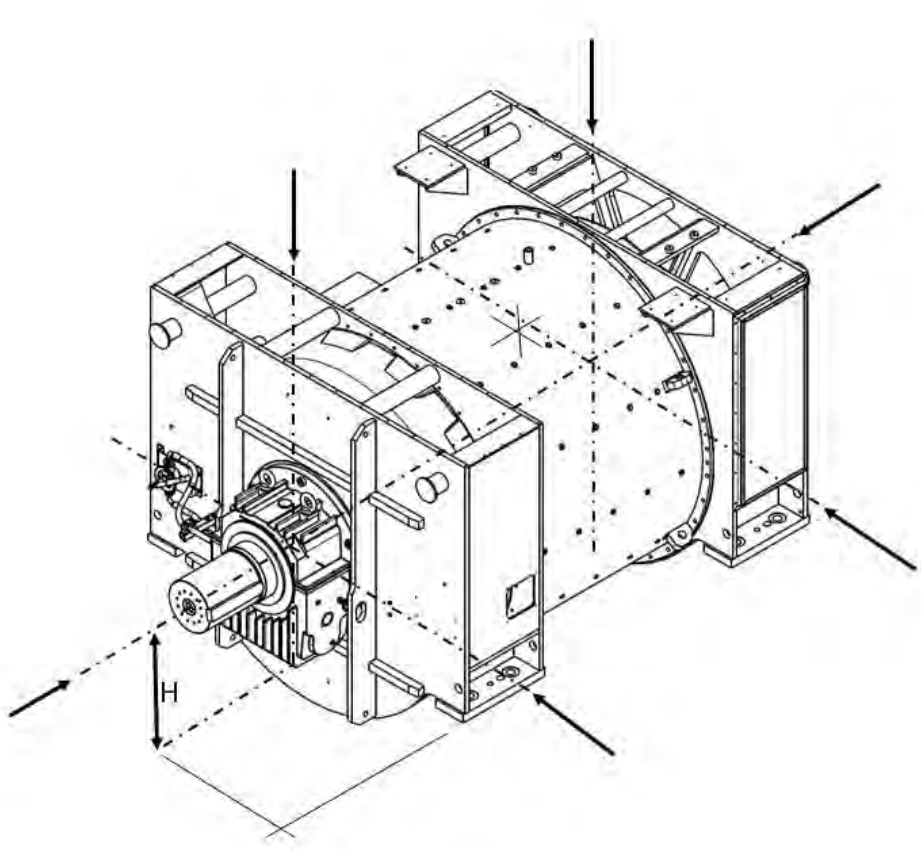


FIGURE 20. DIN 10816-3 - SPECIFICATION FOR MEASURING POINTS

10.5.2 Definition in Accordance with ISO 10816-3

ISO 10816 -3 provides a general description of the two evaluation criteria for determining the magnitude of the vibration on different machine classes. One criterion takes into account the magnitude of the broadband vibration observed, the other takes into account changes in magnitude (both increases and reductions).

TABLE 10. ISO 10816-3

Division of the vibration magnitude zones					
		Large machines with nominal output powers over 300 kW and not more than 50 MW		**Medium-sized machine with nominal output powers 15 kW to 300 kW**	
		Electrical machines with axis heights H > 315 mm		**Electrical machines with axis heights 160 mm < H < 315 mm**	
Sub-assembly	**Zone limit**	**Effective value for the vibration displacement**	**Effective value for the vibration velocity**	**Effective value for the vibration displacement**	**Effective value for the vibration velocity**
		µm	mm/s	µm	mm/s
Rigid	A/B	29	2.3	22	1.4
	B/C	57	4.5	45	2.8
	C/D	90	7.1	71	4.5
Elastic	A/B	45	3.5	37	2.3
	B/C	90	7.1	71	4.5
	C/D	140	11	113	7.1

10.5.3 Definition in Accordance with ISO 8528-9

ISO 8528-9 refers to a broad band of frequencies between 10 and 1000 Hz. The following table is an extract from ISO 8528-9 (Table C.1, value 1). This simplified table contains the vibration limits by kVA range and the speed for acceptable generator set operation.

TABLE 11. ISO 8528-9

Declared engine speed revs/min	**Rated power output of the generating set**		**Vibration velocity V_{rms} Value 1 mm/s**
	(cos phi = 0.8) kVA	**KW**	
> 1300 but < 2000	> 250	> 200	20
> 720 but < 1300	> 250 but < 1250	> 200 but < 1000	20
	> 1250	> 1000	18
=< 720	> 1250	> 1000	15

10.5.4 Warning Values and Shutdown Values

We recommend regularly checking the condition of the generator using a suitable instrument for vibration monitoring during servicing, or checking the condition continuously. For this purpose it is best to measure initial values and to use these values as the basis for the regular monitoring of the generator to detect possible degradations. The warning values and shutdown values are to be adjusted in accordance with the related standard and in combination with the existing operating conditions.

10.6 Servicing the Bearings and the Lubrication System

This section addresses the most important servicing work on the bearings and on the lubrication system.

10.6.1 Sleeve Bearings

In case of normal operating conditions, sleeve bearings only require little servicing.

To ensure reliable operation, the temperature is to be monitored and the oil level as well as the freedom of the bearing from leaks is to be checked.

10.6.1.1 Oil Tank

The oil tank must be designed so that no pressure from the tank can enter the oil return line to the bearing. The oil tank can be either a separate tank or comprise an external oil circuit. In both cases the tank must be arranged clearly below the bearing so that oil can flow to the tank from the bearings.

10.6.1.2 Pressure in the Oil Tank

The atmospheric pressure in the oil tank is to be checked. The pressure must not be higher than the pressure outside the bearing. In case of overpressure, the vent on the oil tank is to be checked or fitted if necessary.

10.6.1.3 Oil Lines

The oil return line is used to return the oil from the sleeve bearing to the oil tank with the lowest possible resistance. This is achieved by using a pipe with an adequately large diameter so that the flow of oil in the return line does not exceed 0.15 m/s (6 inch/s) based in the pipe cross-section.

- Install the oil outlet lines underneath the bearings with a minimum angle of 15°, which corresponds to a fall of 250 - 300 mm/m (3 – 3½ inch/foot).
- The line must be assembled so that the fall stated above is present on all parts of the line.
- Make sure that the line has an adequate diameter, is not clogged and that the entire oil return line has an adequate downward gradient.

10.6.1.4 Oil Flow

The inlet oil flow is calculated for each bearing. The oil flow must be adjusted appropriately during commissioning.

The generator settings are defined on the outline drawing.

10.6.1.5 Oil Level

The oil level for a self-lubricating sleeve bearing must be regularly checked when the generator is at standstill and at ambient temperature. It must be in the area from one third to half of the oil sight glass.

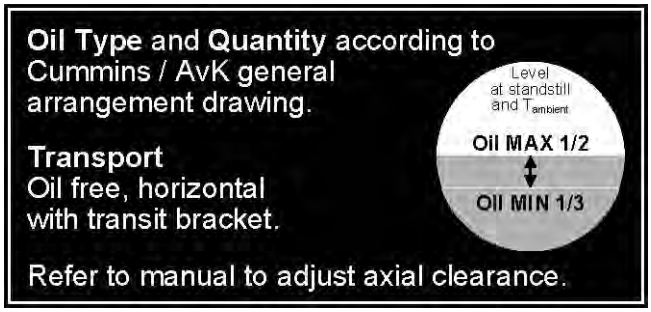


FIGURE 21. OIL LEVEL

Overfilled oil must be drained by opening the oil drain. For externally lubricated sleeve bearings the oil sight glass may be replaced with an oil outlet flange.

10.6.1.6 Bearing Temperature

The bearing temperatures are measured using a resistive temperature sensor Pt-100. A temperature increase in the bearing beyond the alarm limit can be caused by either increased losses or by a reduced cooling capacity. This often indicates a generator problem or a problem in the lubrication system and must be clarified.

Temperature variations may have various causes (see **Section 11.8 on page 114**). If the temperature increase is followed by an increased vibration level, the problem may also be related to the alignment of the generator, see **Chapter 6 on page 33**, or damage to the bearing shells; in this case the bearing must be dismantled and checked.

10.6.1.7 Lubrication of Sleeve Bearings

The generators are equipped with sleeve bearings that feature a very long service life, provided the lubrication functions continuously, the type of oil and quality of the oil correspond to the recommendations from the manufacturer and the instructions on oil changes are followed.

10.6.1.8 Lubricating Oil Temperature

The correct lubricating oil temperature is of significant importance for maintaining the bearing at the correct operating temperature and to ensure there is adequate lubrication. For generators that are operated with oil supply systems, the incorrect function of the oil cooler or the oil heater and an incorrect oil flow can cause temperature problems. If temperature problems occur, check whether the quality and quantity of oil are correct for all bearings. For further information see **Section 10.6.1.9 on page 92** and **Section 10.6.1.11 on page 93**.

NOTICE
On starting the generator pay attention to the ambient temperature. The temperature of the oil must not be below a minimum limit. State the minimum temperatures during order clarification. See standard IEC 60034. Consult Cummins Service department if your installation is below the minimum temperature. Starting at excessively low temperatures can result in serious bearing damage.

10.6.1.9 Recommended Check Values for Lubricating Oil

The lubricating oil is to be checked in relation to the following aspects:

- Use a test bottle to undertake a visual inspection of the oil for color, turbidity and deposits. The oil must be clear. The turbidity must not be caused by water. Check the odor of the oil. A strongly acidic or burnt odor is not acceptable.
- The water content must not exceed 0.05%

- The original viscosity must be maintained within a tolerance of ±10%.
- The oil must not contain any visible soiling. Its purity must correspond to ISO 4406 class 21/18/15 or SAE 4059 class 9
- The amount of metal soiling must be less than 50 PPM. An increase in this value is indicative of bearing damage.
- The increase in the acid number (AN) must not exceed 1 mg KOH per gram of oil. Please note that the AN value is not the BN value (base number).

If in doubt, an oil sample can be sent to the laboratory to determine the viscosity, the acid number, the tendency to foaming etc.

10.6.1.10 Lubricant Check

During the first year of operation it is recommended to take samples of the lubricating oil after around 1,000, 2,000 and 4,000 operating hours. Send the samples to the oil supplier for analysis. The optimal oil change interval can be determined based on the results.

After the first oil change, the oil can be analyzed in approximately middle and at the end of the oil change interval.

10.6.1.11 Oil Quality

See outline drawing.

If a lubricant type is not stated on the outline drawing, please refer to the lubricant recommendation from the sleeve bearing manufacturer.

NOTICE
Check for the correct oil quality using the bearing identification plate and the outline drawing. Incorrect or soiled oil will result in serious bearing damage.

10.6.1.12 Oil Change Schedule for Mineral Oils and Synthetic Oil

⚠ **CAUTION**
Oils can cause skin irritation and eye infections. ***Avoid physical contact by wearing disposable gloves and protective equipment.*** ***Pay attention to all the safety measures stated by the oil manufacturer.***

Perform the oil change interval for self-lubricating bearings after 8,000 operating hours, for externally lubricated bearings after 20,000 h.

For frequent starts, slow turning, high oil temperatures or excessively high contamination due to external effects, shorter intervals are required.

NOTICE
For slow turning and for frequent starts and stops, it is highly recommended to use a hydro static device.

10.6.2 Anti-friction Bearings

10.6.2.1 Bearing Design

After the bearing has been filled with grease for the first time, it is not normally necessary to top-up the grease for a long time. However, in difficult operating conditions the grease must be regularly topped-up or replaced. For this purpose the bearing housing is designed so that the grease is easy to top-up. The bearing housing is designed so that the old grease will be replaced with fresh grease. In the bearing covers there is a space where the grease can be introduced. The grease runs slowly through the bearings and old grease, which escapes on the opposite side of the bearing, is drained via the grease regulator. The grease is guided to the exterior via the grease outlet.

10.6.2.2 Rating Plate: Lubrication and Re-lubrication Intervals

NOTICE
It is imperative the information stated on the rating plate is taken into account during the operation and servicing of the generator.

All generators are supplied with rating plates that are attached to the stator. The rating plates provide information on bearings, for instance:

- Type of grease used
- Re-lubrication interval
- Amount used for re-lubrication

10.6.2.3 Anti-friction Bearing Grease for Extreme Temperature

If the bearing operating temperature is continuously:

- above 75 °C (167 °F)
- below 0 °C (32 °F)

Ask the manufacturer about suitable greases.

10.6.2.4 Re-lubrication

⚠ **CAUTION**
Grease can cause skin irritation and eye infections. ***Avoid physical contact with the hands by wearing disposable gloves.*** ***Pay attention to all the safety measures stated by the grease manufacturer.***

All anti-friction bearings on rotating electrical machines must be regularly re-lubricated, see rating plate. The lubrication can be either manual or with the aid of an automatic system. In both cases make sure that an adequate amount of the correct lubricant reaches the bearing at the stipulated intervals.

Manual re-lubrication of the bearings

Generators that are designed for manual lubrication are fitted with grease nipples. To ensure that no dirt enters the bearings, clean the grease nipples and their surrounding area thoroughly before lubrication.

Only re-lubricate with the generator running!

Re-lubrication is always done at the generator nominal speed. Re-lubrication at standstill is not allowed, as the grease will not be correctly distributed in the bearing. The grease takes the path of least resistance to the opposite side of the bearing. At standstill this means that the grease cannot flow out of the bearing chamber and the replacement of the old grease is not ensured.

10.6.2.5 Lubricating at Load

The load state of the generator is not of significance during re-lubrication. Re-lubrication must be performed at the predominant related operating state on reaching the time for re-lubrication, whether full load or half load. It is important that the re-lubrication intervals are met and also documented.

10.6.2.6 Re-lubricating with Generator Running

⚠ WARNING

Rotating parts will shock or can cause loss of limbs or death.
During lubrication open long hair, loose clothing, and jewelry or similar can become entangled in rotating components and be drawn in.
Very serious injuries can result. Wear PPE.

Do not stand behind the generator for the first 10 hours after lubrication.Re-lubrication can be done in various ways. The grease can be applied to the bearing in one pass or in several stages. The important aspects are the duration of the re-lubrication process and the order.

The re-lubrication of a bearing should not be completed in less than 5 minutes, and should also not take more than 30 minutes. The total amount of grease for the re-lubrication must not be exceeded or dropped below in any circumstances. The manufacturer recommends the use of suitable instruments to measure the amount of grease.

For the order in which the bearings are to be lubricated the combination of fixed, loose, fixed bearing is to be followed.

1. Clean the grease nipple and its surrounding area
2. Make sure that you use grease as per the rating plate
3. Measure (weight or volume) the amount of grease that is pressed in during one stroke
4. Make sure the lubrication pipes are intact
5. Press the stated amount of the type of grease stated into the bearing in the order stated above while following the requirements on the time taken
6. Leave the generator to run for 1-2 hours to make sure the old excess grease is pressed out of the bearing. The bearing temperature may increase temporarily during this time.

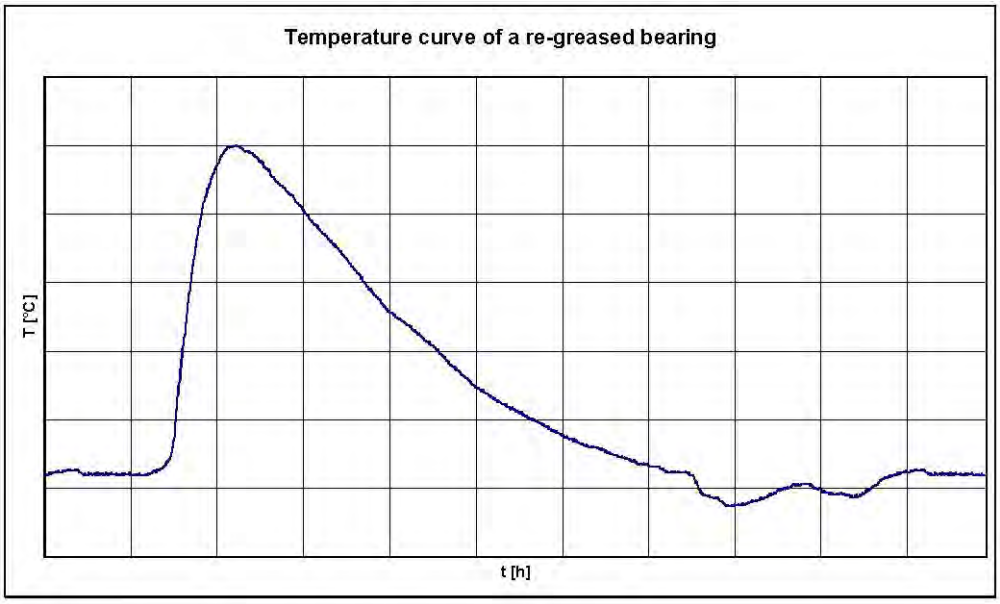


FIGURE 22. TEMPERATURE CURVE DURING RE-LUBRICATION

Engineers contracted by the manufacturer may act otherwise than stated in this section. They will decide on site, depending on the condition of the generator and the ambient conditions, how to re-lubricate. The actions done by the service engineers must not be transferred to other generators or be considered general instructions.

10.6.2.7 Automatic Re-lubrication

Numerous automatic lubrication systems are available on the market. However, we only recommend the use of electromechanical lubrication systems. The quality of the grease entering the bearing is to be checked at least once a year. The grease must be free of contamination and good in use. Do not use the grease after the shelf-life stated by the grease manufacturer. The separation of the base oil from the soap is not acceptable.

If an automatic lubrication system is to be used, consult the manufacturer and the lubrication system manufacturer about the lubrication interval and the amount of grease.

10.6.2.8 Shortage of lubricant

A shortage of lubricant occurs:

- if the correct amounts of grease are not in the bearing.
- if the correct amounts of grease are not in the grease reservoir.
- if the bearing is not re-lubricated at the stipulated intervals using the correct amount of grease.
- if the oil is separated from the grease.

10.6.2.9 Grease Miscibility

Do not mix different types of greases together. The mixing of greases with different thickeners can change the characteristic and physical properties of the grease. Even with thickeners of the same type as a rule there will be differences in the additives with effects on the performance of the grease that can only be determined by checking the anti-friction bearing.

The usage of non-compatible greases leads to bearing damages.

10.6.2.10 Incorrect Grease

Using the wrong lubricating greases results in the premature failure of the generator bearings and cause other damage.

10.6.2.11 Lubricant Pressure During Re-lubrication

When grease is pressed into the grease reservoir and into the bearing during re-lubrication, the pressures will change in the lubrication system. If the grease has been pressed into the grease reservoir during re-lubrication more quickly than the old grease flows out on the opposite side, the pressure on the bearing cover will further increase. With the generator running the grease is now heated and expands. This also results in additional pressure being required for re-greasing the lubrication system.

Pressure too high

If you notice a significant pressure increase during re-lubrication (more force required for re-greasing than usual), check the lubrication system for:

- Unhindered discharge of the old grease
- Kinked or clogged fresh grease lines
- Leaks between shaft and bearing cover
- Leaks between bearing cover and bearing chamber
- Correct function of the grease nipple
- Intact grease gun
- Also check all screw fasteners and the bearing covers. Make sure to remove any discharged grease.

Pressure too low

If you notice a significant pressure decrease during re-lubrication (less force required for re-greasing than usual), check the lubrication system for:

- Leaks between shaft and bearing cover
- Intact fresh grease lines (e.g. broken or burst line)
- Correct function of the grease nipple
- Intact grease gun
- Also check all screw joints and the bearing covers. Make sure that any grease discharged is removed.

10.6.2.12 Temperature Increase due to Re-lubrication

The temperature increase in the bearing during or after re-lubrication is the consequence of the increased working of the grease as long as the currently increased amount of grease in the bearing has not been distributed. (See **Figure 22 on page 96**.)

In a anti-friction bearing with an adequate amount of lubricant, only a small amount of the lubricant is used for building up the lubricating film, not the total amount. Some of the lubricant is sprayed away, and some forms a lubricant flow in front of the rolling element/raceway contact zone.

This temperature increase settles to around the value before re-lubrication after the distribution of the grease.

An elevated temperature in the bearings can exist for up to 96 hours. During this period significant temperature increases can be seen (see **Section 10.6.2.6 on page 95**). An increase in the temperature is helpful for the lubricant change, as the old grease becomes softer and can escape better from the bearing. Finally, the increase in the temperature is a good indicator that the lubricant has actually reached the bearing.

When the temperature increases due to re-lubrication it is important that the warning and shutdown temperatures stipulated by the manufacturer are met.

10.6.2.13 Influence of the Grease Level

With the required amount of grease for re-lubrication, freshly filled bearings have a temperature significantly above the value before re-lubrication for operation hours up to days. The cause of this phenomenon is explained in **Section 10.6.2.12 on page 97**. After the first re-lubrication the grease reservoir in the bearing cover is completely filled, this increases the time required for the bearing temperature to drop again.

10.6.2.14 Grease Contamination

The more contaminants (water, dirt, fibers, metallic abraded material, etc.) found in the grease, the more the properties of the grease will be degraded. Unlike oil lubrication, in which contaminants can be filtered out, contamination can only be removed from the anti-friction bearing lubricant by prompt re-lubrication using fresh grease. The greatest risk is contamination with hard particles that can cause surface damage to the bearing raceways and finally premature bearing failure.

Grease contamination will result in the premature failure of the bearing.

10.6.2.15 Grease Hardening

Grease hardening will result in the premature failure of the bearing.

As a rule, grease hardening is caused by the absorption of dirt and moisture or due to oxidation of the grease constituents over a long period of time. A long storage time or period of generator standstill can cause grease hardening (refer to **Section 5.2 on page 25**). During this process the base oil separates from the thickener. So-called grease "bleeding" occurs.

10.6.2.16 Handling Bearings During Replacement

The bearings have a shorter service life than the generator itself. They therefore need to be replaced from time to time.

- Do not fill a bearing with too much lubricant. The bearing may be damaged as a result. Do not mix different types of lubricant. Change your gloves before handling a different type of lubricant.
- Do not assemble bearings in statically charged environments. Pay attention to a dust-free environment and wear lint-free gloves during assembly.
- Store removed parts and tools in environments that are not statically charged and that are free of dust to prevent damage or soiling.
- A bearing will be damaged by the axial force that needs to be applied to remove it from the rotor shaft. Once removed, a bearing cannot be re-used.
- A bearing will be damaged by the application of force to the rolling element. Do not use force to fit any bearing components.
- Do not try to rotate the rotor by applying a lever to the fan blades. The fan will be damaged as a result.

The servicing of anti-friction bearings requires particular care, special tools and proper preparation to ensure the newly fitted bearings have a long service life.

During the servicing of the bearings, make sure that:

- At no time dirt or foreign bodies can enter the bearing during the servicing,
- The bearings and the rotor are not damaged during dismantling and assembly. Removal requires the use of pullers or heat, installation is done with the aid of heat or special tools.

If you are uncertain during the replacement of the bearings, contact the manufacturer.

10.7 Generators with Bearing Insulation

The insulation resistance test on the bearings is performed in the factory. The insulation is neccessary to avoid bearing currents which result in bearing damages. The insulation at one of the bearings interrupts the path of the current. Both ends of the shaft must not be insulated from the housing without further measures. The standard is that the NDE bearing is insulated.

10.7.1 Bearing Insulation on Sleeve Bearings

For generators with the bearing insulated at the non-drive end, the bearing at the drive end is not insulated.

1. To test the resistance in the non-drive end bearing, remove the bearing shells or the drive end bearing plate and lift the rotor. This ensures that electrical contact between the rotor and another part, e.g. the stator or bearing housing, is not possible. Make sure that the circuit cannot be closed by the lifting equipment.
2. Remove any shaft grounding brushes, rotor grounding brushes and coupling (if they are made of conductive material) for the insulation test.
3. Measure the insulation resistance between the shaft and ground using 500 V DC as a maximum. The minimum insulation resistance is 10 kΩ.

10.7.2 Bearing Insulation on Anti-friction Bearings

The bearing insulation is fitted in the bearing chamber. Check the integrity of the bearing insulation, the bearing chamber and the surrounding bearing plate regularly. A bearing insulation measurement is not possible with the generator assembled. It is necessary to remove the uninsulated bearing from the generator.

Check the bearing insulation when each bearing is replaced.

Remove any shaft grounding brushes, rotor grounding brushes and coupling (if they are made of conductive material) for the insulation test. Measure the insulation resistance between the shaft and ground using 500 V DC as a maximum. The minimum insulation resistance is 10 kΩ.

10.8 Service Windings

10.8.1 Safety Instructions for Servicing Windings

Hazardous servicing tasks on windings include:

⚠ WARNING
Hazardous voltage will shock, burn or can cause death. ***Tests at high voltage (HV) must only be done by authorized specialist personnel following the related safety regulations.***

⚠ CAUTION
Danger of chemical burn and poisonous vapors will chemically burn or burn or cause suffocation. ***Flammable and hazardous substances like solvents, resins and lacquers must be handled and used by authorized specialist personnel only while following the related safety regulations and instructions. These substances must not be inhaled or swallowed or come into contact with the skin or other organs. Seek medical attention immediately in case of an accident.*** ***Take the necessary precautions if you are working in pits or poorly accessible / poorly ventilated areas. Do not smoke or eat in the workplace. Wear PPE.***

For spray lacquering, ensure that the lacquering equipment, the generator frame and the windings are earthed.

Solvents, lacquers and resins are required to clean and re-lacquer the windings.

10.8.2 Scheduling the Servicing

As a guideline the insulation resistance test should be done once a year. This rule is sufficient for the majority of generators under the majority of operating conditions. Additional tests must be performed if problems occur.

You will find a servicing schedule for the complete generator including the windings in **Section 10.3 on page 78**. This servicing schedule should be adapted to the specific circumstances at the customer, in the context of the recommended servicing intervals, i.e. to the servicing of other machines and the general operating conditions.

10.8.3 Correct Operating Temperature of Windings

Ensure the correct temperature of the windings:

- by keeping the external surfaces of the generator clean.
- by checking the cooling system for correct operation.
- by monitoring the temperature of the coolant.

If the coolant is too cold, water may condense inside the generator and the winding becomes damp, resulting in a degradation of the insulation resistance.

For air-cooled generators it is important to monitor the cleanliness of any air filter fitted. The air filter cleaning and replacement interval is to be planned and implemented to suit the local operating environment. Increased winding temperatures can be indicative of a clogged air filter.

The operating temperature of the stator must be monitored using temperature sensors. Large differences between the values from the sensors can be indicative of damage to the windings.

10.8.4 Insulation Resistance Test

Measure the insulation resistance of the stator and rotor windings During the general servicing work , before the generator is started for the first time or after extended standstill.

The insulation resistance value provides information on the moisture and soiling of the insulation.

For new generators with dry windings, the insulation resistance is very high. However it can be very low if the generator is subjected to incorrect transport, storage conditions and moisture, or is operated incorrectly.

- If the measured value is under the rated voltage in kV + 1 MOhm, the windings must be cleaned and/or dried. If these measures are insufficient, consult the manufacturer.

- If a moisture problem is suspected, dry the insulation before the resistance is measured.
- The insulation resistance will reduce with increasing winding temperature.

The insulation resistance stated in the test report is normally higher than that measured at site.

10.8.4.1 Windings Criteria in Normal Condition

The insulation resistance on dry windings should significantly exceed the minimum values. The insulation resistance is dependent on the age and the use of the generator.

Typically, in test field measured insulation resistance values at approx. 25 °C winding temperature:

Rated voltage 3.3 kV up to 1.5 kV: > 1000 MOhm

Rated voltage 380 V up to 1000 V: ≥ 400 MOhm

Main rotor ≥ 300 MOhm

Exciter stator ≥ 50 MOhm

PT100 & anti-cond. heater ≥ 50 MOhm

A low resistance is often caused by excessive moisture or by dirt, even though the actual insulation is intact.

10.8.4.2 Insulation Resistance Measurement on the Stator Windings

⚠ DANGER

Hazardous voltage will shock, burn or cause death.
The windings are to be grounded immediately after the measurement to avoid the risk of electric shock.

The insulation resistance is measured using an insulation resistance tester. Before undertaking the tests, take the following precautions:

1. Make sure that all power supply cables are disconnected from the main power supply and secured against unintentional switching back on.
2. Check the tester for correct function.
3. Make sure the secondary connections on the current transformer including the replacement core are not open.
4. Make sure all power supply cables are disconnected.
5. Make sure the stator and the stator windings as well as the auxiliary exciter stator, exciter stator and any auxiliary windings that are not tested are grounded.
6. Measure the winding temperature on the PT100 of the stator.
7. Ground all resistive temperature sensors
8. Remove any grounding in the voltage transformer.
9. Ground all Rotor cables and exciter rotor cables as well as auxiliary windings.

Measure the insulation resistance measurement in the terminal box. The test is normally done on the entire winding as an assembly; connect the tester between the stator housing and the winding. Ground the stator and leave the three phases of the stator winding connected to the star point. If the insulation resistance measured in the entire winding is lower than stated and the phase windings can be easily disconnected from each other, measure each phase separately. This action is not possible on all generators. To measure separately, connect the tester between the stator and one of the windings. Ground the stator and the two phases not measured.

If phases are measured separately, remove all star points in the winding system.

10.8.4.3 Insulation Resistance Measurement on the Rotor Winding

⚠ DANGER

Hazardous voltage will shock, burn or cause death.

The windings are to be grounded immediately after the measurement for a period equal to the duration of the measurement of the insulation resistance to avoid the risk of electric shock.

Measure the insulation resistance on the rotor winding using an insulation resistance tester. The test voltage for the rotor windings should be 1000 VDC.

1. Make sure that all power supply cables are disconnected from the main power supply and secured against unintentional switching back on.
2. Check the tester for correct function.
3. Make sure the generator and the stator windings as well as the temperature monitoring, auxiliary winding, auxiliary exciter stator, exciter stator are grounded.
4. Make sure the shaft is grounded.
5. During the insulation resistance measurement in the exciter rotor the rotor windings not tested must be grounded. The rotor winding can be connected internally in series or 2 groups connected in parallel.
6. Measure the rotor winding temperatures. If this is not possible, use the stator winding temperatures as a reference.
7. Connect the insulation resistance tester between the entire rotor winding and the shaft. After the measurement, the rotor winding must be grounded for at least as long as the duration of the measurement to discharge the winding.

10.8.4.4 Other Servicing Work on the Windings

Windings are normally trouble-free and only require occasional cleaning and drying in addition to the regular monitoring described above. If unusual conditions make additional servicing work necessary, seek the advice of the manufacturer.

10.8.5 Insulation Resistance Measurement for Ancillary Equipment

The test voltage for the anti-condensation heater must be 500 VDC.

Do not measure the insulation resistance of Pt-100 sensors.

To ensure the correct operation of the generator and its ancillary equipment, refer to the documentation in the Appendix.

10.8.6 The Polarization Index

For the polarization index test the insulation resistance is measured after the test voltage has been applied for 1 minute and 10 minutes. The polarization index depends less on the temperature than on the insulation resistance. If the winding temperature is below 50 °C (122 °F), it can be considered independent of temperature. High temperatures can cause unforeseen changes in the polarization index, for this reason use above 50 °C (122 °F) is not to be recommended.

Dirt and moisture in the windings will normally reduce the insulation resistance and the polarization index as well as their temperature dependence.

There are several rules for determining the lowest acceptable value at which the generator can be safely started.

The minimum PI value for stator windings of class F is 2.

If the insulation resistance of the windings is in the area of several thousand MΩ, the polarization index does not represent a clear criterion for the condition of the insulation and can be ignored.

10.8.7 Servicing the Grounding Brushes

⚠ DANGER

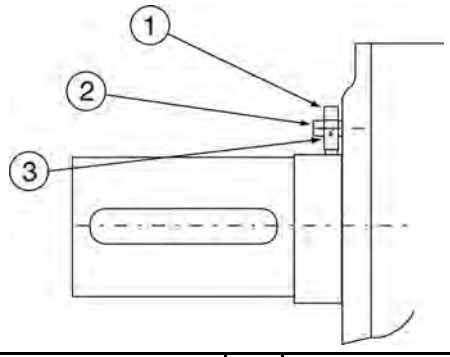
Hazardous voltages, rotating parts and hot surfaces will shock, burn or cause loss of limbs or death.
Only undertake servicing work with the generator at standstill.

Optimal servicing and care of the brushes and slip rings is a prerequisite for low wear. The brushes must be cleaned from time to time by blowing with air or vacuum cleaning.

- The servicing must be done at specific intervals. The frequency of this servicing depends on the size of the generator as well as on the load conditions and ambient conditions.

It is recommended to initially check the brushes every three months to be able to estimate the replacement intervals under the actual operating conditions. Replace only with approved brushes.

- Check all brushes and holders for freedom of movement. Sticking brushes can result in damage.
- Renew worn brushes in good time so that damage to the brush contact surfaces is avoided.



No.	Description	No	Description
1	Brush holder with ground connection and removable carbon brush spring	3	Carbon Brush

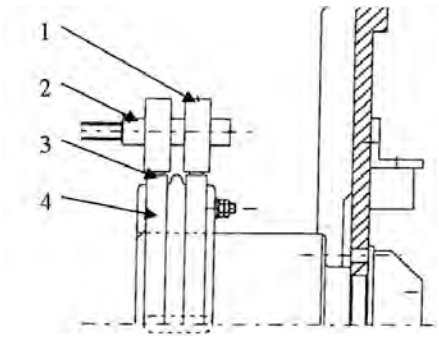
2	Brush pin		

10.8.7.1 Ground Fault Monitoring

⚠ DANGER

Hazardous voltages, rotating parts and hot surfaces will shock, burn or cause loss of limbs or death.

Only undertake servicing work with the generator at standstill.



No.	Description	No	Description
1	Brush holder with connection	3	Carbon Brush
2	Brush pin	4	Slip Rings

FIGURE 23. GROUND FAULT MONITORING

- Renew Worn carbon brushes in good time so that damage to the slip rings is avoided and the correct function of the ground fault monitoring is ensured.

  Open the spring and replace the old carbon brushes with the new ones.

- New brushes must bed in on the slip rings.

Replace only with approved brushes. The ground fault monitoring is installed on the non-drive side of the generator.

10.9 Servicing the Generator Cooling

Check the generator cooling regularly to ensure trouble-free operation.

10.9.1 Servicing Instructions for Generators with Open-circuit Ventilation

The cooling airflow is normally provided by a fan mounted on the rotor. The cooling air must be clean and dry, as dirt and/or moisture entering the generator reduces the cooling performance.

The generator can be equipped with temperature sensors for monitoring the internal cooling air. As long as the temperature sensors indicate a temperature within the specified limits, no servicing other than regular inspection of the generator is necessary.

Check the cooling system if the temperature sensors indicate an abnormal winding or cooling air temperature or a temperature near the alarm limit.

Possible causes of high cooling air temperature are:

- Waste heat from Malfunctions in the lubrication system or excessively high bearing temperatures.

- The minimum distances between the cooling air inlet and neighboring components are not maintained.
- The outlet air is drawn in with the inlet air.
- Defective temperature measuring instruments.

NOTICE
To avoid any material damage ensure that the distance between the air inlet (AI) or air outlet (AO) on the generator and a wall or another plant component is at least a minimum of 500 mm (20 inch). Unhindered AI and AO must be ensured.

10.9.2 Service Instructions for Generators with Air Filters

The servicing must be done at specific intervals. The frequency of this servicing depends on the size of the generator as well as on the operation and ambient conditions.

The filter frame and the filter mats are made of:

Stainless steel with round stainless steel wire mesh fabric depending on the application conditions

Filter class:

EU2 in accordance with DIN 24185 / part 2

Medium filtration efficiency 65 ≤ 80%

- The servicing intervals are to be adapted to the local dust conditions.

Check the filter initially every three months to estimate the cleaning intervals under the actual operating conditions.

10.9.2.1 Cleaning the Air Filter

NOTICE
Remove the filter mats from the generator for cleaning. Do not spray inside the generator using a high-pressure cleaner.

Regular servicing and cleaning of the dust protection filter system is essential for the reliable operation of the generator.

Do not wet filter mats using oil! Pay attention to environmental obligations!

Soiling such as salt, oil, fumes, chemicals, dust, sand etc. will reduce the efficiency of the insulation and result in premature failure of the windings.

Therefore it is necessary to clean the filters regularly. If the temperature sensors in the winding indicate an abnormal temperature close to the alarm level, the filters must be cleaned.

If a monitoring system for the filter differential pressure is used, replace the filters in case of a pressure alarm. The alarm is triggered if 50% of the air filter surface is clogged. Check the filter manually on a frequent basis.

For cleaning the filter with cleaning agent the following applies:

- Commercially available cleaning agents can be used for mechanized cleaning or cleaning using a high-pressure cleaner. The cleaning agent must be compatible with the materials.
- If only manual cleaning is possible, use Repoint / RG 1083 or equivalent.

10.9.3 Servicing Instructions for Generators with Heat Exchangers

Over time soiling on the cooling surface and the pipes wall reduce the cooling performance. Clean the heat exchanger at regular intervals according to local conditions. Check the heat exchanger frequently during the initial operating period.

Clean the heat exchanger using compressed air or clean it using a soft round brass brush. Do not used steel brushes in or on aluminum pipes, a these pipes may be damaged.

10.9.3.1 Air-water Heat Exchanger

If the temperature sensors indicate a normal operating temperature and the leak detectors are not indicating any leak, visual inspection of the generator at a servicing interval is sufficient.

For information on servicing the heat exchanger, see documentation from the manufacturer in the Appendix.

10.9.3.2 Air-air Heat Exchanger

Visual inspection at a servicing interval is sufficient.

For information on servicing the heat exchanger, see documentation from the manufacturer in the Appendix.

10.10 Repairs, Dismantling and Re-assembly

NOTICE
Incorrect handling, repair, dismantling and re-assembly will result in serious damage.

All work related to repair, dismantling and re-assembly must be done by specially trained personnel.

11 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 unauthorized 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 alternator. Compare measurements with the test report supplied with the alternator.

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

11.1 Generator, General

SYMPTOM	POSSIBLE CAUSE	MEASURE
Vibration Noise	Malfunction in the lubrication system	Check quality and quantity of lubricant as well as system function
	Malfunction in the bearing/bearing components damaged	Check condition of the bearing, replace faulty parts
	Malfunction in the bearing/bearing fitted incorrectly after replacement	Open and correct adjustments
	Malfunction in the cooling fan/imbalance/damage on the fan	Check fan, clean, replace in case of damage and identify cause
	Displacement of the machine	Check and make sure correct alignment of the machine
	Imbalance on rotor/shaft or coupling	Check imbalance and re-balance
	Vibration on the prime mover	Check type of coupling, check foundation, check decoupling of the attachments from the unit
	Axial load	Check alignment as well as coupling function and coupling type
	Coupling fitted incorrectly	Check and make sure correct coupling assembly
	Excessive line asymmetry	Ensure compliance with the line symmetry requirements
	Loose part	Repair, replace or re-fasten if necessary
	Damaged parts	Identify and correct the cause and replace damaged parts
Noise	Loose parts	Repair, replace or re-fasten if necessary
	Electrical noises	Check stator, rotor
	Malfunction in the cooling system	Check cooling system, clean and repair as necessary
	Foreign bodies, moisture or dirt in the machine	Check the interior of the generator for damage and clean, dry the windings, remove foreign bodies
Vibration	Inadequate, damaged foundation	Check foundation in consultation with the manufacturer of the unit and Cummins
	Tilting foot, fastening of the generator inadequate	Check fastening and re-align

11.2 Lubrication System and Anti-friction Bearings

SYMPTOM	POSSIBLE CAUSE	MEASURE
High bearing temperature	Inadequate lubrication	Check bearings, check amount of grease in the bearing and re-lubricate, follow manufacturer's grease recommendations,
High bearing temperature, grease in the machine	Inadequate lubrication	Check grease line system for leaks, check re-lubrication intervals
High bearing temperature, grease in the machine	Excessive lubrication	Check bearings, check amount of grease in the bearing and reduce, follow manufacturer's grease recommendations
High bearing temperature	Axial/radial load excessive/coupling and installation defects	Check coupling, installation and alignment
High bearing temperature	Machine displacement	Re-align machine
High bearing temperature, grease in the machine	Grease outlet blocked	Clean grease outlet,
High bearing temperature, bearing noise or vibration	Bearings fitted incorrectly after replacement	Check installation of the bearings and attachments
	Quality of grease degraded/incorrect re-lubrication interval	Check bearings, check re-lubrication log, quality of grease, type of grease
	Bearing currents	Check bearing insulation, repair, replace bearing if necessary
	Bearing damaged/failure of the bearing	Replace faulty bearing parts
	Bearing damaged/normal wear	Replace bearing
Bearing noise or vibration, visible damage	Foreign body in the bearing	Correct cause, replace bearing and check condition of the seal, attachments
Grease leaks, grease in the machine	Line system faulty, grease outlet malfunction	Correct cause, clean grease outlet and generator
High bearing temperature	Instrument fault/temperature sensor faulty	Check bearing temperature monitoring system
Grease leaks	Bearing seals damaged or worn	Replace bearing seals
High bearing temperature	Lubrication system malfunction	Check re-lubrication intervals, quantity and if grease has hardened
Grease leaks	External vacuum/rotating equipment in the vicinity	Check pressures, change position of the rotating equipment

11.3 Lubrication System and Sleeve Bearings

SYMPTOM	POSSIBLE CAUSE	MEASURE
High bearing temperature, oil leaks, bearing noise of vibration, visible degradation of the quality of the oil	Axial load excessive/coupling and installation defects	Check coupling, installation and alignment, check adjustment indicator
High bearing temperature, bearing noise or vibration, visible degradation of the quality of the oil	Inadequate lubrication/oil level low	Check bearing for leaks, top-up oil
	Bearing shells damaged/contamination of the oil	Change oil, check condition of bearing, replace bearing shells if necessary
High bearing temperature, oil leaks, oil in the machine, visible degradation of the quality of the oil	Unsuitable oil quality	Follow manufacturer's oil specification
Oil leaks, oil in the machine	Too much oil and damaged seals	Clean bearings and generator, replace seals and fill with correct amount of oil
High bearing temperature, oil leaks, bearing noise of vibration	Machine displacement	Re-align machine and replace seals if necessary
Bearing noise or vibration, visible degradation of the quality of the oil	Foreign body in the bearing	Remove foriegn body and clean the bearing. Check condition of the seals, and replace if necessary
Oil leaks, oil in the machine	Pressure differences in and on the bearing/pressure equalization malfunction	Correct cause of the pressure difference
High bearing temperature, bearing noise or vibration	Degradation of the quality of the oil/incorrect oil change interval/incorrect oil	Clean bearings and change oil
	Bearings fitted incorrectly	Check installation and adjustment of the bearing
	Bearing shells damaged/bearing currents	Repair bearing insulation, replace bearing shells
	Bearing shells damaged/failure of the bearing	Replace faulty bearing parts
	Bearing shells damaged/normal wear	Replace bearing shells
	Bearing shells damages/increased wear due to number of starts and stops	Replace bearing shells, possibly retrofit hydrostatics
High bearing temperature	Instrument fault/temperature sensor faulty	Check bearing temperature monitoring system
	Function of the oil lubrication or loose lubrication ring degraded	Correct cause
Oil leaks	Bearing seals damaged or worn	Replace bearing seals
	External under pressure or overpressure/rotating equipment in the vicinity	Check pressures, change position of the rotating equipment, fit additional seal if necessary
Oil in the machine	Machine seal damaged	Replace machine seal
Formation of bubbles in the oil	Incorrect oil, contamination of the oil	Follow manufacturer's oil specification, change oil

11.4 Open Cooling System

SYMPTOM	POSSIBLE CAUSE	MEASURE
High winding temperature, high cooling air temperature	High inlet air temperature/ambient air too hot	Change air management
	High inlet air temperature/outlet air is drawn in again	Change air management, ensure adequate space around the machine,
	High inlet air temperature/heat source in the vicinity	Remove or re-position heat sources, check ventilation
	Inadequate air flow/machine interior soiled	Clean generator parts and air gaps
	Inadequate air flow/air ducts incorrectly arranged	Check condition of the air duct, correct installation defects
	Inadequate air flow/inlet openings blocked	Clean deposits from inlet openings
	Inadequate air flow/air filter clogged	Clean or replace air filters
	Fan damaged	Replace fan
	Incorrect speed, direction of rotation	Adjust speed, direction to the manufacturer's specifications
	Instrumentation or measuring system defect	Check measurements, sensors and wiring
High winding temperature	Overload/control system settings	Check generator control system, remove overload
	Line asymmetry	Ensure compliance with the line symmetry requirements
	Winding damage	Check windings
	Reactive load outside the specifications	Correct cause

11.5 Air-air Cooling System

SYMPTOM	POSSIBLE CAUSE	MEASURE
High winding temperature, high cooling air temperature	Drop in the performance of the main cooling system/fan damaged	Replace fan
	Drop in the performance of the main cooling system/fan is rotating in the wrong direction	Replace fan
	Drop in the performance of the main cooling system/interior of the machine soiled	Correct cause of the soiling, clean generator parts and air gaps
	Drop in the performance of the secondary cooling system/external fan damaged	Repair or replace fan
	Drop in the performance of the secondary cooling system/fan is rotating in the wrong direction	Correct direction of rotation of the external fan
	Drop in the performance of the secondary cooling system/cooler leaking	Repair cooler
	High inlet temperature/ambient air too hot	Change air management
	High inlet temperature/outlet air is drawn in again	Ensure adequate space around the generator
	High inlet temperature/heat sources in the vicinity	Remove or re-position heat sources, check ventilation
	Incorrect speed, direction of rotation	Adjust speed, direction to the manufacturer's specifications
	Instrumentation or measuring system defect	Check measurements, sensors and wiring
High winding temperature	Overload/control system settings	Check generator control system, remove overload
	Line asymmetry	Ensure compliance with the line symmetry requirements
	Excessively frequent starts	Leave machine to cool down before the start
	Winding damage	Check windings
	Reactive load outside the specifications	Correct cause

11.6 Air-water Cooling System

SYMPTOM	POSSIBLE CAUSE	MEASURE
High winding temperature, high cooling air temperature, water leak alarm	Drop in the performance of the secondary cooling system/leak in the cooler	Replace cooler
	Instrumentation or measuring system defect	Check measurements, sensors and wiring
High winding temperature, high cooling air temperature,	Drop in the performance of the main cooling system/fan damaged	Check fan, cooling circuit
	Incorrect direction of fan rotation	Replace fan
	Drop in the performance of the main cooling system/interior of the machine soiled	Correct cause of the soiling, clean generator parts and air gaps
	Drop in the performance of the secondary cooling system/coolant pipes blocked	Open cooler and clean pipes
	Drop in the performance of the secondary cooling system/coolant pump faulty	Check pump and repair
	Drop in the performance of the secondary cooling system/incorrect flow rate adjustment	Check coolant flow and adjust correctly
	Drop in the performance of the secondary cooling system/air in the cooler	Bleed cooler
	Drop in the performance of the secondary cooling system/emergency ventilation flap open	Securely close emergency ventilation flap
	Cooling water inlet temperature too high	Adjust cooling water temperature correctly
High winding temperature	Overload/control system settings	Check generator control system, remove overload
	Line asymmetry	Ensure compliance with the line symmetry requirements
	Excessively frequent starts	Leave machine to cool down before the start
	Winding damage	Check windings
	Reactive load outside the specifications	Correct cause

11.7 Faults on the Brushes

SYMPTOM	POSSIBLE CAUSE	MEASURE
Brushes not working correctly	Brushes are worn	Replace the brushes and check the surface of the shaft
	Brushes are sticking in the holders	Loosen the brushes, check the size and if necessary replace the brushes
	Brushes are excessively loose in the holders	If brushes are worn out or are too small, replace
		Wrong size, check the size and replace
	Loose connection at the brush terminals	Tighten the connection
	Incorrect bedding in of the brushes	Replace the brushes
	Incorrect and uneven brush pressure	Re-adjust the holder of the brushes
	Mating faces on the slip rings worn or soiled	Clean and if necessary replace the slip ring and the brushes
	Type of carbon brushes is not suitable for the operating conditions	Operate the generator only according to the rating plate. Consult Cummins service department regarding the operating conditions.
	Imbalance in the generator	Arrange for re-balancing of the generator by specially trained personnel only
	Uneven air gaps as a result of worn bearings.	Check the bearing and replace the bearing if necessary

11.8 Fault Finding Sleeve Bearings

11.8.1 Oil Leaks on Sleeve Bearings

Owing to the design of the sleeve bearings it is extremely difficult to prevent oil leaks. Minor leaks can occur.

However, oil leaks can also occur for reasons that are not related to the design of the bearings, e.g.

- Incorrect oil viscosity
- Overpressure in the bearing
- Low pressure outside the bearing
- Heavy vibration on the bearing
- Incorrect servicing, repair
- Oil foaming
- Over filling of the bearing with oil

In case of excessive leaks, check the following aspects:

1. Make sure the oil used complies with the specifications (see **Section 10.6.1.11 on page 93**)

2. Tighten the bearing house halves and the labyrinth seal cover to the related torque. (See sleeve bearing documentation from the manufacturer). This aspect is particularly important after extended generator standstill.
3. Measure the vibration at the leaking bearing in three directions at full load. If the vibration level is too high, the bearing housing may be open wide enough to allow the oil to flow away between the halves of the housing.
4. Eliminate any causes of low pressure in the vicinity of the bearing. For example a shaft or coupling cover may be designed so that it causes a low air pressure in the vicinity of the bearing
5. Make sure there is no overpressure inside the bearing. Overpressure can enter the bearing via the oil outlet line from the lubrication unit. Provide vents on the bearing housing to relieve the overpressure from the bearing. Also check the vent at the oil supply unit.
6. In case of an external lubrication system, check whether the fall on the oil outlet pipes is adequate.

If it is not possible to correct the leak problem by means of one of the above points, contact the manufacturer.

11.8.2 Oil

For the bearings to function correctly, the oil must meet certain criteria, including viscosity and cleanliness. Only use the oil stipulated by the manufacturer with the correct viscosity. See **Section 10.6.1.11 on page 93**. Incorrect viscosity will result in bearing failures and can seriously damage the bearings and the shaft.

11.8.2.1 Sealant

To prevent oil escaping from the bearing through the joints, apply a sealant along the joint. Use Loctite 2926 for this purpose. On the use of biodegradable oils, request information on the compatibility of the oil with the sealant from the sealant manufacturer. Only Curil T can be used for floating labyrinth seals. Refer to the documentation from the sleeve bearing manufacturer.

11.8.3 Checking the Bearings

If you suspect that the bearing housing itself is leaking, do the following steps:

1. 1. Re-tighten the bolts of the bearing housing
   - This aspect is particularly important during the commissioning of the generator or after extended standstill, as the parts may have loosened.
   - If the halves of the bearing housing are not firmly screwed together, the oil may flush the sealant out of the joint.
2. Open the bearing housing
   - You can open the bearing housing and apply new sealant to the joint.

     Make sure that the seals are not damaged when opening the bearing and that no dirt or foreign bodies enter the bearing. De-grease the joint then apply a very thin layer of sealant. See documentation from the sleeve bearing manufacturer. Make sure that no sealant enters the interior of the bearing when assembling the halves of the bearing housing. Sealant that enters the interior of the bearing can degrade the function of the bearing or labyrinth seals. Make sure that the labyrinth seals are sealed according to the manufacturer of the sleeve bearing.

11.8.4 Check on the Oil Tank and the Oil Lines

If you suspect that the leak is caused by the design of the oil tank or the oil lines do the following steps:

Pressure in the oil tank

Check the atmospheric pressure in the oil tank. The pressure must not be higher than the pressure outside the bearing. In case of overpressure, check the vent on the oil tank or fit one, if necessary.

Oil lines

Make sure that the line has an adequate diameter, is not clogged and that the entire oil return line has an adequate downward gradient.

11.8.5 Vibration and Oil

All generators are subjected to vibration and are designed to withstand this vibration to suit their purpose. However, heavy vibration outside the design specification can result in problems with the function of components other than bearings.

Heavy vibration can affect the oil film between the shaft and the bearing shells and more likely results in bearing failures than oil leaks. Under heavy vibration, parts of the bearing housing may move so far apart that the oil enters the joint between the upper and lower half of the bearing housing. The vibration will also cause the parts of the bearing housing to move in relation to each other. The pumping effect that pumps oil into and out of the joint can flush out the sealant, causing bearing leaks.

11.8.6 Check on Vibration

Measure the vibration on the bearing housing in three directions: axial, transverse (horizontal) and vertical, see **Section 9.4.2 on page 72**.

11.8.7 Hydrostatic System

Possible causes of malfunction:

- The pump motor is faulty or its function is degraded
- The pump pressure is inadequate
- The oil filter is soiled
- The oil flow sensor is not signaling any oil flow, for example in case of intake line fracture

11.8.8 Air Pressure in the Bearing

The bearing housing is not a hermetically sealed unit; overpressure in the bearing housing allows air to escape via the labyrinth seals. As it escapes, the air carries oil vapor with it, and the bearing leaks.

Overpressure in the bearing is normally caused by other components, not by the bearing itself. The most frequent reason for overpressure in the bearing is cavitation in the inlet line or a buildup in the oil outlet line.

11.8.8.1 Check the Air Pressure in the Bearing

Check the air pressure inside and outside the bearing.

The best place to measure the pressure in the bearing is at the oil filter or at the inspection glass for the loose lubrication ring on the top of the bearing.

11.8.9 Air Pressure Outside the Bearing

Similar to overpressure in the bearing, a low pressure outside the bearing will result in the extraction of air containing oil from the inside of the bearing, causing the bearing to lose oil.

Low pressure near the bearing housing is caused by rotating parts that move the air in their vicinity so that there is an area of low pressure at the shaft outlet on the bearing.

11.8.9.1 Check on the Air Pressure Outside the Bearing

⚠ WARNING

Rotating parts can cause loss of limbs or death.
Attach measuring instruments/lines with the generator at standstill.
Only measure with the generator in operation. Risk of injury due to rotating parts.
Do stand within the hazrd area of the generator during the measurement.

Never try to correct low pressure in the bearing by installing a vent, as this would further amplify the leak. Check the air pressure in the vicinity of the shaft outlet on the bearing. This aspect is particularly important if the bearing is mounted on the prime mover using a flange of a coupling, or if the shaft is mounted inside a cover or another construction that together with the shaft can cause a centrifugal air flow.

If a very low pressure is found or suspected, the air pressure is to be measured in the vicinity of point where the shaft leaves the bearing housing.

To be certain that the low pressure outside the bearing may be the cause of the leak, the pressure must also be measured outside the bearing (Pos. 1 and 3 on the DE and Pos. 5, 7 and 9 on the NDE, in the bearing (Pos. 2 on the DE and Pos. 6 on the NDE) and in the area between the bearing plate and the generator seal (Pos. 4 DE and Pos. 8 NDE). During the measurement (Pos. 4 DE and Pos. 8 NDE) the pipe is to be inserted as deep as possible and the ducts must be temporarily sealed, see Figure: Checking the air pressure inside and outside the sleeve bearing.

To analyze the situation, compare the positions 1-4 on the DE with each other and the positions 5-9 NDE with each other. The measurements outside the bearing must be measured free of malfunctions or turbulence in the vicinity of the generator. The following situations can occur:

If all pressures are equal, the leak is not caused by pressure differences.

If the pressure in the bearing is higher than the exterior pressure, there is an overpressure in the bearing.

If the pressure outside the bearing is lower than the pressure at other points, there is low pressure near the bearing.

If all pressures are different, there may be both overpressure in the bearing and low pressure outside the bearing.

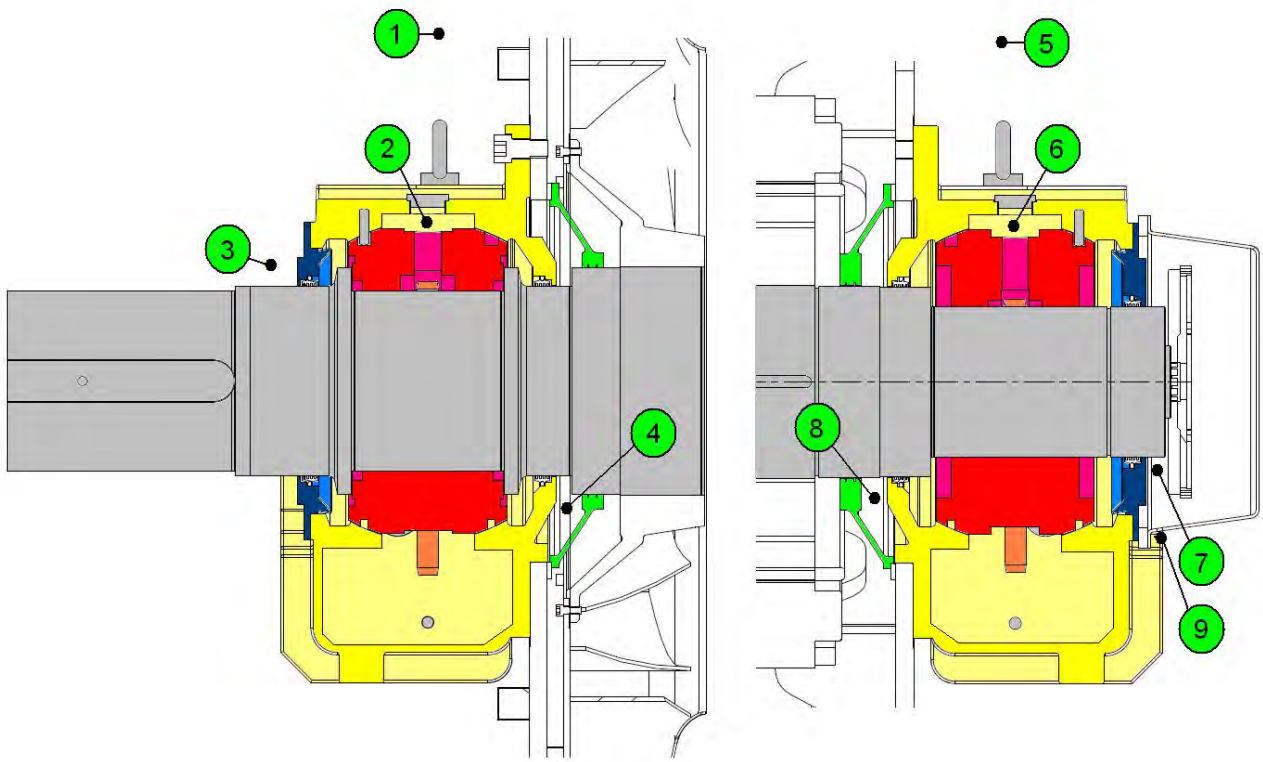


FIGURE 24. CHECKING THE AIR PRESSURE INSIDE AND OUTSIDE THE SLEEVE BEARING (1 - SLEEVE BEARING COVER)

11.9 Electrical Power, Excitation, Control and Protection

The electrical power output of a generator is determined primarily by the condition of the rotor and stator windings and secondly, by the operation of the excitation system. The main servicing of the generator winding is described in **Section 10.8 on page 99**. This section concentrates on troubleshooting the excitation, control and protective system.

11.9.1 Triggering the Protective System

The generator must be protected with alarm and shutdown functions for abnormal electrical or mechanical operating conditions.

Investigate the following events if they trigger an alarm or a protective system:

- Diode failure
- High bearing temperature,
- High temperature in the windings or the cooling air
- Failure of the isolating or matching transformer
- Vibration protection (if fitted)

11.9.2 PT-100 Resistive Temperature Sensors

PT-100 resistive temperature sensors are a significant element of the monitoring and protective system for the generator. They are used to measure the temperature in the stator windings, in the bearings and in the cooling air. The sensors can be damaged by incorrect handling or excessive vibration.

The following symptoms can be indicative of a problem in a Pt-100 sensor:

- Infinite resistance or zero resistance in the PT-100 sensor
- Loss of the measured signal during or after switching on
- A significant difference in the resistance of an individual sensor to the other sensors

If you suspect that a PT-100 has failed, check the connection in the terminal box by measuring the resistance at the PT-100 sensor with the cables disconnected.

If a PT100 in the stator is defect, use the spare one. All other defective PT100 sensors can be replaced.

11.10 Thermal Performance and Cooling System

Unusual generator temperatures rises are caused by the following reasons:

- The efficiency of the cooling system has dropped and the heat of the generator can not dissipate
- The generator itself is generating an excessive amount of heat.

If the temperature of the generator exceeds the normal values, measures must be taken to determine the reason.

Excessive heat production can be caused by damage to the winding, excessive loading or line asymmetry; in these cases corrective measures on the cooling system are ineffective or will cause damage. If you suspect that the efficiency of the cooling system has dropped or the cooling air temperature sensors are indicating an abnormally high temperature, check the cooling system. Check the following:

- Ensure the air circulation is uninterrupted and free of faults
- For heat exchangers, ensure reliability by means of regular cleaning and function checks.
- Check the air or water flow through the heat exchanger. If the cooler is equipped with an external fan, check its function.

Other causes of an abnormally high temperature are:

- Elevated ambient temperature
- High air or water inlet temperature
- Low air or water flow rate

In addition, malfunctions in the lubrication system or the bearings will result in excessively high bearing temperatures and therefore more heat in the cooling system.

An apparently high temperature can also be caused by a problem with the temperature sensors.

This page is intentionally blank.

12 Service Parts and After Sales Service

12.1 Service Parts for Generators

The Aftersales department sells genuine service parts for generators supplied.

You can contact our Aftersales department at:

Cummins Generator Technologies

Bunsenstr. 17

85053 Ingolstadt, Germany

Email: avk.parts@cummins.com

Tel. no.: +49 (0)841 792-192

Tel. no.: +49 (0)841 792 0

Fax no.: +49 (0)841 792 238

Always state the serial number given on the rating plate for quick processing.

12.1.1 General Information on the Service Parts

The generators manufactured by Cummins are designed and built for reliable, trouble-free operation. However, a precondition for their freedom from malfunctions is correct servicing and operation. This servicing includes the replacement of parts subject to normal wear .

The amount of wear cannot be predicted with absolute accuracy. The wear rates on the individual components vary widely depending on the application, environment and specific conditions. For this reason check the condition of these parts regularly and keep an adequate number of service parts in stock. These service parts will help to minimize the downtime if they are required. Decide the scope of the parts held in stock based on the importance of the application, the availability of the related service part and the experience of the local maintenance personnel.

Replacement of parts due to normal wear or due to incorrect operation is excluded from the warranty. If two moving surfaces are in contact, they will wear over time. For generators, the major mechanical wear occurs between the rotating shaft and the fixed parts. The bearing parts, e.g. the anti-friction bearings or the bearing shells and oil lubrication rings in sleeve bearings, wear over time and must be replaced occasionally despite correct lubrication. Other wearing parts are seals, brushes and brush systems that are in continuous contact with the rotating shaft.

The parts mentioned above do not represent a complete list of the mechanical wearing parts. Their actual service life can vary significantly from the calculated service life as a function of the actual operating conditions.

Other types of wear occur due to elevated temperatures, electrical malfunctions and chemical reactions. Wear on the diodes on the rectifier bridge is usually caused by abnormal operating conditions. This is normally a slow process that is heavily dependent on the generator operating conditions and system malfunctions.

The electrical windings have very good protection against wear, provided the servicing and operating instructions are followed carefully. Do not exceed the correct operating temperature and clean the windings regularly to remove dirt. Winding wear can also be a consequence of electrical malfunctions.

In the stator slots there are PT100 temperature sensors for the stator windings; these sensors cannot be replaced and are not available to order.

12.2 Customer Service

You can contact customer service at:

Cummins Generator Technologies

Bunsenstr. 17

85053 Ingolstadt, Germany

Email: uwe.plep@cummins.com

Email: service-engineers@cumminsgeneratortechnologies.com

Tel. no.: +49 (0)841 792-0

Fax no.: +49 (0)841 792 250

Always state the serial number given on the rating plate for quick processing.

12.2.1 Customer Service and Warranty

The service department will handle warranty claims. Claims must be notified in writing during the warranty period .

This department will:

- Decide on warranty claims
- Decide on corrective measures
- Provide technical support within the warranty period

13 End of Life Disposal

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

13.1 Disposal

The large portion of iron, steel and copper in the generator can be recovered by specialist recycling organizations. You can obtain further information from Cummins customer service.

13.2 Introduction

The following instructions are only recommendations for the environment-friendly disposal of the generators. It is the responsibility of the operating organization to follow local regulations. Some customer-specific elements may not be included in this user manual. This section makes no claim to completeness.

13.3 Average Material Content

The average material content used during the manufacture of the generator is as follows:

	Generators with cast iron bearing plates	**Generators with welded bearing plates**
Steel	46–55%	77–83%
Copper	7–12%	10–12%
Cast iron	35–45%	1–5%
Aluminum	0–2%	0–1%
Plastic, rubber, insulating material etc.	1–2%	1–2%
Stainless steel	Less than 1%	Less than 1%
Others	Less than 1%	Less than 1%

Following materials are not used:

- Asbestos
- Polychlorinated Biphenyls
- CFCs
- Haloms
- Other fully halogenated CFCs
- Carbon Tetrachloride
- 1,1,1 Trichloroethane Methyl Chloroform
- Hydrochlorefluorocarbons
- Hydrobromofluerocarbons
- Methyl bromide
- Bromochloromethane

- Tributyl Tins
- Triphenyl Tins
- Tributyl Tin Oxide (TBTO)
- Cadmium and Cadmium Compounds
- Hexavalent Chromium and Hexavalent Chromium Compounds
- Mercury and Mercury Compounds
- Polybrominated Biphenyl (PBBs)
- Polybrominated Dephenyl ethers (PDBEs)
- Polychloronsphthalanes (C1= <3)
- Radioactive Substances
- Certain Shortchain Chlorinated Paraffins

13.4 Recycling Packaging Material

After the generator has arrived at the operating organization, the packing material must be disposed of.

- Wooden packaging can be recycled.
- Recycle the packaging for maritime transport made of impregnated wood in accordance with local regulations.
- Do not burn the packaging made of impregnated wood.
- The plastic material wrapped around the generator can be recycled.
- Anti-corrosion agents that cover the surface of the generator can be cleaned using a petrol-based cleaning agent and a cloth. The cloth is to be disposed of in accordance with local regulations.
- Desiccants are to be disposed of in accordance with local regulations.

13.5 Dismantling the Generator

⚠ DANGER

Heavy loads.

Do not stand under suspended loads. The load may drop due to improper fastening or failure of the lifting equipment and cause very serious injuries or death.

Secure transport routes.

The generator must be transported and unloaded by persons who are familiar with the lifting equipment and related ancillary equipment. All lifting equipment and tackle must be suitable for the weight of the generator and must comply with local regulations.

The safety regulations on handling the generator are to be followed at all times. The generator is assembled with screws and can be dismantled. The high weight of the generator requires the presence of specialist personnel trained in handling heavy components to avoid hazardous situations.

13.6 Separation of the Different Materials

13.6.1 Stator, Bearing Housing, Covers and Fans

These parts mostly comprise mild steel that can be recycled in accordance with local regulations. All additional equipment, cables and bearings are to be removed before melting down the material.

13.6.2 Components with Electrical Insulation

The stator and the rotor are the main components that contain electrical insulation materials. Some additional components are, however, made of similar materials and are treated in a similar manner. These components are:

- Insulators used in the terminal boxes
- The exciter rotor
- The exciter stator
- The voltage and current transformers
- Primary and secondary cables
- Overvoltage arresters
- Diodes and varistors

Not all these components are used in all generators. Components with electrical insulation are in an inert and therefore non-reactive state after the manufacture of the generator. Some components, in particular the stator and rotor, contain a significant copper content that can be separated in a suitable heat treatment process by gasification of the organic binder materials in the electrical insulation. To ensure the correct combustion of the vapors, the furnace must have a suitable afterburner unit.

13.6.3 Hazardous Waste

The oil and grease from the lubrication system is hazardous waste and is to be disposed of in accordance with local regulations.

13.6.4 Residual Waste

All insulation materials can be disposed of as residual waste.

This page is intentionally blank.

Bunsenstrasse 17
85053 Ingolstadt
Germany
Tel: +49 841 7920
Fax: +49 841 792165
www.cumminsgeneratortechnologies.com